JOURNAL

AND

PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES

FOR

1911.

(INCORPORATED 1881.)

VOL. XLV.

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE STATEMENTS MADE AND THE OPINIONS EXPRESSED THEREIN.

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1912.

NOTICE.

The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

Authors of papers desiring illustrations, are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink, so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is 4¼ in. × 6¾ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

ERRATUM.

Page 59, line 2, for "predominance of peripheral over radial contraction etc.," read "predominance of radial over peripheral contraction etc."

PUBLICATIONS.

The following publications of the Society, if in print, can be obtained at the Society's House in Elizabeth-street:—

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

Vol. I.	Transactions of the Royal Society, N.S.W.,	1867,	pp. 83,	,,
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,, XIII.	,, ,, ,, ,, ,,	1879,	,, 255,	,,
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FORM OF BEQUEST.

I bequeath the sum of £   to the ROYAL SOCIETY OF NEW SOUTH WALES, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within   calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[*Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.*]

NOTICE.

Members are particularly requested to communicate any change of address to the Hon. Secretaries, for which purpose this slip is inserted.

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Titles, &c..

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Address...

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Date..........................

To the
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The Royal Society of N. S. Wales,
5 Elizabeth Street, Sydney.

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Transactions or Journal; papers published in the Transactions of the Philosophical Society are also included. The numerals indicate the number of such contributions.

‡ Life Members

Elected.		
1908		Abbott, George Henry, B.A., M.B., Ch. M., Macquarie-street; p.r. 'Cooringa,' 252 Liverpool Road, Summer Hill,
1877	P 5	Abbott, W. E., 'Abbotsford,' Wingen.
1911		Abbott, John Henry Macartney, St. James' Chambers.
1895		Adams, J. H. M., Broughton Cottage, St. James' Rd., Waverley.
1904		Adams, William John, M. I. Mech. E., 175 Clarence-street.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ld., Cement Works, Granville.
1905		Anderson, Charles, M.A., D. Sc. *Edin.*, Australian Museum, College-street.
1909	P 4	Andrews, E. C., B.A., Geological Surveyor, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 17	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1894		‡Balsille, George, 'Lauderdale,' N.E. Valley, Dunedin, N.Z.
1896		Barff, H. E., M.A., Registrar, Sydney University.
1908	P 1	Barling, John, 'St. Adrians,' Raglan-street, Mosman.
1895	P 9	Barraclough, S. Henry, B.E., M.M.E., Assoc. M. Inst. C.E., M. I. Mech. E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Lecturer in Mechanical Engineering, Sydney University; p.r. 'Marmion,' Victoria-street, Lewisham.
1906		Basnett, Nathaniel James, Accountant, Punch-st., Mosman.
1894		Baxter, William Howe, Chief Surveyor, Existing Lines Office, Railway Department, Bridge-street,
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1900		Bender, Ferdinand, Accountant and Auditor, 21 Elizabeth-street, North.
1909		Benson, William Noel, B. Sc.
1905		Bignold, Hugh Baron, Barrister-at-Law, Chambers, Wentworth Court, 64 Elizabeth-street.
1905		Blakemore, George Henry, Australian Club, Macquarie-street.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Fremantle, West Australia.
1893		Blomfield, Charles E., B.C.E. *Melb.*, 'Woombi,' Kangaroo Camp, Guyra.

Elected		
1898		Blunno, Michele, Licentiate in Science (Rome), Government Viticultural Expert, Department of Agriculture, Sydney.
1907		Bogenrieder, Charles, Mining and Consulting Engineer, 'Scibile,' Little's Avenue, off Nicholson-street, Balmain.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1907		Boyd, Robert James, M.E., Assoc. M. Inst. C.E., 'Greenstead,' Park Road, Burwood.
1910		Bradley, Clement Henry Burton, M.B., Ch. M., D P.H., Bureau of Microbiology, Macquarie-street.
1876		Brady, Andrew John, L.K. & Q.C.P. *Irel.*, L.R.C.S. *Irel.*, 3 Lyons Terrace, Hyde Park.
1891		Brennand, Henry J. W., B.A., M.B , Ch. M. *Syd.*, 'Wobun,' 310 Miller-street, North Sydney.
1902		Brereton, Victor Le Gay, Solicitor, Royal Chambers, Hunter-street, p.r. 'Osgathorpe,' Gladesville.
1878		‡Brooks, Joseph, F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.
1876		Brown, Henry Joseph, Solicitor, Newcastle.
1906		Brown, James B., Resident Master, Technical School, Granville; p.r. 'Kingston,' Merrylands.
1903		Bruck, Ludwig, Medical Publisher, 15 Castlereagh-street.
1898		‡Burfitt, W. Fitzmaurice, B.A., B.Sc., M.B., Ch.M. *Syd.*, 357 Glebe Road, Glebe Point.
1890		Burne, Dr. Alfred, Dentist, Buckland Chambers, 183 Liverpool-street.
1907		Burrows, Thomas Edward, M. Inst. C.E., L.S., Metropolitan Engineer, Public Works Department; p.r. 'Balboa,' Fern-street, Randwick.
1880		Bush, Thomas James, M. Inst. C.E., Australian Gas-light Company, 153 Kent-street.
1909		Calvert, Thomas Copley, Assoc. M. Inst. C.E., 'Maybank,' Manly.
1904	P 1	Cambage, Richard Hind, L.S., F.L.S., Chief Mining Surveyor; p.r. Park Road, Burwood.
1907		Campbell, Alfred W., Medical Practitioner, 183 Macquarie-st.
1900		Canty, M., 'Rosemont,' 13 York-street, Wynyard Square.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Rd., Edgecliffe.
1897	P 4	Cardew, John Haydon, M. Inst. C.E., L.S., 75 Pitt-street.
1901		Card, George William, A.R.S.M., F.G.S., Curator and Mineralogist to the Geological Survey, Department of Mines, Sydney.
1891		Carment, David, F.I.A. *Grt. Brit. & Irel.*, F.F.A. *Scot.*, Australian Mutual Provident Society, 87 Pitt-st. *Hon. Treasurer.*
1909		Carne, Joseph Edmund, F.G.S., Assistant Government Geologist, Department of Mines, Sydney.
1903		Carslaw, H. S., M.A., D.Sc., Professor of Mathematics, Sydney University, Glebe.
1909		Chapman, H. G., M.D., Assistant Lecturer and Demonstrator in Physiology, Sydney University, Glebe.
1908		Chauleur, Paul, Officier de l'Instruction Publique, Conseiller du Commerce Extérieur de la France; Secrétaire-Trésorier de la Chambre de Commerce française, Bond-street.
1909	P 10	Cleland, John Burton, M.D., Ch.M., Principal Assistant Microbiologist, Bureau of Microbiology, 93 Macquarie-street.

Elected		
1907		Cobham, Allan Blenman, 'Garthowen,' Myahgah Road, Mosman.
1896	P 2	Cook, W. E., M.C.E. *Melb.*, M. Inst. C.E. Water and Sewerage Board, North Sydney.
1904	P 2	Cooksey, Thomas, Ph. D., D.Sc., *Lond.*, F.I.C., Second Government Analyst; p.r. 'Clissold,' Calypso Avenue, Mosman.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, 'Roseneath,' 8 Wallis-street, Woollahra.
1906		Colley, David John K., Superintendent, Royal Mint, Sydney.
1882		Cornwell, Samuel, J.P., Brunswick Road, Tyagarah.
1909		Cotton, Leo Arthur, B.A., B.Sc. Assistant Lecturer and Demonstrator in Geology, The University of Sydney.
1892	P 1	Cowdery, George R., Assoc. M. Inst. C.E., 'Glencoe,' Torrington Road, Strathfield.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 16 College-street, Hyde Park.
1905		Dampney, Gerald F., F.I.C., 'Doonbah,' Hunter's Hill.
1875		Dangar, Fred. H., c/o W. E. Deucher, 12 and 14 Loftus-street.
1890		Dare, Henry Harvey, M.E., M. Inst. C.E., Public Works Department.
1876	P 3	Darley, Cecil West, M. Inst. C.E., Australian Club, Sydney.
1910		Darnell-Smith, George Percy, B.Sc., F.I.C., F.C.S., Bureau of Microbiology, Macquarie-street.
1886	P 21	David, T. W. Edgeworth, C.M.G., B.A., D. Sc., F.R.S., F.G.S., Professor of Geology and Physical Geography, Sydney University, Glebe. *Vice-President.*
1909		Davidson, George Frederick, Tramway Offices, Hunter-street; p.r. 223 Bridge Road, Glebe Point.
1892	P 1	Davis, Joseph, M. Inst. C.E.
1907		Davys, Hubert John, c/o Messrs. Clutterbuck Bros. & Co., Builders' Exchange, Castlereagh-street, p.r. 'La Bohème,' Marshall-street, Manly.
1885	P 3	Deane, Henry, M. A., M. Inst. C.E., F.L.S., F.R. Met. Soc., F.R.H.S., Commercial Bank Chambers, George-street; p.r. 'Blanerne,' Wybalena Road, Hunter's Hill.
1894		Dick, James Adam, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, 'Catfoss,' Belmore Road, Randwick,
1875	P 12	Dixon, W. A., F.I.C., F.C.S., 97 Pitt-street.
1880		Dixson, Thomas Storie, M.B., M.S. *Edin.*, 151 Macquarie-street.
1906		Dixson, William, 'Abergeldie,' Summer Hill.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Mostyn,' Billyard Avenue, Elizabeth Bay.
1899	P 1	Duckworth, A., F.R.E.S., A.M.P. Society, 87 Pitt-street; p.r. 'Trentham,' Woollahra.
1873	P 2	Du Faur, E., F.R.G.S., 'Flowton,' Turramurra.
1908	P 2	Dun, William S., Palæontologist, Department of Mines.
1906		Epps, William, Secretary, Royal Prince Alfred Hospital, Camperdown, Sydney.
1908		Esdaile, Edward William, Optician, 54 Hunter-street.
1910		Estens, John Locke, 55 Flinders-street, Sydney.

Elected		
1879	P 4	Etheridge, Robert, Junr., J.P., Curator, Australian Museum; p.r. 'Inglewood,' Colo Vale, N.S.W.
1877		‡Fairfax, Edward Ross, *S. M. Herald* Office, Hunter-street.
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1868		Fairfax, Sir James R., Knt., *S. M. Herald* Office, Hunter-st.
1887		Faithfull, R. L., M.D. *New York*, L.R.C.P., L.S.A. *Lond.*, 5 Lyons Terrace.
1902		Faithfull, William Percy, Barrister-at-Law, Australian Club.
1910		Farrell, John, Assistant Teacher, Sydney Technical College; p.r. 55 Surry-street, Darlinghurst.
1909	P 1	Fawsitt, Charles Edward, D. Sc., Ph. D., Professor of Chemistry, Sydney University, Glebe.
1881		Fiaschi, Thos., M.D., M. Ch. *Pisa*, 149 Macquarie-street.
1888		Fitzhardinge, Grantly Hyde, M.A. *Syd.*, District Court Judge, 'Red Hill,' Beecroft.
1900		‡Flashman. James Froude, B.A., B.Sc., M.D., Ch.M., Jersey Road, Burwood.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 141 Macquarie-st
1905		Foy, Mark, 'Eumemering,' Bellevue Hill, Woollahra.
1904		Fraser, James, M. Inst. C.E., Engineer-in-Chief for Existing Lines, Bridge-street; p.r. 'Arnprior,' Neutral Bay.
1907		Freeman, William, 'Clodagh,' Beresford Road, Rose Bay.
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1881		Furber, T. F., F.R.A.S., 'Sunnyside,' Stanmore Road, Enmore.
1876		George, W. R., 318 George-street.
1879		Gerard, Francis, 'The Grange,' Monteagle, near Young.
1859		Goodlet, J. H., 'Canterbury House,' Ashfield.
1906		Gosche, Vesey Richard, Consul for Nicaragua, 1 Bulletin Place, Pitt-street, City.
1906		Gosche, W. A. Hamilton, Electrical Engineer, 1 Bulletin Place, Pitt-street, City.
1897		Gould, Senator, The Hon. Sir Albert John, K.C.M.G., 'Eynesbury,' Edgecliffe.
1907		Green, W. J., Chairman, Hetton Coal Co., Athenæum Club.
1899		Greig-Smith, R., D. Sc. *Edin.*, M. Sc. *Dun.*, Macleay Bacteriologist, Linnean Society's House, Ithaca Road, Elizabeth Bay.
1899	P 2	Gummow, Frank M., M.C.E., Corner of Bond and Pitt-streets.
1891	P 16	Guthrie, Frederick B., F.I.C., F.C.S., Chemist, Department of Agriculture, 136 George-street, Sydney.
1880	P 3	Halligan, Gerald H., F.G.S., 'Riversleigh,' Hunter's Hill.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1909		Hammond, Walter L., Science Master, Hurlstone Agricultural Continuation School, Hurlstone Avenue, Summer Hill.
1887	P 8	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; Government Analyst, Health Department Macquarie-street, North. *Vice-President.*

Elected		
1905	P 1	Harker, George, D.Sc., 35 Boulevarde, Petersham.
1887	P 23	‡Hargrave, Lawrence, Wunulla Road, Woollahra Point.
1884	P 1	Haswell, William Aitcheson, M.A., D. Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. 'Mimihau,' Woollahra Point.
1900		Hawkins, W. E., Solicitor, 88 Pitt-street.
1891	P 1	Hedley, Charles, F.L.S., Assistant Curator, Australian Museum, Sydney.
1899		Henderson, J., F.R.E.S., Manager, City Bank of Sydney, Pitt-st.
1884	P 1	Henson, Joshua B., Assoc. M. Inst. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1905		Hill, John Whitmore, Architect, 'Willamere,' May's Hill, Parramatta.
1876	P 2	Hirst, George D., F.R.A.S., c/o Messrs. Tucker & Co., 215 Clarence-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, 147 Macquarie-st.
1892		Hodgson, Charles George, 157 Macquarie-street.
1901		Holt, Thomas S., 'Amalfia,' Appian Way, Burwood.
1905		Hooper, George, Assistant Superintendent, Sydney Technical College; p.r. 'Branksome,' Henson-street, Summer Hill.
1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 63 Pitt-street.
1906		Howle, Walter Creswell, Medical Practitioner, Bega, N.S.W.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Chief Inspector of Mines, Department of Mines.
1904		Jenkins, R. J. H., 'Ettalong,' Roslyn Gardens, Rushcutters Bay
1905	P 8	Jensen, Harold Ingemann, D. Sc., Government Geologist, Darwin, Northern Territory.
1907		Johnson, T. R., M. Inst. C.E., Chief Commissioner of New South Wales Railways, Public Works Department.
1909	P 13	Johnston, Thomas Harvey, M.A., D.Sc., F.L.S., Biology Department, The University, Brisbane.
1902		Jones, Henry L, Assoc. Am. Soc., C.E., 14 Martin Place.
1867		Jones, Sir P. Sydney, Knt., M.D. *Lond.*, F.R.C.S. *Eng.*, 'Llandilo,' Boulevard, Strathfield.
1911		Julius, George A., B. Sc., M.E., Norwich Chambers, Hunter-street.
1907		Kaleski, Robert, Agricultural Expert, Holdsworthy, Liverpool.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873	P 3	Keele, Thomas William, M. Inst. C.E., Commissioner, Sydney Harbour Trust, Circular Quay; p r. Llandaff-st., Waverley.
1887		Kent, Harry C., M.A., F.R.I.B.A., Bell's Chambers, 129 Pitt-st.
1901		Kidd, Hector, M. Inst. C.E., M. I. Mech. E., 'Craig Lea,' 15 Mansfield-street, Glebe Point.
1896		King, Kelso, 120 Pitt-street.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.G.S. *Irel.*, 'Wellington,' Bondi Road, Bondi.
1881	P 22	Knibbs, G. H., C.M.G., F.S.S., F.R.A.S., Member Internat. Assoc. Testing Materials; Memb. Brit. Sc. Guild, Commonwealth Statistician, Melbourne.
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.

Elected		
1911	P 2	Laseron, Charles Francis, Technological Museum.
1906		Lee, Alfred, Merchant, 'Glen Roona,' Penkivil-st., Bondi.
1909		Leverrier, Frank, B.A., B. Sc., K.C., 182 Phillip-street.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1872	P 57	Liversidge, Archibald, M.A, *Cantab* , LL.D., F.R.S., Hon. F.R.S. *Edin.*, Assoc. Roy. Sch. Mines, *Lond.;* F.C.S., F.G.S. F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.;* Mem. Phys. Soc. *Lond.*; Mineralogical Society, *Lond.;* Edin. Geol. Soc.; Mineralogical Society, *France;* Corr. Mem. Edin. Geol, Soc.; New York Acad. of Sciences; Roy. Soc. *Tas* ; Roy. Soc. *Queensland;* Senckenberg Institute, *Frankfurt;* Société d' Acclimat., *Mauritius;* Foreign Corr. Indiana Acad. of Sciences; Hon. Mem. Roy. Soc., *Vict.;* N. Z. Institute; K. Leop. Carol. Acad., *Halle a/S;* 'Hornton Cottage,' Hornton-st., Kensington, London, W.
1906		Loney, Charles Augustus Luxton, M. Am. Soc. Refr. E., Equitable Building, George-street.
1911		Longmuir, G. F., B.A , Science Master, Technical College, Bathurst,
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 185 Macquarie-street, North.
1887		MacCulloch, Stanhope H., C.M. *Edin.*, 24 College-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1903		McDonald, Robert, J.P., 'Wairoa,' Holt-street, Double Bay.
1891		McDouall, Herbert Chrichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H. *Cantab.*, Hospital for the Insane, Gladesville.
1906		McIntosh, Arthur Marshall, Dentist, William-st., Chatswood.
1891	P 2	McKay, R. T., Assoc. M. Inst. C.E., Geelong Waterworks and Sewerage Trusts Office, Geelong, Victoria.
1893		McKay, William J. Stewart, B. Sc., M.B., Ch.M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Sir Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, Equitable Building, George-street.
1904		McKenzie, Robert, Sanitary Inspector, (Water and Sewerage Board), 'Stonehaven Cottage,' Bronte Road, Waverley.
1880	P 9	McKinney, Hugh Giffin, M.E., Roy Univ. *Irel.*, M. Inst. C.E., Australian Club, Macquarie-street.
1903		McLaughlin, John, Solicitor, Union Bank Chambers, Hunter-st.
1876		MacLaurin, The Hon. Sir Henry Normand, M.L.C., M.A., M.D., L.R.C.S. *Edin.*, LL.D. *St. Andrews*, 155 Macquarie-street.
1901	P 1	McMaster, Colin J., Chief Commissioner of Western Lands; p.r. Wyuna Road, Woollahra Point.
1894		McMillan, Sir William, K.C.M.G., 'Althorne,' 281 Edgecliffe Road, Woollahra.
1899		MacTaggart, J. N. C., M. E. *Syd.*, Assoc. M. Inst. C.E., Water and Sewerage Board District Office, Lyons Road, Drummoyne.

Elected		
1909		Madsen, John Percival Vissing, D. Sc., B.E., P. N. Russell Lecturer in Electrical Engineering, Sydney University.
1883	P 21	Maiden, J. Henry, J.P., F.L.S., Hon. Fellow Roy. Soc, S.A.; Hon. Memb. Nat. Hist. Soc., W.A.. Netherlands Soc. for Promotion of Industry; Philadelphia College Pharm.; Southern Californian Academy of Sciences; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc., Lond.; Corr. Memb. Pharm. Soc. Great Britain; Bot. Soc. Edin.; Soc. Nat. de Agricultura (Chile); Soc. d' Horticulture d' Alger; Union Agricole Calédonienne; Soc. Nat, etc., de Chérbourg; Roy. Soc. Tas., Inst. Nat. Genévois; Hon. Vice-Pres. of the Forestry Society of California; Diplomé of the Société Nationale d' Acclimatation de France; Government Botanist and Director, Botanic Gardens, Sydney. *President.*
1906		Maitland, Louis Duncan, Dental Surgeon, 6 Lyons' Terrace, Liverpool-street.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1897		Marden, John, M.A., LL.D., Principal, Presbyterian Ladies' College, Sydney.
1908		Marshall, Frank, B.D.S. *Syd.*, Dental Surgeon, 141 Elizabeth-st.
1875	P 27	Mathews, Robert Hamilton, L.S., Assoc. Etran. Soc. d'Anthrop. de Paris; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem. Anthrop. Soc. Vienna; Cor. Mem. Roy. Geog. Soc. Aust., Q'sland; Local Correspondent Roy. Anthrop. Inst., Lond.; 'Carcuron, Hassall-st., Parramatta.
1903		Meggitt, Loxley, Manager Co-operative Wholesale Society, Alexandria.
1905		Miller, James Edward, Inverell, New South Wales.
1889	P 8	Mingaye, John C. H., F.I.C . F.C.S., Assayer aud Analyst to the Department of Mines; p.r. Campbell-street, Parramatta.
1879		Moore, Frederick H., Union Club, Sydney.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilqa,' Burwood.
1879		Mullens, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1876		Myles, Charles Henry, 'Dingadee,' Everton Rd., Strathfield.
1893	P 2	Nangle, James, Architect, 'St. Elmo,' Tupper-st., Marrickville.
1891		‡Noble, Edward George, Public Works Department, Newcastle.
1893		Noyes, Edward, Assoc. M. Inst. C.E., Assoc. I. Mech. E., c/o Messrs. Noyes Bros., 109 Pitt-street.
1903		Old, Richard, Solicitor, 'Waverton,' Bay Rd., North Sydney.
1896		Onslow, Lt. Col. James William Macarthur, Camden Park, Menangle.
1875		O'Reilly, W. W. J., M.D., M.Ch., Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 171 Liverpool-street, Hyde Park.
1891		Osborn, A. F., Assoc. M. Inst. C.E.. Water Supply Branch, Sydney, 'Linton,' Parkes-street, Ryde.
1903		Owen, Rev. Edward, B.A., All Saints' Rectory, Hunter's Hill.

Elected		
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 183 Liverpool-street, Hyde Park.
1906		Pawley, Charles Lewis, Dentist, 137 Regent-street.
1901		Peake, Algernon, Assoc. M. Inst. C.E., 25 Prospect Road, Ashfield.
1899		Pearse, W., Union Club; p.r. 'Plashett,' Jerry's Plains, viâ Singleton.
1877		Pedley, Perceval R., Australian Club.
1899		Petersen, T. Tyndall, Member of Sydney Institute of Public Accountants, Copper Mines, Burraga.
1909	P 1	Pigot, Rev. Edward F., S.J., B.A., M.B., *Dub.*, St. Ignatius College, Riverview.
1879	P 7	Pittman, Edward F., Assoc. R. S. M., L.S., Under Secretary and Government Geologist, Department of Mines.
1896		Plummer, John, 'Northwood,' Lane Cove River; Box 413 G.P.O.
1881		Poate, Frederick, Surveyor-General Lands Department, Sydney
1879		Pockley, Thomas F. G., Union Club, Sydney.
1887	P 8	Pollock, J. A., D.Sc., Corr. Memb. Roy. Soc., Tasmania; Roy. Soc. Queensland; Professor of Physics in the University of Sydney. *Hon. Secretary.*
1896		Pope, Roland James. B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1910		Potts, Henry William, F.L.S., F.C.S., Principal, Hawkesbury Agricultural College, Richmond, N.S.W.
1893		Purser, Cecil, B.A., M.B., Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1901	P 1	Purvis, J. G. S., Water and Sewerage Board, 341 Pitt-street.
1908		Pye, Walter George, M.A., B. Sc., Nield Avenue, Paddington.
1876		Quaife, F. H., M.A., M.D., M.S., 'Hughenden,' 14 Queen-street, Woollahra. *Vice-President.*
1890	P 1	Rae, J. L. C., 'Lisgar,' King-street, Newcastle.
1862	P 1	‡Ramsay, Edward P., LL.D. *St. And.*, F.R.S.E., F.L.S., 8 Palace-street, Petersham.
1906		Redman, Frederick G., P. and O. Office, Pitt-street,
1909		Rhodes, Thomas, Civil Engineer, Carlingford and Public Works Department.
1902		Richard, G. A., Mount Morgan Gold Mining Co., Mount Morgan, Queensland.
1906		Richardson, H. G. V., 32 Moore-street.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, 147 Macquarie-st.
1895	P 1	Ross, Herbert E., Equitable Building, George-street.
1904	P 3	Ross, William J. Clunies, B.Sc. *Lond. & Syd.*, F.G.S., Lecturer in Chemistry, Technical College, Sydney.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-street, and Union Club.
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 369 George-street; p.r. 'Mahuru,' Fairfax Road, Bellevue Hill.
1893		Rygate, Philip, W., M.A., B.E. *Syd.*, Assoc. M. Inst. C.E., 164 Pitt-st.

Elected		
1905		Scheidel, August, Ph. D., Managing Director, Commonwealth Portland Cement Co., Sydney; Union Club.
1899		Schmidlin, F., 39 Phillip-street, City.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., Assistant Professor in Chemistry, University, Sydney.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1904	P 1	Sellors, R. P., B.A, *Syd.*, 'Cairnleith,' Military Road, Mosman.
1908		Sendey, Henry Franklin, Manager of the Union Bank of Australia Ld., Sydney; Union Club.
1883	P 4	Shellshear, Walter, M. Inst. C.E., Inspecting Engineer, Existing Lines Office, Bridge-street.
1905		Simpson, D. C., M. Inst. C.E., N.S. Wales Railways, Redfern; p.r. 'Clanmarrina,' Rose Bay.
1900		Simpson, R. C., Technical College, Sydney.
1910		Simpson, William Walker, Merchant, Leichhardt-st. Waverley.
1882		Sinclair, Eric, M.D., C.M. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain; p.r. 'Broomage,' Kangaroo-street, Manly.
1893		Sinclair, Russell, M. I. Mech. E., Vickery's Chambers, 82 Pitt-st.
1891	P 3	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 39	Smith, Henry G., F.C.S., Assistant Curator, Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., Cumberland Heights, Parramatta.
1900		Stewart, J. Douglas, B.V.Sc., M.R.C.V.S., Professor of Veterinary Science, The University of Sydney; 'Berelle,' Homebush Road, Strathfield.
1903		Stoddart, Rev. A. G., The Rectory, Manly.
1909		Stokes, Edward Sutherland, M.A, *Syd.*, F.R.C.P.S. *Irel.*, Medical Officer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1883	P 4	Stuart, T. P. Anderson, M.D., LL.D. *Edin.*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay.
1901	P 4	Süssmilch, C. A., F.G.S., Technical College, Sydney.
1906		Taylor, Sir Allen, 'Woolton,' Darley-street, Darlinghurst.
1906		Taylor, Horace, Registrar, Dental Board, 7 Richmond Terrace, Domain.
1905		Taylor, John M., M.A., LL.B. *Syd.*, 'Woonona,' 43 East Crescent-street, McMahon's Point, North Sydney.
1893		‡Taylor, James, B. Sc., A.R S.M., 'Adderton,' Dundas.
1899		Teece, R., F.I.A., F.F.A., General Manager and Actuary, A.M.P. Society, 87 Pitt-street.
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1878		Thomas, F. J., Newcastle and Hunter River Steamship Co., 147 Sussex-street.
1879		Thomson, Hon. Dugald, M.H.R., Carrabella-st., North Sydney.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Cantab.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.

Elected		
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., 'Inglewood,' Lane Cove Road, Wahroonga.
1894		Tooth, Arthur W., Kent Brewery; 26 George-street, West.
1879		Trebeck, P. C., F. R. Met. Soc., 12 O'Connell-street.
1900		Turner, Basil W., A.R.S.M., F.C.S., Victoria Chambers, 83 Pitt-st.
1883		Vause, Arthur John, M.B., C M. *Edin.*, 'Bay View House,' Tempe.
1890		Vicars, James, M.E., Memb. Int. Assoc. Testing Materials; Memb. B. S. Guild; Challis House, Martin Place.
1892		Vickery, George B., 78 Pitt-street
1903	P 2	Vonwiller, Oscar U., B.Sc., Assistant Lecturer and Demonstrator in Physics, University of Sydney.
1907		Waley, F. G., Assoc. M. Inst. C.E., Royal Insurance Building, Pitt-st.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, Senator The Hon. J. T., 'Wallaroy,' Edgecliffe Road, Woollahra.
1910		Walker, Charles, Metallurgical Chemist, etc., 'Kuranda,' Waverley-street, Waverley.
1910		Walker, Harold Hutchison, Major St. George's English Rifle Regiment, C.M.F., 'Vermont,' Belmore Road, Randwick.
1910	P 1	Walkom, Arthur Bache, B.Sc., Junior Demonstrator in Geology, Sydney University; p.r. 'Lang-hay,' Fisher-st., Petersham.
1901		Walkom, A. J., A.M.I.E.E., Electrical Branch, G.P.O., Sydney.
1891	P 2	Walsh, Henry Deane, B.A.I., *Dub.*, M. Inst. C.E., Engineer-in-Chief, Harbour Trust, Circular Quay. *Vice-President*
1903		Walsh, Fred., George and Wynyard-streets; p.r. 'Walsholme,' Centennial Park, Sydney E.
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1898		Wark, William, Assoc. M. Inst. C.E., 9 Macquarie Place; p.r. Kurrajong Heights.
1883	P 17	Warren, W. H., Wh. Sc., M. Inst. C.E., M. Am. Soc. C.E., Member of Council of the International Assoc. for Testing Materials, Professor of Engineering, University of Sydney.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, Macquarie-st.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville.
1910		Watson, James Frederick, M. B., Ch. M., Australian Club, Sdyney.
1910		Watt, Francis Langston, F.I.C., A.R.C.S., 10 Northcote Chambers, off 16½ Pitt-street, City.
1911		Watt, R. D., M. A., B.Sc., Professor of Agriculture, University of Sydney.
1908		Weatherburn, Charles Ernest, M. A., B. Sc., *Syd.*, B.A. *Cantab.*, Ormond College, Parkville, Melbourne.
1910	P 1	Wearne, Richard Arthur, B.A., Principal, Technical College, Ipswich, Queensland.
1897		Webb, Frederick William, C.M.G., J.P., 'Livadia,' Manly.
1903		Webb, A. C. F., M I.E.E., Vickery's Chambers, 82 Pit-street.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Town Hall, Sydney.

Elected		
1907		Weedon, Stephen Henry, C.E., 'Kurrowah,' Alexandra-street, Hunter's Hill.
1907		Welch, William, F.R.G.S., 'Roto-iti,' Boyle-street, Mosman.
1881		‡Wesley, W. H., London.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., *Dub.*
1909		White, Charles Josiah, Science Lecturer, Sydney Training College; p.r. 'Patea,' Miller Avenue, Ashfield.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Sellinge,' Albert-st., Woollahra.
1907		Wiley, William, 'Kenyon,' Kurraba Point, Neutral Bay.
1876		Williams, Percy Edward, 'St. Vigeans,' Dundas.
1908	P 1	Willis, Charles Savill, M.B. Ch.M. *Syd.*, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H., Roy. Coll. P. & S. *Lond.*, Department of Public Health.
1901		Willmot, Thomas, J.P., Toongabbie.
1890		Wilson James T., M.B., Ch.M. *Edin.*, F.R.S., Professor of Anatomy, University of Sydney.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1906	P 6	Woolnough, Walter George, D.Sc., F.G.S., Assistant Professor and Demonstrator in Geology, University of Sydney.
1909		Yeomans, Richard John, Solicitor, 14 Castlereagh-street.

Honorary Members.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1900		Crookes, Sir William, Kt., O.M., LL.D., D.Sc., F.R.S., 7 Kensington Park Gardens, London W.
1905		Fischer, Emil, Professor of Chemistry, University, Berlin.
1911		Hemsley, W. Botting, F.R.S., Formerly Keeper of the Herbarium, Royal Gardens, Kew, 24 Southfield Gardens, Strawberry Hill, Middlesex.
1901		Judd, J.W., C.B., LL.D., F.R.S., F.G.S., Formerly Professor of Geology, Royal College of Science, London; 30 Cumberland Road, Kew, England.
1908		Kennedy, Sir Alex. B. W., Kt., LL.D., D. *Eng.*, F.R.S., Emeritus Professor of Engineering in University College, London, 17 Victoria-street, Westminster, London S.W.
1908		Liversidge, Archibald, M.A., LL.D., F.R.S., Emeritus Professor of Chemistry in the University of Sydney, 'Hornton Cottage,' Hornton-street, Kensington, London S.W.
1905		Oliver, Daniel, LL.D., F.R.S., Emeritus Professor of Botany in University College, London.
1894		Spencer, W. Baldwin, C.M.G., M.A., F.R.S., Professor of Biology in the University of Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., The Ferns, Witcombe, Gloucester, England.

Elected	
1908	Turner, Sir William, K.C.B., M.B., D.C.L., LL.D., Sc. D., F.R.C.S. *Edin.*, F.R.S., Principal and Emeritus Professor of the University of Edinburgh, 6 Eton Terrace, Edinburgh, Scotland.
1895	Wallace, Alfred Russel, O.M., D.C.L., LL.D., F.R.S., Old Orchard, Broadstone, Wimborne, Dorset.

OBITUARY 1910.

Honorary Members.

1875	Bernays, Lewis A.
1880	Hooker, Sir Joseph Dalton.
1903	Lister, Right Hon. Joseph, Lord.

Ordinary Members.

1879	Chard, J. S.
1884	Jones, Llewellyn Charles Russell.
1876	Josephson, J. Percy.
1883	Osborne, Ben. M.
1906	Oschatz, Alfred Leopold.
1876	Voss, Houlton H.
1867	Weigall, Albert Bythesea.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

THE LATE REVD. W. B. CLARKE, M.A., F.R.S., F.G.S., etc.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia. The prefix * indicates the decease of the recipient.

Elected

1878 *Professor Sir Richard Owen. K.C.B., F.R.S.

1879 *George Bentham, C.M.G., F.R.S.

1880 *Professor Thos. Huxley, F.R.S.

1881 *Professor F. M'Coy, F.R.S., F.G.S.

1882 *Professor James Dwight Dana, LL.D.

1883 *Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S.

1884 *Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S.

1885 *Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.

1886 *Professor L. G. De Koninck, M.D., University of Liège.

1887 *Sir James Hector, K.C.M.G., M.D., F.R.S.

1888 *Rev. Julian E. Tenison-Woods, F.G.S., F.L.S.

1889 *Robert Lewis John Ellery, F.R.S., F.R.A.S.

Elected.

1890 *George Bennett, M.D., F.R.C.S. *Eng.*, F.L.S., F.Z.S.

1891 *Captain Frederick Wollaston Hutton, F.R.S., F.G.S.

1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., LL.D., Sc. D., F.R.S., F.L.S., late Director, Royal Gardens, Kew.

1893 *Professor Ralph Tate, F.L.S., F.G.S.

1895 Robert Logan Jack, F.G.S., F.R.G.S., late Government Geologist, Brisbane, Queensland.

1895 Robert Etheridge, Junr., Curator of the Australian Museum, Sydney

1896 *Hon. Augustus Charles Gregory, C.M.G., F.R.G.S.

1900 Sir John Murray, K.C.B., LL.D., Sc. D., F.R.S., Challenger Lodge, Wardie, Edinburgh.

1901 *Edward John Eyre.

1902 F. Manson Bailey, F.L.S., Colonial Botanist of Queensland, Brisbane.

1903 *Alfred William Howitt, D. Sc., F.G.S.

1907 Walter Howchin, F.G.S., University of Adelaide.

1909 Dr. Walter E. Roth, B.A., Pomeroon River, British Guiana, South America.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney for paper on 'The Tin deposits of New South Wales.

1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.

Elected.

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper on 'The Australian Aborigines.

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper on 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper on 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper on the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper on 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper on 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

ISSUED OCTOBER 24th, 1911.

Vol. XLV. Part I.

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1911.

PART I., (pp. 1-64).

CONTAINING PAPERS READ IN

MAY to JUNE *(in part.)*

WITH THREE PLATES.

(Plates i, ii, iii.)

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1911.

F. WHITE Typ., 344 Kent Street Sydney.

PRESIDENTIAL ADDRESS.

By T. W. EDGEWORTH DAVID, C.M.G., B.A. F.R.S., Hon. D.Sc. *Oxon.*

With Plates I, II.

[Delivered to the Royal Society of N. S. Wales, May 3, 1911.]

THE privilege having once more been accorded me of addressing you as your President, I propose on this, the ninetieth anniversary of the existence of our Society, to touch briefly on the history of the Society during the last twelve months, then to offer some notes on the chief tectonic lines of Australia in particular and Australasia in general.

I—Royal Society of New South Wales.

The number of members on the roll on the 30th of April, 1911, was 315; 12 new members were elected during the past year. We have, however, lost by death two ordinary members and two honorary members, and nine by resignation. There is thus left a total of 316 members. This number, however, does not include the 14 honorary members. The losses by death were—Honorary Members, Sir William Huggins, Upper Tulse Hill, London, and Stanislao Cannizzaro, Reale Universite, Rome. Ordinary Members, Dr. Walter Spencer and W. J. MacDonnell.

Dr. WALTER SPENCER, M.D. *Brux.*, was for fourteen years a member of our Society, and for seven years was a member of our Council, whose meetings he attended with great regularity. Dr. Spencer is probably best known to our scientific world as the President of the British Science Guild, a position which he occupied at the time of his death last year in Mexico City. He was most enthusiastic in his devotion to the work of that body, and was chiefly instrumental in moving the Government of this State to provide increased ground space for the recreation of children, especially school children. His efforts at securing better methods for the carriage of stock for our Sydney Meat Supply further proves how near was the health and general welfare of the community to his heart. Throughout the whole of his life amongst us he proved himself to be a most conscientious and sympathetic worker in the cause of humanity no less than in that of science.

Wm. John MacDonnell, Fellow of the Royal Astronomical Society, was a member of our Society for forty-two years. An active member of the British Astronomical Association he was president for two years and secretary of the New South Wales Branch for several years, occupying that post when he died. He was a most enthusiastic amateur astronomer. His memory was remarkable, he could quote volume and almost page for hundreds of articles which he had read in the *English Mechanic.* Years ago when the Royal Society had an astronomical section, he was at that time one of its most active members. He participated in one of the Transit of Venus Expeditions. He was also a keen numismatist, making a specialty of Greek coins.

In regard to our Library it may be stated that books and periodicals have been purchased this year at a cost of £41 13s. 7d. A great number of unbound books and periodicals are about and will continue to be bound in a cheap style of binding in order to make them accessible to the members.

The number of Institutions on the exchange list numbers 429, and the publications received in exchange for the Society's Journal and Proceedings during the year were 222 volumes, 1815 parts, 161 reports, 282 pamphlets, and 20 maps, making a total of 2,500.

During the past year the Society held eight meetings at which 32 papers were read, the average attendance of the members being 34.

The following is a list of the series of Popular Science Lectures, illustrated by lantern slides etc., and of the Lecturers during 1910:—"The Velocity of Chemical Changes," by Professor Fawsitt, D.Sc., F.C.S.; "Early Blue Mountain Exploration, (Barallier's furthest West) by Mr. R. W. Cambage, L.S.; "The Mountains of New South Wales, their nature and origin," by Mr. C. A. Süssmilch, F.G.S.; "Modern Methods of Recording Earthquakes," by Rev. E. F. Pigot, B.A., M.B., S.J.; "The Social View of Capital," (two lectures), by Mr. R. F. Irvine, M.A. The excellent attendance at these lectures, and the enthusiastic way in which they were received is proof of their usefulness, and the hearty thanks of our Society are due to the lecturers who have so unselfishly placed their services at the disposal of our Society for the sake of the advancement of science.

May I also on your behalf and my own, express on this occasion, our deep gratitude to the Hon. Secretaries, Mr. J. H. Maiden, F.L.S., and Mr. F. B. Guthrie, F.I.C., as well as to the Hon. Treasurer, Mr. David Carment, F.I.A., for their unremitting and generous services in the best interests of our Society. It is satisfactory to note that the finances of the Society are sound.

On the occasion of my recent visit to England, it was my privilege on several occasions to meet our old colleague, whom we have all come to look upon as a second founder of this Society, Professor Liversidge, and members will be pleased to hear that he is in excellent health and engaged in active research on lines made familiar to us by so many of his papers published in our journal. He desired me to convey his kindly greetings to all the members, greetings which, I am confident we all heartily reciprocate.

It was obvious that he had played an important part together with Professor Masson of Melbourne, Professor Martin of the Lister Research Institute, R. Threlfall (late

Professor of Physics at the University of Sydney) Professor J. P. Hill and others of our former colleagues in so successfully pressing the invitation of the science bodies of Australia to the British Association for the Advancement of Science to come over and visit us in 1914. It was also obvious from the names mentioned of the intending visitors that the British Association would be well and worthily represented on what we all hope will be a happy and helpful meeting between the old world and the new.

II—Notes on some of the Chief Tectonic Lines of Australia.

The relief model of Australia reproduced on *Plate 1*, and the lines of section which accompany it, represent some of the chief structural trend lines which have presented themselves to one's notice up to the present. Suess in his magnificent and monumental work, "Das Antlitz der Erde," has already furnished a masterly sketch of some of the main trend lines of Australasia.[1]

The late Captain F. W. Hutton, F.R.S., has furnished an excellent and succint account of the chief structural features of New Zealand.[2] The Horn Expedition to Central Australia threw much light on its dominant trend lines.[3] In 1893, in a Presidential Address to the Linnean Society, I attempted to sketch from somewhat meagre data the then state of our knowledge of the leading trend lines of Australia.[4] Professor Gregory, F.R.S., has indicated some of the chief trend lines of Victoria.[5] Mr. W. H. Twelvetrees, F.G.S., the Government Geologist of Tasmania and

[1] Suess, The Face of the Earth, Translation by Hertha, B. C. Sollas and W. J. Sollas, Vol. II, pp. 149 – 164; and Vol. IV, pp. 301 - 321 and 501.

[2] Q.J.G.S., May, 1885, Sketch of the Geology of New Zealand, by Capt. F. W. Hutton, F.G.S., pp. 191 - 220, figs. 1 – 4.

[3] Report of the Horn Exploring Expedition in Central Australia, Geology by Prof. Ralph Tate and J. A. Watt, B.A., B.Sc., pt. 3, pp. 1 – 81

[4] Proc. Linn. Soc., 1894, Vol. VIII, Ser. 2, pp. 540 – 607, pls. xxvii, xxviii.

[5] Geography of Victoria, Whitcombe and Tombs. By Professor J. W. Gregory, F.R.S.

Mr. G. A. Waller have done similar work for Tasmania.[1] Still more recently Mr. E. C. Andrews,[2] Mr. C. A. Süssmilch,[3] and Mr. C. Hedley,[4] have dealt with the physiography, epeirogenic uplifts, disjunctive lines, and warping of New South Wales. In a later paper Mr. E. C. Andrews[5] has summed up our knowledge of recent and Tertiary earth movements in Eastern Australia and Tasmania. Mr. Walter Howchin, F.G.S.,[6] has greatly added to our knowledge of the tectonic lines of South Australia. Mr. A. Gibb Maitland, F.G.S., the Government Geologist of South Australia, has summed up a vast amount of information obtained by himself and the officers of his survey on the geological structure of West Australia in his presidential address to the Australasian Association for the Advancement of Science,[7] and aiso in his recent paper on "The Foundation Stones of West Australia." He has also contributed for my present address a valuable note on the chief lines of fault traversing that State. In regard to Queensland. nearly all our knowledge of its structural features are contained in the reports of the Geological Survey, notably those by Dr. R. L. Jack, F.G.S., Messrs. W. H. Rands, F.G.S., and B. Dunstan, F.G.S. For the structure of Northern Territory the chief information is given in the official reports by Mr. H. Y. L. Brown, A.R.S.M. F.G.S., Government Geologist of South Australia, and by his assistant Mr. Basedow, B. Sc. [8]

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[1] Report Austr. Assoc. Adv. Sci., Dunedin, 1904, pp. 613, 622 – 629.

[2] Physical Geography of New South Wales. by E. C. Andrews, B.A., pp. 55 – 94.

[3] This Journal, Vol. XLIII, 1909, pp. 331 – 354, pls. ix – xiv.

[4] Proc. Linn. Soc. N. S. Wales, Presidential Address, Vol XXXV, 1910 and *ibidem* Vol. XXXVI, pp. 9 – 21, pls. i, ii.

[5] This Journal, Vol. XLIV, pp. 420 – 480, figs. 1, 2, The Physiographic Unity of Eastern Australia, by E C. Andrews, B A.

[6] The Geography of South Australia, by Walter Howchin, F.G.S., edited by Professor J. W. Gregory, 1909; also see Howchin, Journ. Roy. Soc. S. Australia, Vol. XXVIII, pp. 253 – 280, pls. xxxvii – xliv, and Vol. XXX, pp. 227 - 262, pl. xii; also Q.J.G.S., Vol. LXIV, pp. 234 – 258, pls. xix – xxvi.

[7] Report Austr. Assoc. Advt. Sci., Adelaide, 1907, Presidential Address by H. Gibb Maitland, F.G.S., pp. 131 – 137.

[8] Report on the Geology of Northern Territory, By Authority. Adelaide 1895 and 1906.

It may be added that in the matter of late epeirogenic uplifts of Australia much light has been shed by the palæontological researches of Messrs. R. Etheridge and W. S. Dun; and new and promising line of investigation bearing on recent movements of the East Australian coast line based on the present distribution of our forest trees in relation to soils and geological formations has been instituted by Mr. R. H. Cambage, L.S.[1]

The excellent seismograph records now being published from time to time by the Rev. E. F. Pigot, S.J., from the Seismograph Observatory at St. Ignatius College, Riverview are yielding invaluable information as to the areas of modern re-adjustment of the earth's crust in the neighbourhood of Australia. Other references will be given in their proper place throughout this address.

The relief map of Australia and Tasmania reproduced on *Plate 1*, was specially prepared for this address by Mr. W. K. McIntyre of Sydney University, from data generously placed at our disposal by Mr. H. E. C. Robinson, to whom Australian cartography is very deeply indebted. In this relief map the following features at once arrest attention: (1) The strongly marked eastern ranges approaching so closely to the coast near Cape Howe and in the neighbourhood of Hinchinbrook Island and the Bellenden-Ker Ranges. (2) The broad basin lying to their west extending from the Gulf of Carpentaria to the Australian Bight with the eastern branch of the Darling-Murray Basin, and the immense western extension around the head of the Great Australian Bight as far west as Cape Arid. The boundary on the south of the Darling-Murray Basin introduces us to a new tectonic element, (3) The Victorian Main Divide in which an east to west line of warping or uplift has dominated the older meridional lines, an uplift which is comple-

[1] Report Austr. Assoc. Adv. Sci., Vol. XI, pp. 473 - 483.

mentary to the inthrow of the parallel and adjacent structure of (4) Bass Strait. The boundary of the Darling-Murray Basin on the west reveals element (5), the great fork of the Mount Lofty and Flinders Ranges thrust far north into the great basin. The deep indents of St. Vincent and Spencers Gulfs and the basins of Lakes Torrens and Eyre, suggest strong tectonic disturbances extending from here towards the Gulf of Carpentaria.

The main western boundary of the Great Basin is (6) the plateau of Central Australia, Northern Territory and West Australia, accentuated at its eastern edge by the strong east and west trend lines of the MacDonnell and Musgrave Ranges, and terminating south-westwards in the Darling Range peneplain, interrupted by the bold bluffs of the Stirling Range. The western boundary of the Darling Range is followed further west by what Mr. Gibb Maitland has shown to be one of the most remarkable tectonic features of Australia, a deep, long and narrow rift valley. Cape Leeuwin and Cape Naturaliste lie on the west side of this valley, the deep indent between Cape Naturaliste and Bunbury being due to this tectonic feature. I cannot do better than here quote Mr. A. Gibb Maitland's account of this feature as well as on other fault lines in West Australia: "In the short time available it has been found quite impossible to wade through the forty-one bulletins and fifteen annual reports of the Geological Survey. The following however, are the more important main fault lines, so far as is known :—1. The face of the Darling Range from the South Coast to somewhere about Minginew (S. Lat. 29 – 34°) appears to be marked by a major fault, which there is some reason for believing marks the eastern wall of a long "rift valley," of which probably part of the western wall is to be found in that narrow ridge of ancient crystalline rocks from Flinders to Geographe Bay. The fundamental rocks of the islands of Rottnest and Houtmens Abrolhos possibly mark the northward extension of these latter. The eastern fault which forms the escarpment of the range brings the palaeozoic and newer rocks in juxtaposition to the ancient crystalline schists, which are believed to be of Archaean Age. The sedimentary rocks which fill this "rift valley" are so arranged that there is a gradually ascending series southwards from the Irwin River Coal Field. Cretaceous rocks outcrop at Gin Gin, they have been met with in some of the bores in the metropolitan area, beneath Perth, and also rise to the surface to the southward along the coastal plain. The most recent beds in this "rift valley" make their appearance near Bunbury, and are associated with more or less horizontal sheets of basalt, these latter outcrop at Bunbury, at several places in the bed of the Blackwood and the south coast between Cape Leeuwin and Cape D'Entrecasteaux, they have also been met with in a bore put down in the valley of the Donnelly River. There seem reasons for believing these to be contemporaneous with the bedded basalts of South Australia and Victoria, if so then it is very likely that this fault is Late or Post Tertiary.

"2. On the Warrawoona Field, Pilbarra Gold Field, (Bull. 40, plate 10, of reprint of Bulls. 15, 20, and 23) a very marked fault at least six miles in length, traverses the field in a N.W. and S.E. direction, and probably extends far beyond the limits of the area mapped. The fault hades to the N.E. at about 60 degrees. A glance at the map shews several bands of quartzite disposed somewhat in the shape of a fan, the ribs of which open out gradually to the west. The peculiar mode of occurrence, and ending off of these beds is strongly suggestive of this line marking an important fault, which, however, makes no show at all on the surface. Further evidence of this hypothesis is to be found in the fact that the continuity of the newest diabase dykes, which cross the field in a direction about north-east and south-west, is very materially affected. Many of the rocks are sheared, and the quartz reefs folded and overthrust, all of which points to this being a region of great dynamic movement.

"3. The Warrawoona belt extends northwards fifteen miles to Marble Bar, which field is also traversed by at least four major faults, which have a general northerly strike. These faults have played great havoc with the newer diabase dykes, as may be seen by an inspection of the geological map (pl. 14, Bull. 40). Of the age of the faulting both here and at Warrawoona, there is no direct evidence, other than that it is younger than that of the newest diabase dykes, of whatever age they may be.

"4. The Collie Coal Field is bounded by two faults trending generally north-west and south-east. The faults are of considerable horizontal extent as well as of great downthrow. I am rather inclined to regard the boundaries of the great Stirling Range, as marking the extension of the Collie group of faults."

The trend and positions of these lines of faults are shown on *Plate 2*, and the rift valley and the folds in the adjacent peneplain are shown in figure 1.

FIG. I. DIAGRAMMATIC SECTION ACROSS THE GREAT TROUGH FAULT OF WEST AUSTRALIA. from data suggested by A. Gibb-Maitland F.G.S. Vertical Scale 8.000 Feet to an inch.

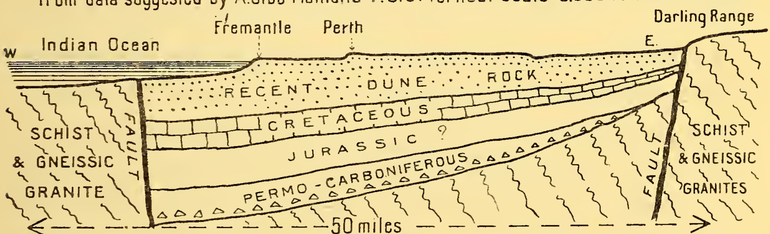
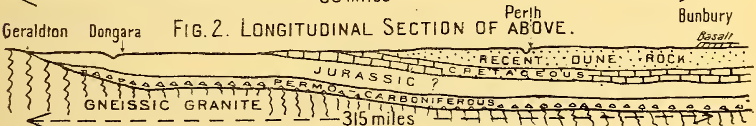


FIG. 2. LONGITUDINAL SECTION OF ABOVE.

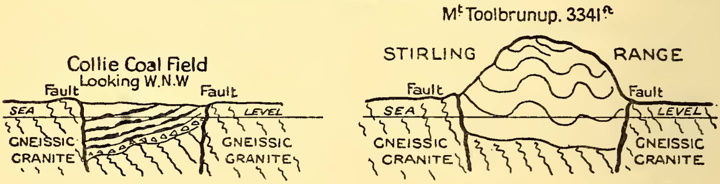


Vertical Scale 20.000 Feet to an inch

As already stated by Mr. Maitland, the faults bounding the Collie Coal-field[1] are probably continuous with those which have given origin to the Stirling Range.[2] Mr. Maitland states in regard to the Stirling Range that lateral compression has worked from the south, and has formed three anticlines in a distance of ten miles. Mount Toolbrunup, the highest point in the range is nearly 4,000 feet above sea level. A prolongation of these faults to the E.S.E. runs through Cape Riche. The southern of these two faults, or perhaps zone of faults, has a throw of approximately the order of 2,000 feet.

In regard to the rift valley of the west coast, the sharp trend northwards of the Murchison River close to its mouth, and the remarkable coastal indents near Shark Bay are very suggestive of a prolongation of this rift valley in that direction. The probable geological structure of this rift valley are shown on Figs. 1 and 2, and that of the Collie-Stirling fault zone on Fig. 3.

FIG 3. DIAGRAMMATIC SECTIONS ACROSS COLLIE-STIRLING TROUGH
Vertical Scale 8000 feet to an inch



In addition to the evidence of the faults, the trend lines of West Australia are indicated by:—

(1) Prevalent strikes of folds in sedimentary rocks.

(2) The trend of the metalliferous (especially auriferous) belts.

(3) The direction of the foliation and schistose structure in the gneisses and schists.

(4) The trend of the banded jaspers and hornstones.

[1] Permo-Carboniferous. [2] Older Palæozoic.

(5) The prevalent strike of the long axes of masses of eruptive rocks such as granite, quartz-porphyry, diabase, dolerite, etc.

(6) Prevalent strike of quartz reefs.

(7) Trend of joints in rocks.

(8) Trend of rivers and lakes.

The banded jaspers and hornstones are such a conspicuous feature in the geology of West Australia, and so wonderfully persistent for distances of hundreds of miles, that they deserve special mention here.

At Northampton in West Australia, there is a great development of what Mr. Maitland has termed sheeted zones of micaceous and garnetiferous granulite, traversed by much puckered and contorted veins of quartz. "These sheeted zones trend generally north-west and south-east. These are not planes of bedding, but they represent gliding planes, along which the rocks have yielded to the irresistable lateral pressure, resulting, *inter alia*, from the contraction of the earth's crust. The result of this lateral earth creep is that many of the rocks have been milled down, as it were, and in some cases rocks having all the external characters of finely banded slates or schist have resulted. An excellent instance of this occurs in the valley of the Helena River where the normal granite as a result of the operations of the great earth mill has been ground to powder or rock flour, producing a rock termed mylonite."

That the mylonites represented by the banded red jaspers and hornstones have been subject to earth movements since their formation is proved by the fact mentioned by Mr. Maitland, that at Boogardie and on the Murchison field, as well as at Tuckanadra, 26 miles N.E. of Cue, they have been thrown into a series of gentle curves. They are crossed by numerous faults almost at right angles, and pockets of gold ore occur at the intersection.

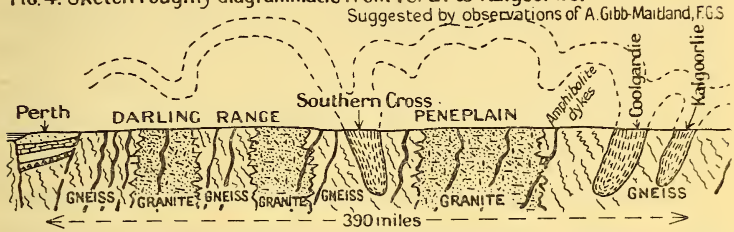
As regards prevalent strikes of folds in the sedimentary rocks and schistose structure in the gneisses and schists at the Porongorup Range near Albany, the massive gneisses are foliated in a direction N.W. to S.E. This trend is fairly constant amongst the older crystalline rocks of the southern part of West Australia, The three anticlines of the Stirling Range strike approximately parallel to the major faults which bound that range, the general trend being from W.N.W. to E.S.E. Mr. Maitland considers that the folding force has in this case operated from the south northwards. Further north, as in the Coolgardie and Kalgoorlie gold-fields, the strike of the foliation and bedding is more meridional being about N.N.W. and S.S.E.

At Northam the trend of gneissic foliation is N.W. to S.E., while that of the quartz-dolerite or quartz-diabase dykes is chiefly from S.W. to N.E. From the Murchison through Cue to Leonora, the trend lines in the older rocks are still a little W. of N. and E. of S.

The same remark applies to the great auriferous belts. According to Mr. Maitland's views, these consist of highly inclined metamorphic and sedimentary rocks associated with contemporaneous interbedded eruptive rocks. Some of these are distinctly amygdaloidal, and there is every reason to believe them to be ancient lava flows. These, in Mr. Maitland's opinion, have been infolded in great synclines, amongst the gneisses, and have been subsequently intruded by newer rocks such as serpentines, quartz-dolerites (quartz-diabase), acid-porphyries, and granites, the last intersected still later by greenstone dykes.

According to Mr. Maitland's view the great gold belts of Western Australia would therefore present some such an appearance as is shown diagrammatically on Fig. 4. The other alternative seems to be to regard these belts as overthrust, rather than as overfolded areas. There can be little doubt that both overfolding and overthrusting are present.

FIG. 4. Sketch roughly diagrammatic from Perth to Kalgoorlie.



As the Pilbara region is approached, all the trend lines, as shown on *Plate 2*, swing from the nearly meridional once more into a N.W. and S.E. direction. This trend is well shown in the directions of the Ashburton, Fortescue, and De Grey Rivers, as well as in the trend of ranges like the Hammerley Range and the Throssell Range.

The Doolena Gorge, "the gateway of the north-west," and the Bangemall Anticline both have a N.W. to S.E. trend. The S.W. limb of this large anticline is steeper than the N.E. line, which suggests that the overfolding in this case came from the N.E. The fold 'pitches' to the S.E., which suggests that the earth-movement was more intense towards the N.W. At Warrawoona the newer dolerite dykes intersect the older folded rocks in enormous numbers. Their dominant strike is from S.W. to N.E., as in the case of the Northam dykes.

In the Kimberley district of West Australia, Mr. E. T. Hardman[1] has described Pre-Cambrian, Cambrian, Devonian and Carboniferous Rocks. Mr. H. P. Woodward[2] has also described part of this area, as well as Dr. R. L. Jack, LL.D., F.G.S.[3] Their observations show that the schists, gneisses,

[1] Report on the Geology of the Kimberley District, by E. T. Hardman By authority, Perth, 1884.

[2] Report on the Gold-fields of the Kimberley District, by H. P. Woodward. By authority, Perth, 1891.

[3] Bull. Geol. Survey, West Australia, No. 25, pp. 1–46.

and banded jaspers strike in a N.W. direction through the King Leopold Range to King's Sound. This belt of metamorphic rocks is 10 to 30 miles wide and 120 miles in length. The Devonian rocks in the central and eastern part of the Kimberley region have been folded in broad open folds on axes which trend in a N. E. and S. W. direction. The Carboniferous (Permo-Carboniferous Rocks) have not been folded, but merely tilted.

In regard to the Devonian rocks of the Kimberley district Mr. Hardman estimated their thickness at nearly 11,000 feet, and Mr. H. P. Woodward describes these Devonian rocks as striking N.E. and S.W. The question that obviously here suggests itself, is do these fold troughs of the central and eastern part of Kimberley, such as those of the Carr-Boyd Ranges, Saw Ranges and Lubbock Range meet Pre-Cambrian folds of the King Leopold Range in linking or in syntaxis. These trend lines from S.W. to N.E. agree in general direction with the folding of the Devonian Rocks of the Burdekin district as well as with one of the two directions of folding on the Gilbert Gold-field of Queensland. From a letter received from Mr. Gibb Maitland it would appear probable that these two directions of folding at Kimberley in West Australia form part of a syntactic arc, and they may therefore provisionally be grouped as such. At present the evidence as to the folds being symmetrical or asymmetrical in this region is insufficient. One cannot therefore as yet arrive at a definite conclusion as to the sense in which the folding force has operated.

That we know so much already about the structure lines of West Australia, more probably than we know about those of any of the other States of the Commonwealth, is due chiefly to the enthusiastic and sustained efforts of Mr. A. Gibb Maitland and his colleagues, notably Mr. H. P. Woodward, Mr. E. T. Hardman and others who have toiled so hard and so long in a country where travel bristles with dangers and difficulties.

If now we turn to South Australia we find that most interesting features have lately come to light. The early report by A. R. C. Selwyn[1] revealed a rough plan of the build of the Mount Lofty Ranges. The numerous records and reports by Mr. H. Y. L. Brown, Assoc. R.S.M.,[2] contain much information as to trend lines at intervals over this vast territory, and still more important information is afforded by his geological map of South Australia. The Horn Exploring Expedition to Central Australia elucidated the chief tectonic features of the MacDonnell Ranges.[3] Mr. H. Basedow has published useful information as to the trend lines of the Musgrave, Mann, Everard, and Ayers Ranges.[4] Dr. W. G. Woolnough[5] has contributed a paper, chiefly petrological, on the Mount Lofty Ranges. Dr. Douglas Mawson, B.E., D.Sc.,[6] has dealt with the structure of the north-eastern virgation of the Mount Lofty Range where it spreads away into the Barrier Ranges. Of late years a flood of light has been thrown on the obscure questions of the trend lines of South Australia by Mr. Walter Howchin.[7]

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[1] Geological Notes of a Journey in South Australia from Cape Jervis to Mount Serle. Parl. Paper No. 20, Adelaide, 1859.

[2] Chiefly on the mining fields of South Australia and Northern Territory, published by the Mines Department of South Australia or as Parliamentary Papers.

[3] Horn Scientific Expedition to Central Australia. Report on the Geology by Professor Tate and J. A. Watt, M.A., B.Sc.

[4] Trans. and Proc. Roy. Soc. S.A., Vol. XXIX, pp. 57 – 102, pls. xiii – xx.

[5] Trans. and Proc. Roy. Soc. S.A., Vol. XXXII, pp. 121 – 137, pls. i, ii.

[6] Thesis for D.Sc. Degree presented to the University of Adelaide, 1909-10.

[7] Trans. and Proc. Roy. Soc. S.A., Vol. XXVIII, (1904), pp. 253 – 280. pls. xxxvii – xliv; *Ibid.*, Vol. xxx, (1906) p. 227. Rep. Austr. Ass. Adv, Sci., Vol. XI, p. 114. The Geography of South Australia including the Northern Territory, by Walter Howchin, F.G.S., and Professor J. W. Gregory, D. Sc., F.R.S. Q.J.G.S., Vol. LXIV, 1908 pp. 234 – 258, by Walter Howchin.

In his introduction to Mr. Howchin's Geography of South Australia, Professor Gregory contends that (*op. cit.*, p. 25 26, fig. 6) there is evidence of two distinct groups of folds in South Australia, differing in date of birth as well as in direction. The older group has dominant E. and W. trends, the newer according to Gregory, have a nearly meridional trend inclining slightly to W. of N. His conclusions are evidently based on the observations of Mr. Howchin (*op. cit.*, pp. 77–92). This very important problem will be discussed presently.

Reference to the relief map, *re* South Australia, makes it clear that the most conspicuous tectonic feature is that of the depressed area in which lie Lakes Eyre and Torrens prolonged southwards into the subsidence regions of Spencer's Gulf and St. Vincent's Gulf, and bounded eastwards by the western escarpment of the Mount Lofty and Flinders Ranges. Westwards the depressed area is bounded by the eastern edge of the great plateau of Central Australia near the west shores of Lake Torrens. If we refer to the map on *Plate 2*, commencing at Kangaroo Island and trace the lines of fold northwards, we cannot fail to be struck with the evidence of either a gradual change in the trend of the fold lines, or of the existence of two different groups of folds as argued by Mr. Howchin and Professor Gregory. The geological map is strongly in favour of a virgation and general meeting of the trend lines in syntactic arcs from Kangaroo Island to the Mount Lofty Ranges, and from the Mount Lofty Ranges to the Barrier Ranges. Dr. Woolnough in the paper just quoted, argues that the crystalline rocks on the eastern side of the Mount Lofty Ranges represent folded Pre-Cambrian rocks, the trend of whose folds agrees approximately with the later folds of the Cambrian strata. Mr. Howchin on the other hand holds that these crystalline rocks of the eastern Mount

Lofty Ranges represent Cambrian strata which have experienced intense contact metamorphism as the result of the intrusion of large contiguous belts of granite.

Mr. Howchin, at the same time, has recorded the existence of Pre-Cambrian rocks in the neighbourhood of Aldgate in the Mount Lofty Ranges, where their general trend lines, as far as they can be seen, correspond with those of the overlying Cambrian rocks. Certainly the Cambrian cleavages and joint planes pass directly downwards into those of the Pre-Cambrian.

Mr. W. N. Benson, B.Sc.[1] states (*op. cit.*, p. 107) that "in each of the three periods of great earth-movements evidenced in the Mount Lofty Ranges, viz. (1) the Pre-Cambrian, (2) the older Palæozoic Post-Cambrian, (3) the late Tertiary, the axis of folding or faulting was almost a meridional one. From Yankalilla to Aldgate, in the southern part of the Mount Lofty Ranges there appears to be an approximate agreement in direction between the Pre-Cambrian and older Palæozoic Post Cambrian folding. At the same time it is generally admitted that there is a strong unconformity between these two groups of rocks."

Again in Yorke Peninsula, near the Parara Mine, west of Ardrossan, Mr. Otto Tepper[2] shows that there is no great divergence between the strike of foliation there of the schists of Pre-Cambrian age and that of the Lower Cambrian limestone. He gives the strike of these Pre-Cambrian strata as N. 5° W.,[3] at the Parara Mine, and N. 8° E. at Mooloowurtie, the dip of the foliation at the Parara

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[1] Trans. Roy. Soc. S. Australia, Vol. xxxiii, 1909, Petrographical Notes on Certain Pre-Cambrian rocks of the Mount Lofty Ranges, with special reference to the Geology of the Houghton District, pp. 101 - 140, pls. i - v.

[2] Trans. Phil. Soc. Adelaide, 1877-8, pp. 71 – 79, Cliffs and Rocks at Ardrossan, Yorke Peninsula.

[3] The bearings given from here to the end of the paper are magnetic, except in the case of the bearings relating to West Australian areas. The latter bearings are true.

Mine he gives as from about 60° to 70° easterly. The lower Cambrian rocks when traced northwards from Mount Lofty and eastwards into the Barrier Range district of New South Wales show, near Poolamacca a strike of N. 10° W. (magnetic) to N. 20° W., has been observed by me at Campbell's Creek in that vicinity, the dip being easterly at about 70°. At Torrowangie the lower Cambrian limestone (probable equivalent of the Brighton limestone near Adelaide) dips E. 15° N. at about 13° up to 20°. At Paps Creek about 32 miles northerly from Broken Hill, near the locality of Campbell's Creek above referred to, Dr. Mawson has observed an unconformable junction between the lower Cambrian system and a group of schists (talc and mica schists) immediately to their west. There can be little doubt that these schists are Pre-Cambrian.

The authors of the geology of the Broken Hill lode[1] point out that there is a divergence of strike between that of the schists and that of the Cambrian strata at Paps Creek of from 25° to 33°. These talc or mica schists although Pre-Cambrian may not be Archæan. Now at Broken Hill, only 32 miles to the south, the true Archæan gneiss and amphibolite schists strike about E. 40° N., and have been strongly overfolded as well as overthrust in a south easterly direction. There is thus a wide divergence between the trend of the folia of these Archæan rocks of Broken Hill and the strike of the lower Cambrian glacial beds and limestones near Campbell's Creek and Torrowangie, the divergence amounting in this case to about 60°. But there is also a divergence between the trend of the Broken Hill Archæans and that of the Paps Creek schists. Possibly the latter may be Algonkian, for which age in the Mount Lofty region Dr. Woolnough has proposed the term Barossian.

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[1] Australasian Inst. Mining Engineers, Vol. vi, No. 11, April 1910, by Messrs. R. J. Donaldson, C. W. Matters, R. T. Slee, J. C. Coldham, H. H. Walman, F. Voss Smith, and H. W. Davies.

There probably seems evidence in the Broken Hill region for a considerable divergence between the strike of the Archæan gneiss and that of the lower Cambrian rocks.

This Broken Hill evidence suggests that Mr. Howchin's conclusions as to the difference in strike of the Pre-Cambrian mountains of South Australia and the Cambrian may be reconciled with the apparent conformity of the two directions of strike in the Mount Lofty Ranges on the assumption that in the Pre-Cambrian complex there are at least two distinct groups, (1) an Archæan group chiefly formed of gneiss and other coarsely crystalline rocks, (2) an Algonkian (or Barossian) group, and that the folding of group (1) took place much earlier than that of group (2) and was divergent in direction from it. It may also be assumed that group (2) was heavily folded before the deposition of the lower Cambrian beds, so as to leave a considerable unconformity between it and the Cambrian system, but that the direction of folding was less divergent from that of the Cambrian than it was from that of the Archæan. Mr. Howchin concludes that there is strong evidence of the divergence of the Archæan folds of what he terms the Willouran and Babbage line, and those of the Cambrian in the region between Lake Torrens and Lake Eyre. The other alternative is to assume that both Algonkian and Archæan rocks have been folded on similar trend lines, which mostly diverge from the later trend lines of the Cambrian, though in places they coincide.

On the whole it may be said that in the neighbourhood of Spencer's Gulf, St. Vincent's Gulf and the Mount Lofty Ranges the divergence between the trend lines of the Barossian group and the Yorke Peninsula group on the one hand and those of the Cambrian on the other, do not appear to be very strongly marked. On the other hand there is strong evidence of (1) a spiral structure, and (2) of virgation.

The great spiral commences in Kangaroo Island where an east and west trend swings gradually into a N. by E. to N.N.E. direction through the Mount Lofty Ranges, with a fine series of overfolds directed towards the west. As the Barrier Ranges are approached, the trend lines virgate striking about E.N.E. (true) near Broken Hill. There the folds are overturned and the fault planes overthrust towards the S.S.E. Thus the 'sense' of the folding changes in the country which intervenes between the Mount Lofty Ranges and the Barrier Ranges. Mr. Howchin has shown that in the region which lies between the Barrier Ranges and Lake Torrens, the Flinders Ranges are not folded asymmetrically. Mr. Howchin[1] has shown that in the northern section of the Flinders region the trend lines, near Beltana, strike N.W. Mr. H. Basedow also states[2] (p. 81) that the Cambrian strata near the head (northern end) of Lake Torrens appear to strike from N. 25° W. round to W. This suggests that the old trend lines of the western part of the great virgation are swinging round to meet the trend lines of the Musgrave Ranges.

These ranges described by Gosse,[3] 1873, and by H. Y. L. Brown[4] and V. Streich[5] have also been examined and reported upon by Mr. H. Basedow,[2] who shows that these Pre-Cambrian ranges formed of gneiss, schist, granite, quartzite etc., have a dominant strike nearly E. and W. At Opparinna Spring he figures a strong overfold directed to the north. In the Kelly Hills the schists strike about

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[1] The Geography of South Australia, Whitcombe and Tombs, 1909, p. 90.

[2] Trans. and Proc. Roy. Soc. S.A., Vol. xxix, 1905, Geol. Rep. on the country traversed by the S.A. Gov. N.W. Prospecting Exp. 1903, pp. 57–103, pls. xiii – xx.

[3] Gosse, Central and Western Exploring Expedition. By authority, Adelaide, 1873.

[4] Rep. Journey from Warrina to Musgrave Ranges, p. 2, Adelaide. By authority, 1889.

[5] Sci. Results Elder Expl. Exp., Trans. and Proc. Roy. Soc. S.A., Vol. xvi, pp. 77 and 83.

N.N.E. (true), dipping at 40° to E. 21° S. (true). Mount Woodroffe, 5,200 feet high, in these ranges is perhaps the highest peak in South Australia. Beyond the western end of the Musgraves rise the Mann and Tomkinson Ranges. The Mann Ranges, also formed mostly of Pre-Cambrian rocks, exhibit planes of foliation and schistosity trending from between N.E. and S.W., to W. by N. and E. by S. The folding as shewn by Basedow (*op. cit.*, p. 62 and Pl. xix) is intense but not very asymmetrical. As far as can be judged from his figure there is a slight tendency for the folds to be forced over towards the north.

The Tomkinson Ranges, formed of Pre-Cambrian gneisses and schists, also have large intrusive dykes of olivine-gabbro and norite. The gabbro intrusions trend about E. and W. Diorite dykes follow the same trend. The planes of foliation of the gneisses trend north-easterly (Basedow, *op. cit.*, p. 75). In Ayers Range the gneissic folds have a general trend a little S. of W. and E. of N.

At Mount Conner there is a great unconformity between the Ordovician quartzites and the Pre-Cambrian crystalline group. The strike of the quartzite varies from W. up to W. 30° N. (magnetic). Mounts Kingston, Olga, and Ayers Rock are formed respectively of quartzite, conglomerate and metamorphic grit, considered by Tate and Watt to lie at the base of the Ordovician Series.[1] The Levi Ranges to the south of the MacDonnell Ranges are also formed of Ordovician rocks and folded according to the same authors on approximately E. and W. axes. The folds appear to be nearly symmetrical.

In the MacDonnell Ranges the same authors show that the Pre-Cambrian gneisses, schists, and quartzites of that region are very strongly folded, and that the trend in the central and eastern part of the MacDonnells is nearly E.

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[1] Rep. Horn Exp. Centr. Austr., General Geology, p. 59.

and W., whereas westwards the folds bend somewhat to W. of N. inclining eventually to W.N.W. As far as can be judged from the sections supplied by these authors, there is a slight overfolding from N. to S.

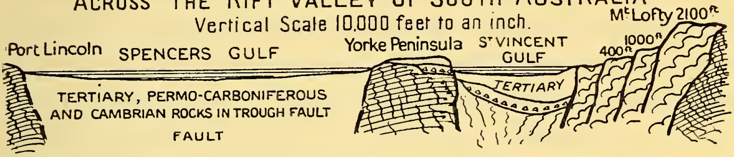
As regards newer structure lines it seems probable from the steepness of the southern escarpment of the MacDonnells and its narrow rocky cañons, such as those of Redbank Gorge, and the gorge of the Finke River, that there has been comparatively recent movement along an old E. and W. fault plane. The most important of these newer tectonic lines, as has been indicated by Mr. Howchin,[1] Prof. Gregory,[2] and Mr. W. N. Benson, B.Sc.,[3] are the series of important and comparatively recent zones of fractures which run more or less meridionally between the western scarps of the Mount Lofty Ranges and the high western plateau bounding Lake Torrens on the west. In this fractured and foundered area, termed by Professor Gregory the 'Rift Valley of Australia,' lie St. Vincent and Spencer Gulfs, Lake Torrens, Lake Eyre etc., the last mentioned at its centre being about sixty feet below sea level. This region appears to have been an area of subsidence from very early time. Even the lower Cambrian strata of Mount Lofty crept westwards in their effort to fill up this senkungsfeld; and in his latest paper Mr. Howchin has shown that even the Miocene strata to the south of Adelaide have been overfolded in the same direction.

The earthquake which visited the Adelaide region on September 19th, 1902, appears to have had its epicentre near Warooka towards the southern end of Yorke Peninsula. This proves that movement of the earth's crust along this important zone is still in progress. The accompanying

[1] Q.J.G.S., Vol. LXIV, p. 234 - 263, pls. xxvi – xxix. Geography of S. Australia, pp. 88, 89 and 100; and Trans. Roy. S. S.A., Vol. XXVIII, 1904, pp. 253 – 280, pls. xxxvii – xliv, and *ibid.* Vol. xxx, 106, pp. 227 – 262, pl. xi.
[2] Dead Heart of Australia.
[3] Trans. Roy, Soc. S.A., Vol. XXXIII, 1909, pp. 106-7, and *ibid.* 1910.

section, Fig. 5, after Howchin, shows the probable structure of this senkungsfeld.

FIG 5. SKETCH SECTION. (Suggested by works of Walter Howchin)
ACROSS THE RIFT VALLEY OF SOUTH AUSTRALIA
Vertical Scale 10,000 feet to an inch.



We may now glance briefly at the trend lines of Northern Territory, as far as they are known. The Rev. J. E. Tenison-Woods[1] figures a highly folded series of crystalline rocks without giving the trends of the folds. Mr. H. Y. L. Brown[2] in several reports has, with his assistants, placed us in possession of our present information as to the dominant structure lines of that region. The following conclusions may be provisionally drawn from Mr. Brown's reports:—

(1) That the Pre-Cambrian schists and gneisses have been folded on lines whose directions vary from N. and S. to N.N.W. and S.S.E.

(2) That the lower Cambrian *Salterella* limestones and associated strata strike about N.W. and S.E. with lines of major faulting and zones of crushing trending in the same direction.

(3) That the Ordovician quartzites have been somewhat folded and strongly tilted, the chief direction of the tilt being towards a little W. of S. This tilting appears to be connected with the great tectonic lines which extend through New Guinea in an E. by S. and W. by N. direction.

(4) That the Permo-Carboniferous rocks have not been folded.

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[1] Report on the Geology and Mineralogy of Northern Territory. By authority, Adelaide, 1886.

[2] Northern Territory Exploration, 1895. Northern Territory of S.A., Report by H. Y. L. Brown. By authority Adelaide, 1905.

(5) That recently hot springs, such as those of the Douglas River have broken out along lines which trend between N. 35° W. and N.W.

We thus see in the Northern Territory evidence first of a N. by W. foliation of the Pre-Cambrian rocks, followed by a N.W. folding of the Cambrian strata, and this in turn succeeded by a general tilting of all the strata from Cretaceous downwards in a S. by W. direction, showing that this part of Australia has probably of late fallen under the control of the New Guinea lines of uplift. Much information on the subject of the tectonic lines of Northern Territory may be expected from Dr. W. G. Woolnough on his return from the Scientific Exploring Expedition in Northern Territory. We may now turn to the south eastern part of Australia, and review the tectonic lines of Tasmania, Victoria, and New South Wales.

Tasmania.—Mr. W. H. Twelvetrees, F.G.S.,[1] and Mr. T. Stephens, M.A.,[2] and Mr. R. M. Johnston, F.G.S.,[3] have devoted some attention to the dominant trend lines. Mr. Twelvetrees has shown that on the west coast of Tasmania the schists of Pre-Cambrian age strike about N. 20° W., at the Rocky River on the Waratah Corinna Road, and at Cox's Bight on the south coast Pre-Cambrian (Algonkian) biotite schists and quartzite strike N.N.W. to N.W. They dip at low angles to the S.W. Mr. Twelvetrees estimates a minimum thickness for these beds of about 13,000 feet. On the N.W. coast at Rocky Cape quartzites and quartz-schists (Algonkian) trend N. and S., or a little W. of N., and E. of S. At the Forth River micaceous schists, hornblendic schists with garnet and zoisite, and quartzites strike W. of N. with a westerly dip.

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[1] Rep. Austr. Assoc. for Adv. of Sci., Vol. XI, 1907, pp. 466 – 470, and *ibid.*, Vol. x, 1904, pp. 613 and 622 – 630.

[2] Proc. Linn. Soc. N. S. Wales, Vol. XXXIII, pt. iv, pp. 752 – 767, pls. xxiv – xxviii.

[3] Geology of Tasmania, by R. M. Johnston, F.G.S., etc. By authority, Hobart, 1888.

Infolded amongst these Algonkian rocks are strata of Cambrian, Ordovician and Silurian Age thrown into long folds approximately parallel to the older trend lines of the Pre-Cambrian rocks. These strongly marked N.N.W. and S.S.E. trend lines of the western side of Tasmania are crossed by a line of granite intrusion which may be termed the Waratah axis, as it runs through the Mount Bischoff Mine at Waratah; this trends about N.E. and S.W. On the east coast the long meridional line of granite intrusions extending from the Hippolyte Rocks on the S., through Maria and Schouten Islands, Freycinet's Peninsula, St. Patrick's Head, St. Helens and Cape Barren Island and Flinders Island, marks a strong N. and S. tectonic line.

In the V formed by these two dominant trend lines is enclosed the Permo-Carboniferous and Trias-Jura basin with their massive sills of quartz-dolerite or quartz-diabase. Mr. Twelvetrees has shown that the alkaline rocks of the Port Cygnet district have broken out along a line trending S. 40° W., and that the distribution of the melilite basalts of Tasmania indicate an eruptive line trending about E. and W., near Lake Sorrell, and about E. 10° N. near Hobart between Rokeby and One Tree Point. The geological faults of Tasmania have not yet been worked out. Mr. Montgomery[1] records minor faults with throws of about 200 feet at Beaconsfield to the north of Launceston.

Mr. E. C. Andrews[2] has enumerated some probable lines of heavy fault as indicated by physiographic evidence, as follows:—Ben Lomond, Western Tiers, Mounts Roland and Wellington, north-east coast and east coast. R. M. Johnston[3] has already figured, on direct stratigraphic evidence several important faults on the south side of Mount Wellington. The line of melilite basalt eruption already

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[1] Rep. Austr. Assoc. for Adv. of Sci., Hobart, Vol. IV, pp. 321 – 327.
[2] This Society's Journal, Vol. XLIV, 1910, p. 477.
[3] Geology of Tasmania, p. 163, see section opposite page.

mentioned trending about E. 10° N., probably marks a fault along this line. The great scarp to the west of Cradle Mountain, 5,069 feet high, the highest point in Tasmania, probably marks a line of major faulting with a heavy throw to the west. At the same time the existence of the great resistent sills of quartz-dolerite thrust over the thick masses of soft sediment of the Trias-Jura and Permo-Carboniferous systems afford exceptionally favourable conditions in this part of the island for the formation of steep scarps by sapping, unassisted by faulting. A prolongation of this hypothetical line of faulting to the west of Cradle Mountain trends towards Hobson's Bay, in Victoria. Another possible dislocation line in Tasmania is the gap through which the railway line from Launceston to Hobart passes between Ross and Oatlands. There can be little doubt but that in Tasmania block-faulting has assisted sapping in producing the steep scarps of the 'tiers,' that inland plateau so much of which is over 4,000 feet above sea-level, with peaks such as Mount Wellington 4,400 feet, Mount Field (or Humboldt) 4,721 feet, Ironstone Mountain 4,736 feet, and Cradle Mountain 5,069 feet above sea-level.

Victoria.—A glance at *Plate 2* at once reveals the important fact that there are at least two widely divergent trend lines in Victoria. First there is the obvious trend of the Main Divide of Victoria from E. to W. Then there are the older lines having a nearly meridional trend, which mark the position of the Grampians, Howitt-Wellington mountains, Snowy River porphyries, and the deep valleys of the Kiewa and Mitta-Mitta Rivers, the former sunk some 4,000 feet below the summit of the Bogong Mountain. The geological map of Victoria shows that trending sympathetically with the Main Divide is the belt of Trias-Jura sandstone of the Wannon, Otway, and Gippsland areas. Between the last two regions lies the great valley of Victoria.[1]

[1] The Geography of Victoria, by Prof. J. W. Gregory, D.Sc., F.R.S., p. 77

The central and western parts of this great valley are occupied by the basaltic lavas mapped on the sheets of the Victorian Geological Survey and recently described in detail by Professor E. W. Skeats.[1] This east to west sag of the trough of the "great valley" has led to the isolation of the Wannon Trias-Jura area from that of the Otway area, as the result of the inflow of the sea and deposition of marine sediments over this part of the basin in Tertiary time. The isolation has been further completed still later by the outflow of vast sheets of basaltic lava. Dr. T. S. Hall[2] has emphasised the isolation of the Otway region as the result of this subsidence along the great valley in his chapter "The Otways as an island." Mr. Reginald A. F. Murray[3] has given a brief account of the metamorphic rocks and crystalline schists of Victoria and their trend lines, as well as of those of the older Palæozoic rocks. He remarks that (*op. cit.*, p. 34) "The leading characteristics of the Lower Palæozoic rocks of Victoria are the normal N. Westly to N. N. Easterly strike, and the high rate of inclination of their bands caused by the crumpling or folding process to which they were subjected at a period not long subsequent to their deposition etc."

According to R. A. F. Murray, following A. R. C. Selwyn, Victoria as regards its older rocks and the lines of folding in older and newer Palæozoic time is a vast syncline extending from the crystalline schists of the Wannon and Glenelg Rivers on the west to the similar rocks of the Mitta-Mitta massif, or Benambra Highland on the east (*op. cit.*, pp. 37, –78). Professor Skeats figures as Archæan[4] (*op. cit.*, p. 231) the foundation rocks between the Hummocks and the

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1 Rep. Aust. Assoc. Adv. of Sci., Brisbane, 1909, pp. 173 – 229, pls. i – iv.
2 Victorian Hill and Dale, by T. S. Hall, M.A., D.Sc., Melbourne, T. C. Lothian, 1909, pp. 99 – 106.
3 Victoria, Geology and Physical Geography. By authority, Melbourne 1887, pp. 36, 37.
4 Rep. Austr. Assoc. Adv. of Sci. Brisbane, 1909, pl. i, p. 230.

Mount Stavely Range. This geosyncline between Benambra and the Glenelg River is warped across in a direction trending from about N. and S., or a little E. of N. and W. of S. by ancient axes or hinges of folding referred to by Professor Gregory as the line of the Colbinabbin Range.[1]

On the latest geological survey map of Victoria this area is coloured 'Heathcotian,' and referred with a query to the Cambrian. Sections across this supposed Cambrian axis have been published by Professor Gregory.[2] In section 7 (*op. cit.*) he shows a parallel axis to the Colbinabbin axis at Dookie. On the other hand Professor Skeats in his able and well illustrated paper marks with a query as basal Ordovician the diabase series of the Knowsley district N. of Heathcote. In any case all the Victorian geologists seem agreed that there is an old axial line of folding running approximately meridionally through Heathcote.

On either side of this Colbinabbin axis lie troughs of Ordovician rocks. These have been folded very strongly as shown by Mr. E. J. Dunn,[3] on lines about N. 25° W. (true) and E. of S. The folds near Bendigo (Sandhurst) are somewhat asymmetrical, the source of the thrust being to the E., so that the folds are overturned towards the W. So much have these Ordovician strata been compressed that for considerable distances they now occupy only one half of their original dimensions measured along E. and W. directions. Professor Gregory shows four troughs of Silurian rocks[4] infolded in the eastern Ordovician syncline between Keilor and Mount Wellington. A glance at the geological map of Victoria shows that the Snowy River porphyries of Lower Devonian (?) time were developed along a line of eruption approximately meridional, and the middle Devonian

[1] The Geography of Victoria, p. 69, 70.
[2] Proc. Roy. Soc. Victoria, 1902, pl. xxv.
[3] Report on the Bendigo Goldfield. By authority, Melbourne, 1896.
[4] Proc. Roy. Soc. Vict., 1902, pl. xxv, section 5.

Buchan and Bindi limestones lie in troughs also approximately meridional. A very strongly marked trough is that in which lie the so called (on the geological map) Devonian, by others considered Carboniferous, rocks of the Mitchell, Avon, and Macallister River regions. These strata contain in places *Lepidodendron australe*. They mark a strong N.N.W. to S.S.E. trend line from Mount Wellington 5,363 feet to Mount Howitt and beyond. A good section across this area is given by Professor Skeats.[1] To the W. of the Macallister River a strong fault is marked having a trend presumably about N.N.W. and S.S.E. The upper Palæozoic rocks of the Mount Wellington and Macallister are shown dipping off an axis of intrusive serpentine.

With these late Devonian or early Carboniferous rocks folding in Victoria practically ceased. The Permo-Carboniferous glacial beds are mostly either nearly horizontal or but gently inclined. But near Bacchus Marsh, as shown by Messrs. C. C. Brittlebank and G. Sweet, F.G.S.,[2] they dip in a general southerly to south-easterly direction at angles of from 5° up to in places 45°. As the grooving on the rock surfaces and the carry of the erratics all points to the ice having moved from S. to N., and the whole surface of the country was probably overridden by ice from at least as far as Bacchus Marsh on the south to Beechworth on the north, the present Main Divide could not then have existed, but the gathering ground of the snowfields must have been situated near to, or south of, the present southern coast of Victoria. The strong southerly dip of the Permo-Carboniferous glacial beds near Bacchus Marsh suggests that the warping up of the Main Divide of Victoria took place chiefly in very late Palæozoic time, and was connected with the intrusions of the large batholiths of granite which lie

[1] Rep. Austr. Assoc. for Adv. of Sci., Brisbane, 1909, pl. ii, fig. 2, p. 233.
[2] Rep. Austr. Assoc. for Adv. of Sci., Adelaide, 1893.

mostly a little north of the present Main Divide. At the same time the distribution of these granites between the Strathbogie Ranges and Cape Liptrap suggests that meridional trend directions were still operative though on the whole dominated by the E. and W. trends. That the warping was continued into Mesozoic time is proved by the tilting into broad basins of the Wannon, Otway, and Gippsland Trias-Jura strata with their associated coal seams. These E. and W. lines, which may be termed Bassian lines (after Bass Strait), continued to develop during Tertiary and Post Tertiary time. Eocene marine strata along the axis of the Great Valley of Victoria have been raised fully 800 feet above sea level. As already stated, the line of major fault, which has given rise to the steep escarpment W. of Bacchus Marsh, appears to have originated in Tertiary time and developed along the Bassian lines as did the E. and W. fault near Sorrento on the southern side of Hobson's Bay (Port Phillip). Nevertheless while the E. and W. warp lines dominated earth movement in Victoria in Mesozoic and Cainozoic times, evidence is not wanting to show that the forces which had produced the old N. and S. trend lines were not entirely in abeyance.

Mr. Stanley Hunter[1] has shown that the floors of the Tertiary rivers have been much warped, so that for some distances the drainage direction is reversed, so that streams once flowing south like those of Ballarat have now a rising instead of a falling gradient down stream, and moreover they show evidence that their eastern bends have been tilted up showing that the ranges to the east have been uplifted subsequent to the formation of the lead. He also records the fact that comparatively recent fault lines are occasionally met with in the alluvial workings for gold with displacements of about 30 feet, (*op. cit.*, p. 5). This

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[1] Mem. Geol. Surv. Victoria, No. 7, Deep Leads. By authority, Melbourne, 1909, p. 4.

evidence agrees with that mentioned to me by Mr. — Mahony, B.Sc., of the Geological Survey of Victoria that the recent dune rock near Sorrento is heavily faulted to the east of Sorrento in a N. and S. direction with a downthrow to the W. This fault trends northwards through the gap in the range through which the Melbourne to Sydney railway line passes to the south of Seymour.

The homoseismic lines for the earthquakes of May 10, 1897, and May 27, 1900, suggest that the older meridional lines and the newer Bassian lines are still being followed by earthquake cracks.[1] The nature of the folding to which Victoria has been subjected is shown on fig. 6 *a* and *b*, and the trend lines are shown on *Plate 2.*

SECTIONS ACROSS VICTORIA

Fig.6(a).

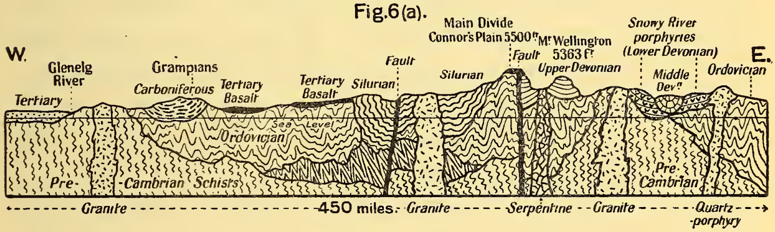
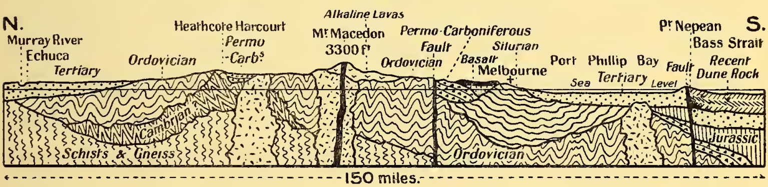


Fig.6(b).



New South Wales.—The outlines of the chief tectonic features of this State were traced with a masterly hand by the Rev. W. B. Clarke, F.R.S.[2] The late Government Geologist, C. S. Wilkinson, constructed a valuable map of

[1] Geography of Victoria, by Professor Gregory, p. 175.

[2] Southern Goldfields of New South Wales, and remarks on the Sedimentary Formations of New South Wales. Fourth edition 1878.

the Hartley Bowenfels District which shows the folds of the Devonian rocks of that neighbourhood, and did much to elaborate the geological map outlined by Mr. Clarke. This has been added to under the direction of Mr. Wilkinson's successor Mr. E. F. Pittman, Assoc. R. S. M., by himself and the officers of his Geological Survey, notably Mr. J. E. Carne, F.G.S., and Mr. E. C. Andrews, B.A., while the maps of the Southern Coalfield by Messrs. J. B. Jaquet, Assoc.R.S.M., and L. F. Harper, F.G.S., and that of the Hunter River Coalfield by Messrs. G. A. Stonier, W. S. Dun, O. Tricket and myself have added information on tectonic movements of the crust since Permo-Carboniferous time. These observations have been supplemented by the valuable work of Dr. H. I. Jensen, D.Sc., on the alkaline rocks of the Canobolas, Warrumbungle and Nandewar Ranges.[1] Messrs. C. A. Süssmilch, E. C. Andrews, and C. Hedley, have lately contributed useful and suggestive papers on the physiography of New South Wales, references to which have already been given at the commencement of this address. Dr. W. G. Woolnough, D.Sc.,[2] and Mr. F. G. Taylor, B.A., B.E., B.Sc.,[3] have also added to our knowledge of the physiography of this State. The physiographic method of study of earth tectonics is obviously of special value in New South Wales, where along the whole of its Main Divide and coastal area marine strata later than the Permo-Carboniferous are unknown. In New South Wales there are two chief lines of trend, the older trends, (the direction of which is well shown by the orientation of the trough axis of our main

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[1] Proc. Linn. Soc. N. S. Wales, 1909, Vol. xxxiv, pt. 1, by C. A. Süssmilch, F.G.S., and H. I. Jensen, D.Sc., pp. 157 – 194; *ibid.* 1907, xxxii, pt. 3, by H. I. Jensen, pp. 557 - 626, 842 etc. Also for general reference to distribution and trend lines of these alkaline rocks of East Australia together with references, see *ibid.* 1908, Vol. xxxiii, pt. 3, pp. 491 - 588, and particularly Fig. 10 on p. 585.

[2] *Ibid.*, 1906, Vol. xxxi, pp. 546 – 554.

[3] Commonwealth Bureau of Meteorology. Physiography of Proposed Federal Territory at Canberra, Bulletin No. 6, 1910, and *ibid.* Bull. No. 8.

coal basin) running N.N.W. and S.S.E., inclining to a more meridional direction southwards towards Kosciusko, and newer trends running parallel or sub-parallel to the present Pacific Coast, and that trends N. by E. to S. by W.

The latter trends are well shown by Mr. Andrews.[1] The tectonic feature which is most conspicuous in the geology of New South Wales is the great syncline, in which lies the Permo-Carboniferous coal-basin, the main axis of which extends from Sydney to Gunnedah and Narrabri. This divides at once the Bathurst-Monaro highlands, or tableland, from the New England tableland. In the former tableland the older trend lines are well shown by the direction of outcrop of the chief beds of limestone, of Silurian age, which there run N. and S. Towards the northern edge of this plateau these fold lines swing more to the W. of N., the chief synclinal troughs in the upper Devonian series lying along N.N.W. to N. 30° W. directions. There is a strongly marked unconformity, recorded and figured by Dr. W. G. Woolnough in the gorge of the Shoalhaven near Tallong, between the Ordovician slates and the Silurian limestones. The folding of the Ordovician rocks has also been much more intense than those of the Silurian. In the Yass district the general trend of the folds in the Silurian and Lower Devonian rocks is about N. 15° W. and S. 15° E., as shown by Mr. Harper[3] and myself.[4] The prevailing dip is to about W. 15° S. At Yalwal Mr. Andrews has shown that the Upper Devonian rocks, lying in a long and narrow basin, trend nearly due N. 30° E. (true). If we examine the direction of strike of elongated masses of intrusive granite from Delegate on the S. to Bathurst on the N., we find that there is a slight tendency to virgation, the great mass

[1] This Society's Journal, Vol. XLIV, p. 347.
[2] Proc. Linn. Soc. N.S. Wales, 1909, Vol. XXXIV, pp. 783 – 5.
[3] Geol. Surv. N.S. Wales, 1909, Vol. IX, pt. 1, pp. 1 – 53.
[4] Ann. Rep. Depart. Mines, 1882, p. 148, with maps and sections.

of granite extending from Bombala to Braidwood runs N. 15° E. and S. 15° W., but the mass extending from the Snowy near Forest Hill to Adelong trends about N. 8° W.

In the Forbes-Parkes Goldfield[1] Mr. Andrews shows the trend of the Silurian folds to be N.N.E. with suggested overthrusts to the E.S.E., an approximation to the Broken Hill trends in pressure directions. In the Cobar region Mr. Andrews finds the strike of the Silurian limestones and conglomerates and Devonian quartzites is generally about N.N.W., with several major faults apparently overthrusts striking in the same direction with the overthrusting being towards the west. Traced in the direction of Girilambone, the strike changes to N. and even N.E., the rocks there being schists and quartzites, possibly, as Mr. Andrews thinks at present, Pre-Cambrian. Possibly these latter rocks represent an offshoot from the Pre-Cambrian series of Broken Hill which have, as already stated, prevalent north-easterly trends. Mr. C. S. Wilkinson[2] shows that the strike of the Devonian beds, W. of the Blue Mountains is N.N.W. and S.S.E., and Mr. J. E. Carne's work confirms this. At the same time the strike of the Jenolan Cave *Pentamerus* limestone, in the Silurian rocks, is nearly N. and S. with a westerly dip. Mr. C. A. Süssmilch[3] and Dr. H. I. Jensen[4] have referred to the folded rocks of Silurian and Devonian age in the Canobolas region, and the former determines the strike of these folds as about N. 30° W. (true).

Near Ponto to the west of Wellington, a very strongly developed and intensely folded trough in the Devonian and Silurian rocks has lately come under my notice. If the

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[1] Depart. of Mines, Geol. Surv., Mineral Resources No. 13, by authority 1910.

[2] Geological map of the districts of Hartley, Bowenfels, Wallerawang, and Rydal.

[3] This Society's Journal, Vol. XL, p. 130, 1906.

[4] Proc. Linn. Soc. N. S. Wales, Vol. XXXIV, pt. 1, 1909, pp. 158 - 194.

strata are not repeated by isoclinal folding and faulting, nearly 10,000 feet of red sandstones and shales are there developed lying in a trough, the axis of which trends nearly N. and S. from a little W. of Wellington towards Molong. Mr. Süssmilch[1] has already called attention to the strong disturbances of the nature of recent faulting, determined on physiographic evidence, extending from Jindabyne and Cooma, in the former case north-easterly, in the latter northerly. The Cooma-Colinton line of fractures is parallel to the upper course of the Murrumbidgee, that is about N. 5° W. Mr. T. G. Taylor has further examined the zone of faults between Lake George and the Murrumbidgee River near the site of the Federal Capital at Canberra. In his latest work he refers to this Snowy-Murrumbidgee line of disturbances as a rift valley running northwards to the volcanic region of the Canobolas, and thence by way of Wellington to the volcanic zone of the Warrumbungle volcanic necks. These faults, described by Süssmilch and Taylor, are of course recent faults for the most part belonging to the present cycle of erosion, but they appear to be established along old lines of intense folding and major faulting. It is much to be desired that a reliable cross section of this beautiful tectonic region between Bathurst and Parkes be obtained by actual survey. An important fact to be noted in the Bathurst-Monaro tableland lying to the south of the great central coal-basin, is that along its north-eastern margin is an extensive belt of Devonian rocks which strike nearly conformably with the axis of the main trough of the great coalfield. One would expect to find the overfolds of the Devonian rocks directed here towards the main axis of subsidence ; on the whole, though the dips are often reversed in the neighbourhood of axes of intrusive masses of granite, the marginal

[1] This Society's Journal, Vol. XLIII, pp. 331 – 354, pls. ix – xiii.

Devonian rocks show a tilt towards the E.N.E., that is in the direction of the main basin.

If now we examine the important unit of the New England tableland, the following tectonic lines are obvious:—The long belt of serpentine recently described in detail to this Society by Mr. W. N. Benson. This extends for fully 150 miles from Nundle to Bingara, striking in a general N.N.W. and S.S.E. direction. The Carboniferous and Devonian rocks have been folded and powerfully fractured along the same line, the pressure coming from E.N.E. from about E. 17° N. (true). Further north in the Emmaville district of New England, the Permo-Carboniferous, and perhaps Carboniferous claystones, are folded on lines trending about N. 30° W. and S. 30° E., with evidence of the pressure having come from E. 30° N. The trend of the Permo-Carboniferous limestones near Kempsey is about N. 35° W. (true). On the other hand the great intrusive masses of granite which occupy so large a part of the country between Tamworth and Wallangarra on the Queensland border strike about N. 22° E. (true). This direction is almost exactly parallel with the coast line, and shows that in New South Wales as in Victoria, the axes along which the granites were intruded belong to the newer trend lines which determined the position and orientation of the present coast line.

Mr. E. C. Andrews has shown that in the New England district the granites have strongly intruded the Permo-Carboniferous rocks, whereas in the Lithgow district of the western coal-field rolled pebbles of the Hartley granite are very frequent in the basal upper marine Permo-Carboniferous rocks of that area. The long axis of the Clarence Basin is exactly meridional (true). Another important tectonic line is the belt of alkaline lavas which form such conspicuous elevated and isolated groups on the relief model, *Plate 1*, extending from the extinct volcanoes of the Canobolas through those of the Warrumbungle mountains to those of the Nandewar Ranges.

The trend of this great alkaline belt and its prolongation in Queensland through the Macpherson Range, Cunningham's Gap, and the Glasshouse Mountains on to Yeppoon, near Rockhampton, and thence to Clermont, has been well shown by Dr. H. I. Jensen.[1] The trend of the Canobolas to Nandewar line is about N. (true) from the Canobolas to the Warrumbungles, and N. 35° E. from the Warrumbungles to the Nandewars. The line of trachytic eruptions is prolonged in a S.S.W. direction from the Warrumbungle mountains to the Gibraltar Rock near Dubbo.

As regards now the chief tectonic lines in the great central coal-field, there are two well marked directions, the first set running more or less parallel to the general axis of the trough in which the basin lies, (in the Lower Hunter district this is shown by the Greta etc. faults, running from between E. 30° S. and E. 10° S. to W. 30° N. and W. 10° N., in the southern coal-field they trend in a general E.S.E. and W.N.W. direction). In this first set of faults the throw in each case is in towards the centre of the basin. The other set of faults runs more or less parallel with the coast line. A well marked trend belonging to this set, is the flat asymmetrical anticline forming the eastern escarpment of the Blue Mountains. This was referred to by me in previous papers to this Society.[2] The general trend of this fold is N. 15° W. (true). It is to be noted that this structure makes an angle of nearly 35° with the fold of the continental shelf. It cannot therefore be correctly described as a parallel structure. The continental shelf has been ably described in detail by Hedley.[3]

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[1] Proc. Linn. Soc. N.S. Wales, 1908, No. 131, pt. 3.

[2] This Society's Journal, Vol. xxx, 1896, pp. 33 – 41; Vol. xxxvi, 1902, pp. 399 – 370, pls. xvi, xvii.

[3] Presidential Address, Proc. Linn. Soc., 1909, and *ibid.* 1910.

The heavy fracture known as the Elderslee Fault, west of Branxton, has a throw to the west of perhaps 5,000 feet.[1] Its trend is at its southern end N. and S. (true), and north of the Hunter River N. 9° W. (true). The strata in this part of the coal basin are thrown into a series of broad synclines and anticlines whose axes trend a little W. of N. and E. of S. Their steeper sides face inland, as though the pressure came from the direction of the Pacific Coast and pushed the strata in towards the subsidence region of the great coal basin. Thus there is evidence of a crustal creep towards the coal basin, but along hinges of folding which have an orientation intermediate between that of the long axis of the coal basin and the trend of the coast line. It is the evidence of the new pressure lines, (which eventually merged into the epeirogenic uplift which eventually formed our coast line and Main Divide) beginning to assert themselves. The principal lines of faulting in late Tertiary and Post Tertiary time, mapped chiefly on physiographic evidence have been ably described by Messrs. E. C. Andrews,[2] C. A. Süssmilch,[3] and T. Griffith Taylor.[4] These faults in the Monaro tableland are not parallel to the coast line but diverge some 25° to 30° from it. The trend of these fractures is mostly between N. 5° W. and N. 10° W. (true). But in the case of the fault scarp to the east of the Gourock Range Mr. Andrews shows this as being parallel to the coast. In the New England tableland the fractures on either side of the axis of granitic upheaval, as far as they have been traced, trend somewhat W. of N. following near to the direction of folds in the older rocks. The newest

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[1] Geological Map of the Hunter River Coal-field, Geol. Survey, Dept. of Mines, Sydney.

[2] This Society's Journal, Vol. XLIV, pp. 420 – 480.

[3] *Ibid.*, Vol. XLIII, pp. 331 – 354, pls. ix – xii.

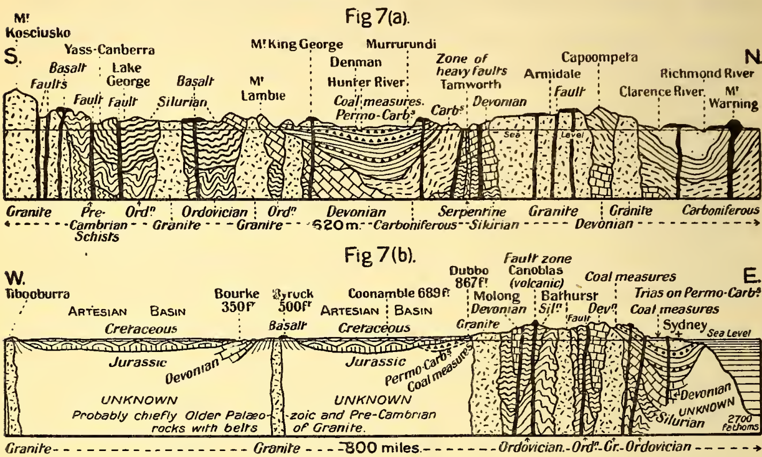
[4] Proc. Linn. Soc. N.S. Wales, 1907, Vol. XXXII, p. 327; also Commonwealth Bureau of Meteorology, Bulletin No. 6, 1910, "The Physiography of the Proposed Federal Territory at Canberra,"

scarps of all may be more nearly parallel with the coast, but this point yet awaits investigation. Mr. Andrews has well shown that in this latest epeirogenic uplift the maximum effect was produced at the mountain knot of the S.E. corner of Australia where the meridional direction of flexing met the cross flexing of the Bassian lines (*op. cit.*, pp. 431-2).

The recent epeirogenic uplift which has produced the present Main Divide and coast line and accentuated the continental shelf has the form of a gentle wave with its steeper side directed to the Pacific, a fact emphasized by Hedley. Hence for some time past the tendency has been for the Divide to be forced inland, that is westwards, through the steeper eastern rivers capturing the upper portions of the watersheds of their more sluggish western neighbours. Quite recently a downward joggle has taken place for a considerable distance along the coast, especially marked along the seaward edge of the great coal basin. This depression has amounted to about 200 feet. A very recent negative movement of the strand-line to the extent of about 15 feet is so general around Australia as to suggest that it may have been due to a eustatic negative movement of the whole ocean surface in the Southern Hemisphere, due to some such cause as a locking up of sea water in the snowfields and glaciers of the Antarctic following on after extreme deglaciation during an interglacial epoch.

We thus see in New South Wales a marked example of development of two sets of tectonic lines, the older an orogenic set of strong folds with numerous normal and some overthrust faults in each case directed inwards towards that master warp the great central coal-field, the newer set, of an epeirogenic nature, is a gentle flex, the hinge parallel to the continental shelf, coast line, and present Main Divide; but the normal faults with downthrows away from the main axis of upheaval in many cases show by their orientation a compromise in direction between the older orogenic folds and the newer line of epeirogenic uplift.

SECTIONS ACROSS NEW SOUTH WALES.



Queensland.—We may now glance at the salient points in the tectonic geology of Queensland. Reference to *Plates 1* and *2* of this address reveal the following dominant features:—

(1) Ranges mostly of Palæozoic rocks forming the highlands of the Main Divide, an ancient peneplain trending about N. 33° W.

(2) A great basin of newer and softer rocks, the Cretaceous basin, with at its S.E. extremity an older basin of soft rocks, the Trias-Jura Basin. This forms a Y, the lower stroke of which is the Clarence Basin of New South Wales.

(3) A plateau of older rocks in the neighbourhood of Cloncurry, rising to the Barclay Tableland near Camooweal.

(4) The Great Barrier Reef may be added as a fourth unit which has shared in the tectonic development of Queensland.

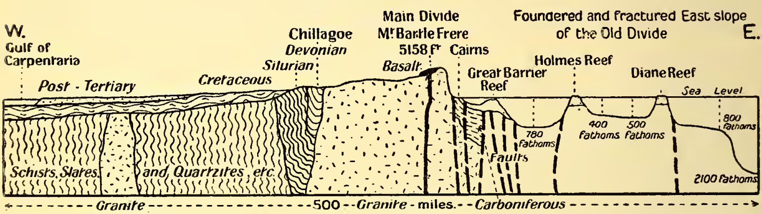
As regards topographical relief one of the most conspicuous features in Queensland is that of the steep-to Ranges along the northern coast. These ranges form a very steep-to coast from opposite Hinchinbrook Island through the Bellenden-Ker Ranges, 5,438 feet high, (the highest ranges in Queensland) to the north of Cairns. The Bellenden-Ker are situated only about ten miles inland from the coast, and Hinchinbrook Island, formed of granites, schists, slates, etc., is 3,650 feet high. This steep-to coast has remarkably short rivers draining eastwards, as the Main Divide is here so close to the ocean. Western rivers, like the Gilbert and Mitchell, on the other hand, flow down long gentle slopes to the Gulf of Carpentaria. This steep-to coast is situated, for the most part, all along the area facing the Great Barrier Reef.

There can be no doubt that a very important tectonic feature is indicated by this remarkable type of coast. Mount Bartle Frere in the Bellenden-Ker Range is 5,438 feet above sea-level; is formed of granite and is yet only fourteen miles inland from the coast. Peter Bott, also of granite, and 3,311 feet high, is only five miles back from the coast. "Rough Round Hill," about one hundred miles north of Princess Charlotte Bay, only three miles inland is 1,543 feet high, and also formed of granite. In fact the Main Divide near the Bellenden-Ker Range just north of Cairns is only eight miles distant from the Pacific on the east, whereas the nearest ocean, the Gulf of Carpentaria on the west is 275 miles distant. This extraordinary position of the Main Divide taken in conjunction with the evidence of waterfalls like the Barron Falls, 800 feet high, and the numerous high granite and slate islands is almost certainly due to comparatively recent crust foundering on a grand scale along the region of the Great Barrier Reef, whereby almost the whole of the eastern side of the old

Divide has been let down below sea-level. Thus only a few miles of the heads of the eastern rivers have been preserved. As the result of this extreme betrunking they have become greatly overhung above the foundered area. Hence the steep-to coast and high waterfalls. The theoretical structure of this part of Queensland, near Cairns, is shown on Fig. 8.

SECTIONS ACROSS QUEENSLAND.

Fig. 8.



As regards unit (1) the Main Divide, an examination of the geological map of Queensland shows that it is formed largely of granites, and so-called Gympie rocks[1] which may be more appropriately termed the Star Series. These differ from the true Permo-Carboniferous rocks in containing *Lepidodendron* and *Aneimites*, allied to *Rhacopteris*, as contrasted with the *Glossopteris-Gangamopteris* Flora of the Permo-Carboniferous System. West of Townsville the Middle Devonian rocks of the Burdekin System form part of the Divide, and near Chillagoe Mr. R. Etheridge[2] has recorded *Halysites* from Silurian rocks. Probably older rocks of slates, schists, quartzites, etc., extend from Springsure to near Townsville, and from west of Canoona in the Rockhampton District in the direction of Bowen.

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[1] As the Gympie Rocks in the type district now prove to be Permo-Carboniferous, in the meaning of that term as used by New South Wales geologists, it is no longer an appropriate term for the *Lepidodendron* Beds of the older (Carboniferous or possibly Upper Devonian) formations. The term Star Series will be used in this address for the latter.

[2] Geol. Sur. Queensland, Publication No. 190. Records No. 1, VIII, pp. 30–32.

Enclosed between these two old belts of Silurian or Pre-Silurian rock is the northern end of the great coal-basin of Queensland. This extends to near the head of the Dawson River. Its main axis strikes about N. 27° W. (true). The long axes of the intrusive masses of granite follow approximately parallel directions, as do the folds in the Gympie rocks.

At its north end the Bowen Coal Basin is abruptly rounded off by an immense bar of granite trending nearly due E. and W. (true). At Peak Downs the folds have a general north-easterly to south-westerly trend. At the Cape and Charters Towers the trend of the folding in rocks of Pre-Burdekin (Pre-Devonian) age is about W.N.W. and E.S.E.. W. H. Rands[1] estimates that the schists and quartzites of the Cape River Gold Field may have a thickness, without allowing for possible repetition of beds, of from five and a half to six miles, they dip at 30 – 35° towards S.S.W. At Chillagoe the folds strike about E.S.E.. In the Middle Devonian rocks of the Burdekin Basin the folds trend about N. 40° E. and S. 40° W. Dr. R. L. Jack, in 1894, wrote to me "There is no evidence as to when this folding took place in Queensland as the Devonian is not seen anywhere in contact with newer rocks, and so we cannot tell whether they have been folded together or not. The hiatus, however, between middle Devonian and our next series (Gympie) itself implies an upheaval and in all probability a folding prior to Gympie," (*i.e.* Carboniferous times.—T.W.E.D.)

It is worthy of note that these Burdekin folds trend at right angles to the adjacent coast line. In the Gilbert Gold-field, still further north, there are two well marked sets of folds, trending respectively E.S.E. to W.N.W., and

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[1] On the Cape River Gold Field. By authority Brisbane, 1868.

W.S.W. to E.N.E. The latter are in sympathy with the Burdekin and Kimberley lines, and the former with those of the Cape Gold-field and the New Caledonia to New Guinea lines and the Charters Towers granite axis.

Dr. R. L. Jack wrote me in 1894, "The folding of the Gympie formation [Gympie here used in the sense of *Pre-Star* (that is Pre-Upper or Middle Carboniferous) and Post Burdekin (Post-Middle Devonian)—T.W.E.D.] must have been the chief factor in the evolution of the eastern coast range. That it took place before the deposition of the Star formation I have little doubt in my mind, as the latter though nowhere observed in contact with the Gympie, is comparatively undisturbed." Dr. Jack would probably in view of later palæontological determinations which show that much of the Gympie beds are really newer than the Star beds, and that the Gympie has certainly in places been folded fairly strongly, see his way to modify this statement, so that one might conclude that one of the chief factors in the evolution of the Main Divide has been the folding of the Carboniferous and Permo-Carboniferous rocks along lines mostly coincident with the long axes of the granite batholiths. Trend lines are also indicated in the Main Divide unit by the general distribution of the main basalt flows and volcanic foci. Notably to the east of Clermont these foci are grouped along N. 40° W. and S. 30° E. lines.

Dr. H. I. Jensen[1] has indicated the trend lines of the foci and general zone of the alkaline lavas in the Mount Flinders and Fassifern districts and the east Moreton and Wide Bay districts. In the former district the zone trends about N.E. and S.W. (true), but the local groups of volcanic foci appear to trend about N. 15° W. to S. 15° E. (true). In the

[1] Proc. Linn. Soc. N. S. Wales, 1903, pt. 4, ap. 842 – 875, pls. xlvi – l; *ibid.*, 1906, pt. 1, pp. 73 – 173, pls. v, v *bis* – xvi; *ibid.*, 1908, Vol. xxxiii, pt. 3, pp. 491 – 588, especially p. 585; *ibid*, 1909, Vol. xxxiv, pt. 1, pp. 67 – 104, pls. i – vi.

latter district the trend is N. and S. (true). Trend lines are also shown by the belt of serpentine to the west of Gympie (about N. 10° W., true) and the immense mass of serpentine to the north of Rockhampton. The latter trends N.W. and S.E. true, and is evidently situated on a zone of heavy fractures. These extend all the way from Gladstone to Herbert Creek at Broadsound. The trachyte volcanic centres of Yeppoon and Berserker Ranges are close to these major lines of fracture. They are doubtless part of the group of great fractures along which the former eastern side of the Divide has been stepped down below sea-level. There is both physiographic and stratigraphical evidence for this fault at Curtis Island.

Mr. Lionel V. Ball, B.E.,[1] shows on map 11 of his instructive report, that there is a basin of Burrum Beds (Trias, or Trias-Jura) thrown against Devonian rocks. The Boyne River follows this line of fault, which, presumably throws to E. 40° N. The channel between Curtis Island and the mainland is on a continuation of this fracture. Beyond Keppel Bay it seems to divide, an eastern branch going to Shoalwater Bay and the Northumberland Islands, the western to the estuary of Herbert Creek, at Broadsound. Another profound fracture, observed by me in 1891, bounds the Styx River Coal-field on the East. I estimate that it has a throw of fully 3,000 feet. It is probably prolonged to where on the chart of the Barrier Reef, north of Broadsound, the note occurs "it is unsafe to pass to the eastward of this line." If so, this fault has a length of fully 250 miles. This trends in a S. by E. direction, striking for the Dawson River to the east of Duaringa. Several important faults have been recorded by Mr. B. Dunstan in this region.

[1] Geol. Surv. Queensland, Publication No. 194, "Certain iron ore, manganese ore, and limestone deposits in the Central and Southern Districts of Queensland." Brisbane, by authority, 1904.

The trend of the "Gympie" and Permo-Carboniferous-*Glossopteris* Beds is, according to Dunstan, about W. 40° N. with a dip to S. 40° W.[1] The Cumberland Islands and Whitsunday Island are almost certainly horsts amongst a network of faults. The trachytic volcanoes described by Mr. A. Gibb Maitland[2] to the W. and N.W. of Mackay, such as Mount Mandurana, Mount Jukes, etc., mark a continuation of the disturbance lines in this zone, upon which are seated the above extinct trachyte volcanoes. A few other important fault lines may be mentioned. Dr. Jensen[3] figures a probable line of fault running from near Mount Flinders in a N. by W. direction to the west of Ipswich. Several faults are figured on the geological survey maps of the Ipswich Coal-field, these have a general trend N.W. to N.N. W., with a throw to N.E. Dr. Jensen[4] has figured a fault north of Brisbane, striking W. 40° N. to S. 40° E., and throwing probably at least 1,000 feet to N. 40° E. To the south-west of this fault lie the phyllites, hornblende schists, glaucophane schists, anthophyllite schists, cyanite-rutile granulites, etc. of the Mount Mee and D'Aquilar Range area. This appears to have been the core of the old Main Divide. In the Gympie Gold-field are a large number of faults which have been mapped by Mr. W. H. Rands, F.G.S.,[5] and Mr. B. Dunstan.[6] The "Smithfield Crosscourse" runs E. 10° N. (true) with a N. 10° W. downthrow of 530 feet. The normal strike of the Gympie strata is in a general N. by W. and S. by E. direction. The Inglewood Fault strikes near E.

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[1] Geol. Surv,, Queensland, Bulletin No. 11. Report on the Geological Features of the country between Warren and Mount Lion in the Rockhampton District. Brisbane, by authority, 1900.

[2] Geol. Surv., Queensland. Geological Features and Mineral Resources of the Mackay District. By authority, Brisbane, 1889.

[3] Proc. Linn. Soc. N. S. Wales, 1909, Vol. xxxiv, pt. 1, pp. 67 – 104, and specially pl. i.

[4] Proc. Linn. Soc. N. S. Wales, 1906, Pt. 1, p. 103, and see fig. 3, p. 76.

[5] On the Gympie Goldfield. By authority, Brisbane, 1889.

[6] Report of Geol. Surv. in course of publication.

30° S., with a throw to N. 30° E., and the Laing's Fault strikes N.N.W. to N.W., with a throw towards N.E.

An important tectonic structure to the south of Princess Charlotte Bay, to the north-west of Cooktown is the senkungsfeld of the Little River Coal-field. This strongly marked trough is well figured by Dr. R. L. Jack.[1] The indent in the coast at Princess Charlotte Bay is probably of tectonic origin. A significant fact in the structure of the unit of the Main Divide of Queensland is the newness of the folding and faulting. In the southern part of New South Wales the Permo-Carboniferous strata are simply thrown into broad undulations. In the New England district they are strongly folded and altered by granites. At Gympie they are much disturbed and considerably altered in places. About five miles north-west of Gympie specimens of *Protoretepora* occur completely replaced by stibnite.[2]

The Trias-Jura Coal-measures of the Styx River at Broadsound are thrown into broad folds, and at Maryborough the Maryborough Beds, classed by R. Etheridge as of Upper Cretaceous age, dip at angles varying from 7 – 12° up to 30 – 45° on the Isis River, as recorded by W. H. Rands.[3] The general dip is north-easterly. Nowhere else in Australia, as far as I am aware are strata as new as Upper Cretaceous so much disturbed, as in the above district. The comparatively recent character of the volcanic eruptions in the Cairns district is proved by the crater lake surrounded by scoria described by Mr. Meston, Lake Eacham.[4] The great submarine volcanoes perhaps the largest, which have as yet been discovered in the Australian

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[1] Report on the Little River Coalfield. By authority, Brisbane, 1882.

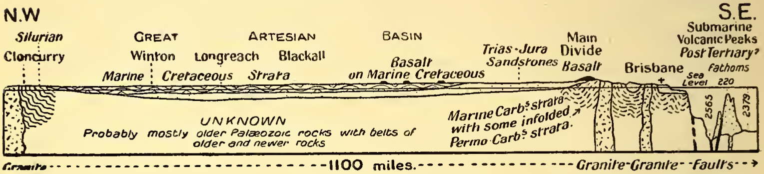
[2] Geology and Palæontology of Queensland and New Guinea, Jack and Etheridge. By authority, Brisbane, 1892, p. 83.

[3] Report on the Burrum Coal-field. By authority, Brisbane 1896.

[4] Geol. and Pal. etc. *supra*, p. 587.

region, lying between 104 – 128 miles east of Brisbane are probably of recent origin. These have been referred to by C. Hedley,[1] and are shown on the accompanying fig. 9.

Fig. 9



The highest of these mountains is about 14,000 feet in height, at Lat. 28° 42′ 2″, Long. 155° 37′ E. As far as can be judged from the soundings these submarine volcanoes have a general N. by W. to N.W. trend.

As regards unit (2) the Queensland portion of the Great Artesian basin, little need be said from a tectonic point of view, except that the basin represents an area which was partly covered by great warp lakes in Trias-Jura time, and wholly covered by sea in Cretaceous time. The basin was deepest near its centre just over the border of South Australia from Queensland. There the sediments of Cretaceous and perhaps Trias-Jura age in part are a mile in thickness. Between Cloncurry and Hughenden (J. B. Henderson)[2] a large sill of Palæozoic rocks, rising to within about 1,000 feet of the surface of the ground, forms a partial subterraneous barrier to the Artesian basin. It trends in an E. to W, direction. The north-westward flowing tributaries of the Darling, such as the Bogan, Macquarie, Castlereagh, Namoi, Gwyder in New South Wales formerly entered the south-eastern shore line of this Cretaceous sea by separate mouths. Subsequently, in Eocene time, a broad epeirogenic uplift supervened raising the whole basin, especially in the

[1] Proc. Linn. Soc. N.S. Wales, Vol. xxxvi, pt. 1, pp. 32, 33.

[2] Hydraulic Engineer's Report. By authority, Brisbane.

direction of New Guinea, the southern shore line of Australia undergoing submergence in Victoria, the southern part of South Australia, and the south-western part of New South Wales. This tilting from N. to S. in time started the Darling, the Bogan, and Macquarie rivers etc., now forming what Mr. T. G. Taylor[1] has called 'boathook bends' with the main stream.

(3) In reference to the third unit, that of the Cloncurry region ascending to the Barclay Tableland beyond Camooweal, information as to its tectonic lines is at present very meagre. As regards recent uplift, as shown by Mr. E. C. Andrews,[2] the Main Divide of Queensland has been warped up synchronously with the Main Divide of New South Wales. Dr. Jack[3] has pointed out in an able lecture, quoted by Mr. Hedley, that the Main Divide of Queensland was formerly close to Brisbane, but now has been pushed westwards by the rivers draining the eastern, the steeper, slope of the warp, so that it is now, at the latitude of Brisbane, some 50 miles west of its former position, owing to the eastward flowing rivers having cut back their channels through the hard argillites and granites, just west of Brisbane, into the soft rocks of the Ipswich Coal-measures. Their progress further west has been checked at Toowoomba by the great sills and flows of basalt extending for some distance N.W. towards the head of the Burnett River. The latter river and the Dawson are fast eating their channels back through the Trias-Jura, and are touching the sediments of the old Cretaceous sea. The Nogoa and Belyando Rivers have broken right across all the old rocks of the plateau of the old Main Divide, so that now around their sources the Main Divide is situated on the Upper Cretaceous, Desert

[1] Commonwealth Bureau of Meteorology, Melbourne. Physiography of the Proposed Federal Capital Site at Yass-Canberra, Bulletin No.6, p. 8.

[2] This Society's Journal, Vol. XLIV, pp. 420 – 480.

[3] Lecture Reported in *Brisbane Telegraph*, 22/5/94.

Sandstone, rocks. Further north in the Cairns District a portion of what was perhaps the original old Divide still survives. In this case heavy crust foundering has all but completely effaced the old eastward flowing river system, leaving so narrow a strip of eastern watershed as to make it impossible for any great rivers to gather, in the ten miles which intervene between the crest of the present Main Divide and the ocean.

It seems strange that the very powerful lines of upheaval of New Guinea running about E.S.E. and W.N.W. have left so little impression upon the tectonic plan of Australia. Possibly the W.N.W. to E.S.E. trend of the schists of the Cape River Gold Field is due to these New Guinea pressure lines, as well as the N. to S. tilt of the Cretaceous Basin and tilt of the Ordovician rocks near the Victoria River in Northern Territory.

New Guinea.—Brief reference will suffice for what is known as to the tectonic lines of New Guinea. At Port Moresby Mr. A. Gibb Maitland[1] found strata formed of sandy limestones and calcareous shales with flints. These contained a *Voluta* which Mr. C. S. Wilkinson, the late Government Geologist of N. S. Wales, considered to be of Miocene or Eocene Age. The Rev. J. E. Tenison-Woods considered the formation to be Pliocene. Lithologically the material somewhat resembles that of the Eocene beds of South Australia, which is also characterised by the presence of flints. The strata are steeply inclined, often vertical, the dip generally is E.N.E. to E. 30° N., at 30 – 55°. Meridional strikes with vertical dips are also recorded. At Yule Island the dip is N. 40° E. at 20 – 30°. At Ware (Teste) Island the limestones are folded on N. and S. axes. At the island of Einauro (Cette) the dip is W. by N. at 50°. In a recent letter Dr. W. G. Woolnough, informs me that he

[1] Geological Observations in British New Guinea in 1891.

thinks, as the result of a personal examination of the beds, that the pressure came from the north. Dr. Lorentz[1] has referred to limestones discovered by himself in the Wilhelmina Range as of Cretaceous Age. He calls them *Alveolina* limstones. They have been uplifted to over 14,000 feet above sea level.

A good account of the geological structure of German New Guinea is given by P. Steph. Richarz.[2] A further account is given by P. Reiber.[3] He gives a section of the Cretaceous rocks of the Torricelligebirge. These dip N.N.W. at 80 – 85°. Richartz considers that the Upper Cretaceous rocks participated in the folding. Beneath the Cretaceous rocks are crystalline schists. In the Ortzengebirge west of the Finisterregebirge, these strike N.W. and S.E. dipping at 70 – 80°, and above the Port Moresby beds are newer sediments, including recently raised reef, ranging up to 2000 feet above sea-level. The Mt. Victory volcano is still active. Thus in New Guinea we see Pre-Cretaceous schistose rocks with N.W. to S.E. trends. These are followed by much folded and greatly elevated Cretaceous rocks, the W.N.W. and E.S.E. directions predominating. These in turn have been succeeded by the Tertiary Port Moresby Beds which have been violently disturbed and uplifted in Post-Eocene, possibly Post-Miocene time. In this later series some northerly to north-westerly lines cross the older lines of folding in the schists and Cretaceous rocks.

Summary of the Tectonic Movements.

In the present imperfect state of our knowledge, the sequence of events in the building of Australia may be briefly outlined as follows :—

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[1] Geogr. Jour., Vol. xxxvii, 1910, p. 496.

[2] Neues Jahr. für Min. Geol. u. Pal., xxix, Beilage Band, Zweites Heft Stuttgart 1910. Der geologische Bau von Kaiser Wilhelm's Land nach dem heuteren Stand unseres Wissens.

[3] *Ibid.*, xxix Band, Zweites Heft 1911.

Pre-Cambrian.—In Pre-Cambrian time the rocks of that age in West Australia were folded in the form of an open inverted S, thus Ƨ. In South Australia from Kangaroo Island to Broken Hill the Pre-Cambrian rocks are folded on the pattern of a normal but very open S. At the southern part the overthrusting is to the N.W. and W., in the northern to the S.E. and E. Still further north virgation takes place. In central Australia, at the Musgrave and MacDonnel Ranges, the folding is nearly E. and W. with a tendency in the Musgrave to overfold northwards, and in the MacDonnel Range southwards. In West Australia the direction of folding in the southern part of the reversed S is towards the W. and W.S.W., and in the northern portion partly to the N.E., partly to S.W.

In Tasmania N.N.W. trends predominate, and there appears to be a virgation of the folds, from between N.N.W. to a little E. of N., but this does not become strongly accentuated until Post-Silurian time. The Tasman folds thus form a V. In the Northern Territory the folds run a little W. of N. and E. of S. In the Kimberley District of West Australia they form an arc, the convexity of which is directed southwards.

The *Cambro-Ordovician* rocks are strongly unconformable to the Pre-Cambrian, but in Tasmania and Victoria they appear to have been folded sympathetically with the latter. In the Mount Lofty and Yorke Peninsula areas of South Australia the folds of Cambrian and Pre-Cambrian rocks closely agree, but to the N. of Lake Torrens and S.W. of Lake Eyre there is considerable divergence between the Cambrian and Pre-Cambrian trends, the former inclining to meridional, and the latter to nearly E. and W. lines. The Cambrian Divide lay S. or S.E. of Adelaide in the direction of Jeffreys Deep, the quarter from which moved the ice which produced the vast boulder clays and erratics of the Lower Cambrian of South Australia. In Northern Territory the Cambrian strata are folded and faulted on N.W. to S.E. lines, while the Ordovician rocks are tilted in a S.W. to S. direction.

In *Silurian* time the west-Tasmanian, the Melbourne Lilydale and other basins in Victoria were folded on N.N.W. lines. In the Monaro-Bathurst Tableland of New South Wales the folds strike mostly W. of N. and E. of S., without pronounced overfolding. In the Forbes and Cobar areas the folds swing around to E. of N. and W. of S., conforming more to the Broken Hill lines. At Chillagoe the Silurian strata are folded on E.S.E. to W.N.W. lines.

In *Devonian* time, in the Victorian areas, there is a slight tendency for the folds to fan out or virgate north of the Tasmanian V. On the upper Murrumbidgee near Burrinjuck, they strike north north-westerly, and are uncomformable to the Silurian strata though folded on the same lines, the folding being from W. to E. At Yalwal they strike N. by E. and S. by W. Along the S.W. portion of the Blue Mountain area of New South Wales the Devonian rocks are folded sympathetically with the main axis of the trough of the great coal-field. There is a tendency for these strata to be overfolded inwards towards the centre of the trough. In the New England area the Devonian rocks still preserve a N.N.W. to N. 30° W. strike with a dip towards the trough of the coal basin. In the Burdekin Basin of Queensland the Middle Devonian rocks are folded on north-easterly lines. In the Ord River region of the Kimberley District of West Australia they describe an arc with its convexity directed southwards.

Carboniferous.—In Victoria, in the Avon and Mansfield districts the rocks are folded on N.W. to S.E. lines. In the Grampians area the strike is more meridional. In New South Wales the Carboniferous rocks form a selvage to the

Permo-Carboniferous Basin striking at first N. by W. then bending northwards into a N. 30° W. direction. They too dip in towards the trough of the Permo-Carboniferous Basin. In Queensland the Star Beds of this age build a large portion of the old Main Divide, and their folds curve mostly in sympathy with the coast line. Immense intrusions of serpentine, like those of Marlborough N. of Rockhampton in Queensland, Nundle to Bingara in New South Wales, the Wellington area in Victoria, the serpentine regions in N.W. of Tasmania, etc., took place during this period.

Permo-Carboniferous.—In Tasmania the open end of the V became filled with Permo-Carboniferous sediments. In Victoria and South Australia the earliest strata of this age were formed by ice moving from a general southerly direction, from the old highland Divide which seems to have still survived since Cambrian times, lying considerably south of Kangaroo Island and south of part, at all events, of Tasmania. During this period one of the greatest warps of which we have record in the Australian region in Palæozoic time developed from near Sydney as the centre of the trough, N.N.W. into Queensland, as least as far as Townsville, and probably still further north under what is now the region of the Great Barrier Reef. At this time Eastern Australia was probably, from New England to Townsville, isolated from the portion lying further to the west, first by the Permo-Carboniferous sea, and later by the lakes and swamps of that period. A large portion of Northern Territory, the great desert south of Kimberley in West Australia from near North-west Cape in the north to the Collie Coal-field in the South, was overspread with Permo-Carboniferous marine, or glacial, or swamp sediments. With the intrusions of granite in Victoria, Tasmania, New South Wales and Queensland, the new trend lines of the modern Main Divide were outlined, and in Victoria a strong east and west warp became developed, while in Bathurst-Monaro, and New England, northerly to north north-easterly trends crossed the older north north-westerly trends. The Queensland Divide was at this time probably very close to the Queensland east coast line.

In *Trias-Jura* time great lakes isolated the New England area from the southern end of the old Main Divide near Brisbane, and a prolonged subsidence set in over the region between Brisbane and Lake Eyre, and to the south of the rising Main Divide of Victoria, which had now tilted backwards the glacial beds of Permo-Carboniferous age towards the old, now destroyed Divide far south. (See Fig. 6 *b*.) The Wannon-Otway-Gippsland sediments were laid down in a trough trending east and west, the southern portion extending far up into the V of Tasmania.

In *Cretaceous* time a great sagging continued of the region between Lake Eyre and Roma, as well as on a meridional direction from midway between these points and the Gulf of Carpentaria. The epicontinental sea of the Cretaceous transgression may have completely severed eastern Australia from western from the Gulf of Carpentaria, viâ Lake Eyre, to the head of the great Australian Bight. In Tasmania the further sagging of the old Trias Jura Basin was accompanied by the extrusion on its southern margin of immense sheets of quartz-dolerite. The Cretaceous transgression also submerged a little of the northern part of Northern Territory and an extensive but narrow strip along the west coast of West Australia.

In *Cainozoic* time warping ceased at the northern and central portions of what is now the largest artesian basin in the world, the Cretaceous Basin, from the Gulf of Carpentaria towards Lake Eyre. Further south downward warping submerged much of the southern portion of Victoria, the north-west coast of Tasmania, the south coast of South Australia, and the coastal areas of the great Australian Bight for some distance inland as far west as Cape Arid. Epeirogenic uplift followed. This in east Australia took the form of a gentle warp trending east and west in Victoria, and through New South Wales and Queensland trending parallel with the coast and continental shelf. A new continental shelf was formed across the old gulf of the Permo-Carboniferous Basin in New South Wales. This uplift in east Australia approximately compensated for the downward warping of the great Cretaceous Basin. It ranges from 3,000 feet or 4,000 feet in Queensland to about the same amount in most parts of east New South Wales and of Victoria, attaining its maximum at Mount Kosciusko, 7,300 feet, at the knotting point between the meridional and east and west trends of the great warp.

In South Australia the Mount Lofty and Flinders peneplain was elevated from 2,000 to 3,000 feet above sea-level. In West Australia the vast peneplains are raised from 1,000 to 2,000 feet above sea-level. The determination of the marine fossils (Eocene ?) which overlie this peneplain at Lake Cowan, is of prime importance for the elucidation of the Cainozoic physiography of Australia. Basic volcanic eruptions followed approximately the trend of the warp of the eastern Main Divide. The outflow of basalt was specially heavy in Victoria. The distribution of the alkaline Cainozoic lavas also mark important trend lines in eastern Australia. The photograph of the relief model, (*Plate 1*) shows the trend of the three great volcanic piles of the Canobolas, the Warrumbungles, and the Nandewar mountains. This upward warping was accompanied by heavy inbreaks and foundering of the crust. This is especially marked all along the region of the great Barrier Reef with its archipelago of 'horst' islands of granite, slate, limestone, etc. Nearly the whole of the eastern watershed of the old Divide to the east of Cairns was hereby sunk beneath the sea, leaving merely the sources of the rivers perched high up on the top side of the fault scarp as is the case with the Barron River at the Barron Falls. Profound fractures like those of Broadsound and Curtis Island are ample proof of the heavy crust foundering in this area. The Snowy-Murrumbidgee Rift, and the faults on either side of the Main Divide in New South Wales and Victoria, on the whole tend to throw down the crust on either side of the main axis of elevation. The fact that the old trough of the great coal-field, so long a sinking region, was warped up before the end of Tertiary time, suggests, that, on the isostatic theory of crustal equilibrium, compensation had by this time been established. At the same time the fact must not be overlooked that in Post-Tertiary time the dominant movement along the east coast of Australia has been one of submergence rather than emergence, the submergence amounting to fully 200 feet. Bass Strait was formed by further sag of the E. to W. trough, and development of the Bacchus Marsh and Point Nepean etc. E. to W. faults.

Another great subsidence area developed itself west of the Mount Lofty Range near Adelaide, trending northwards through St. Vincent and Spencer Gulfs to the Lakes Torrens and Eyre regions. This downward warping in the Lake Eyre neighbourhood was probably preceded by a slight tilt of the Cretaceous basin from N. to S., which started the Darling River on its S.W. course: in Cretaceous time the drainage from the N.W. part of New South Wales had gone to the N.W. The 'boathook' junction of the Macquarie, Castlereagh etc. rivers with the Darling is proof of this reversal of the drainage in Post-Cretaceous time.

The interesting case recorded by Mr. Charles Hedley[1] of an extensive change in the position of the Continental

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[1] Proc. Linn. Soc. N.S. Wales, Vol. xxxvi, pt. 1, pp. 17 and 18.

Shelf off Breaksea Spit at the north end of Fraser Island, is probably due, in the opinion of Captain Sharp and myself, to excavation of the sea floor by a powerful marine current. The chart published by Mr. Hedley (*op. cit.* p. 18) shows that the bottom has deepened between the years 1870 and 1904, by no less an amount than 200 fathoms. As far as I am aware no earthquake shocks have been recorded from this region. This makes it improbable that the change of depth is due to bodily crustal re-adjustment. On the other hand the earthquake shocks which from time to time visit the Adelaide region, the Bass Strait area and the Kosciusko area show that adjustment of the earth's crust is still going on at those localities. Recent observations by the Rev. E. F. Pigot, S.J., etc., at Riverview Observatory, Sydney, show that the chief earthquake shocks to which the east coast of Australia is subject, come from deeps in the Tasman Sea, such as Carpenter's Deep and Thomson's Deep.

Conclusions.—The following deductions from the study of the structure of the Australian Continent are only tentative:—1. That Australia, in late Cainozoic time, was larger than at present. It has lost in area peripherally through collapse of marginal segments under gravitational pull.

2. That orogenic movement has affected Australia up to near the end of the Palæozoic Era.

3. That this orogenic movement took the form largely of S-shaped spirals, indicating a tendency of the earth's crust to fold itself in two directions making a wide angle with one another. The dominant direction of the fold lines seems to be about N. by W. to N.N.W., with a tendency on the whole to an overfolding to the west. These meet, mostly in 'syntaxis,' in places in 'linking,' other trend lines directed more E. and W. This spiral arrangement of the trend lines cannot reasonably be correlated with the shape

ERRATUM.

Page 59, line 2, for "predominance of peripheral over radial contraction etc.," read "predominance of radial over peripheral contraction etc."

or distribution of masses of intrusive rock, but is probable evidence of the great predominance of peripheral over radial contraction of the earth's surface.

4. The most extensive granite intrusions which have so much controlled the development of the present Main Divide of Eastern Australia group themselves in time around the Permo-Carboniferous glacial epoch. That epoch was evidently a very critical time in folding, faulting injection of batholiths, and mountain building.

5. Since the close of Palæozoic time Australia has been subjected to broad warps, but not to true folding, except in the direction of New Guinea, where Cretaceous, and even early Tertiary strata are highly folded. New Guinea is thus a new fold region: and even in Australia tectonic movements are newer as New Guinea is approached.

6. In the neighbourhood of large sag basins basic rocks have been erupted, as in the case of the quartz-dolerite (quartz-diabase) sills and dykes of Tasmania, the basalts of the Great Valley of Victoria and the serpentine belt of New England.

7. At least one important basin which has been an area of subsidence for several geological periods, and therefore probably has been an area where gravity has been in excess, has ceased to subside, and has taken part in the upward warping of Eastern Australia in late Tertiary time. On the isostatic theory of crustal equilibrium this would imply that in such an area (as the central coal basin of New South Wales) compensation has now been attained. This may also imply that an extra heavy area, (where gravity is in excess) may eventually become an area of mean density. The rift valley of South Australia from near Adelaide to Lake Eyre is perhaps still subsiding. Bass Strait, and the Snowy-Murrumbidgee rift valley are also probably still subsiding. It would be of considerable scientific interest to have an

accurate gravity survey made across the rift valley of South Australia, across the islands of Bass Strait, and across the islands of Torres Straits and the mainland. The Government Astronomer at Melbourne, Mr. Baracchi, has the necessary instruments for such a survey.

8. While, as already stated, the dominant crust creep in Australia has been westerly, there has also been a tendency, in accordance with the principle enunciated by Suess, for subsidence areas to be overthrust, or, perhaps as others state it, for the subsidence areas to underthrust adjacent regions, or for overthrusting above and underthrusting beneath.

9. The wide gaps in our knowledge of the trend lines of Australia emphasize the urgent need for a vastly extended series of observations, both on land and sea, before any satisfactory theory can be advanced as to the plan upon which this island continent has been built.[1]

Acknowledgments.—In addition to those whose help has already been acknowledged at the beginning of this address, I desire to express my gratitude to Mr. W. S. Dun for numerous references, and to Dr. W. G. Woolnough, Messrs. Leo A. Cotton, B.Sc., W. R. Browne, B.Sc., and A. B. Walkom, B.Sc., for assistance in correlating trend lines. Further I am much indebted to Messrs. E. C. Andrews, B.A., C. Hedley, and C. A. Süssmilch, F.G.S., for much useful information in the preparation of the relief model forming *Plates 1* and *3*.

[1] Subsequent to the reading of the above address, the following valuable papers have been published, containing much additional information on the evolution of Australia :—"Physiography of Eastern Australia," by T. Griffith Taylor, B.Sc., B.E., B.A., F.G.S., Commonwealth Bureau of Meteorology, Melbourne, Bulletin 8, May, 1911. An able summary of trend lines and earth movements in areas adjacent to Australia is given by Professor P. Marshall, M.A., D.Sc., F.G.S., Rept. Austr. Assoc. Adv. Sci., Brisbane, 1910. "Ocean Contours and Earth Movements in the South West Pacific," pp. 432 - 449, with four maps.

NOTES ON TRANSITION CURVES.

By WALTER SHELLSHEAR, M. Inst. C.E.

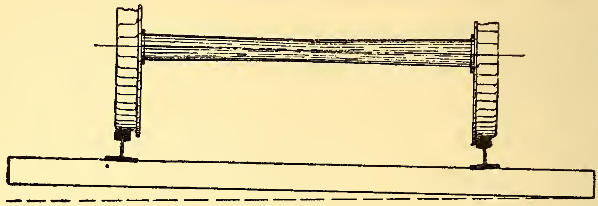
[*Read before the Royal Society of N. S. Wales, June 7, 1911.*]

IN a paper read before this Society in 1888, the author pointed out the advantage of introducing a short length of a cubic parabola as a transition curve between the straight and a circular curve in laying out railway lines. It was pointed out that when the length of the transition curve was small in proportion to the radius of the circle the cubic parabola was extremely simple to apply. Subsequently several papers giving a very interesting investigation of the cubic parabola were contributed to the Society by Mr. C. J. Merfield, F.R.A.S. Since the date of these papers the Railway Construction Branch has adopted a four chain transition for curves up to forty chains radius, and the extensive tables published by Mr. Merfield have been reprinted and issued to the surveyors of that branch with certain instructions for the work in the field.

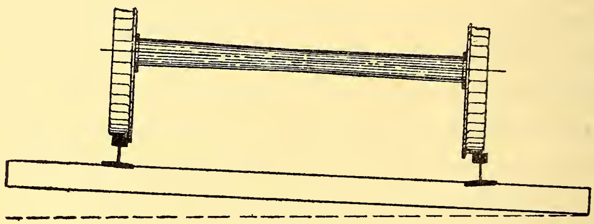
Many lines have been laid out with these transition curves in New South Wales, and there can be no doubt of the advantage of transitions in the endeavour to ensure easy running. But the question is whether it is necessary to make the transition of the adopted length and with the complicated field work which is involved in the method indicated. Let us see what is really required to meet the case.

When no transitions are used the necessary superelevation of the outer rail has to be graded up on the straight before the tangent is reached, with the result that the flanges of the wheels tend to slide down on to the low rail, so that when the tangent is reached the change of direction is accompanied by a blow caused by the sudden movement of the flanges from the low to the high rail. (See fig. 1.)

Fig. 1.

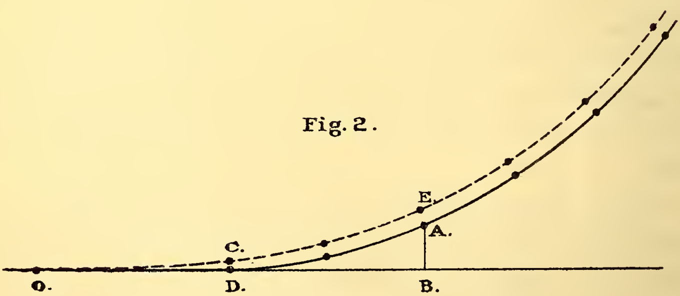


Cant on Straight.



Cant on Curve.

Fig. 2.



$OD = DB.$

$AE = \frac{1}{3} AB.$

$CD = \frac{1}{6} AB = \frac{1}{2} AE.$

Froude, in his method of easing curves when a short length of cubic parabola is used, makes the length of the curve of adjustment proportionate to the cant, and assumes that the grade from level to maximum cant should not exceed 1 in 300. Thus for a curve of twenty chains radius and a speed of forty miles per hour the length of his transition is 113·6 feet, and the amount of shift (distance between the original and parallel tangent) is only ·407 of a foot.[1]

On lines of standard gauge where a mixed traffic of passenger and slow goods trains is worked, it is not advisable to give a greater cant than four inches, as with a high cant the road is so over-canted for the slow goods trains that the wear on the low rail is very excessive and there is a danger of the engines leaving the road at low speed on account of excessive weight on the low rail. Now a two chain transition and a four inch cant would give a grade of 1 in 396 from the level to the maximum cant, and therefore a two chain transition should be sufficient for the curves in ordinary use on our lines. By making the length of the transition a multiple of a chain, instead of a multiple of the cant as in Froude's method, the distance of the parallel tangent (or shift) can be found at once, as it is one-third of the tangent offset, and the middle ordinate of the curve is one-half the shift.

As to the degree of accuracy of the method explained in the paper of 1888, if the total length of the transition does not exceed one-tenth of the diameter of the circle, the method is as accurate as it is possible to work to with ordinary platelaying. In using the approximate method the centre line would be laid out as if no transitions were used, the stakes marking out the curve being subsequently shifted inwards by the amount of the shift or distance of the parallel tangent.

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[1] Rankine's Rules and Tables p. 140.

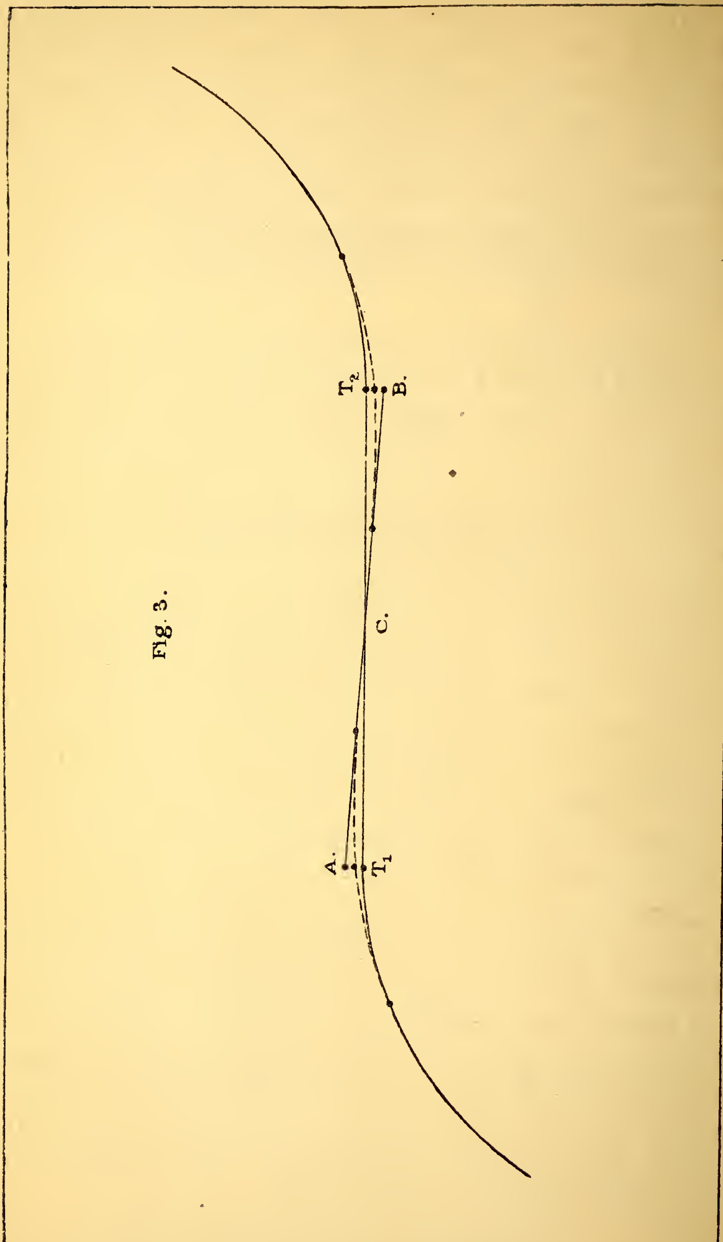


Fig. 3.

CONTENTS.

ISSUED FEBRUARY 8th, 1912.

Vol. XLV. Part II.

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1911

PART II., (pp. 65-224).

CONTAINING PAPERS READ IN

JUNE (*in part*) to SEPTEMBER.

WITH SEVEN PLATES.

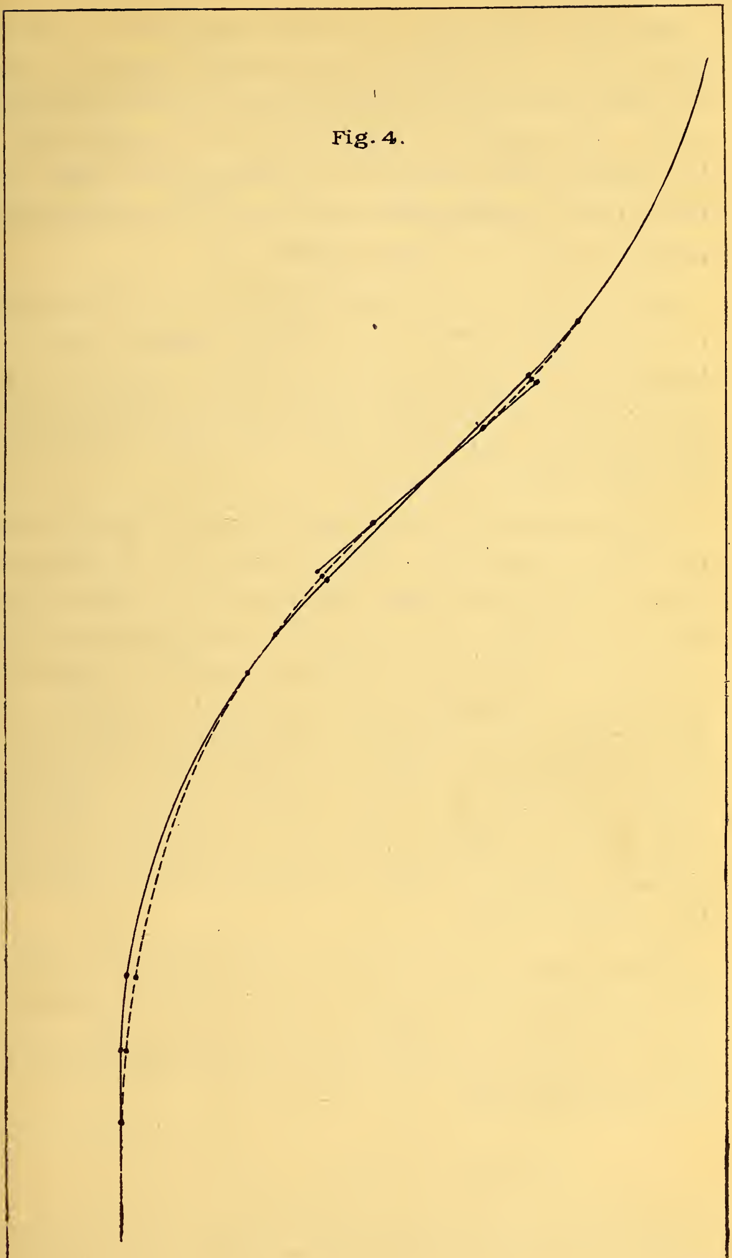
(Plates iv, v, vi, vii, viii, ix, x.)

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1912.

F. WHITE: Typ., 344 Kent Street Sydney.

Fig. 4.



Example:—To apply a two chain transition to a fifteen chain curve.—The distance of the parallel tangent or shift is equal to one-third the off-set at one chain for the circular curve. (See figure 2.) Let $O\ D\ B$ be the tangent line, D the tangent point, and $A\ B$ the off-set at one chain, then $O\ D = D\ B = 1$ chain, shift $= \frac{1}{3}\ A\ B = \frac{26{\cdot}4''}{3} = 8{\cdot}8'' = A\ E$, middle ordinate $= \frac{1}{6}\ A\ B = D\ C = 4{\cdot}4''$.

As the distance of the parallel tangent (or shift) is small, in many cases it would be possible to apply a two chain transition to an existing line by pulling in the curve by the amount of the shift without widening the cuttings or bank. This would not be possible with a four chains transition as the shift would be too great.

In the case of two reverse curves with a short straight between, a transition could be introduced as follows:—Mark off the shift for each curve as shown on figure 3 and slew the straight. Let T_1 and T_2 be the tangent points, measure the shift T_1A and T_2B, join A and B, and apply the transition. The angle $A\ C\ T_1$ and $B\ C\ T_2$ would be very small in the case of a straight several chains long, and the distance between A and the true tangent could be neglected. Again, in the case of one end of a curve being treated as above, and the other end being on a long straight, the shift could be absorbed as shown on figure 4 without affecting the running of trains.

These suggestions may not be mathematically correct, but the approximation is so close that if applied to an existing road where no transitions have been used, a great improvement in the smoothness of running would be effected at a moderate cost.

OBSERVATIONS ON THE CORROSION OF STEEL IN WATER.

By G. J. Burrows, B.Sc., and C. E. Fawsitt, D.Sc.

[Contribution from the Chemical Department, University of Sydney.]

[With Plate IV.]

[Read before the Royal Society of N. S. Wales, July 5, 1911.]

Our attention has been specially drawn to this subject recently in connection with the corrosion of Artesian Bore casings. The corrosion of steel, in spite of investigations by many experimenters, presents peculiarities which are not properly understood and are often contradictory. It is safe to say that conclusions of a general character can only be drawn from series of observations made wholly under the superintendence of one observer who is entirely acquainted with the conditions of experiment.

(1) **Theory of Rusting.**—The production of rust from iron requires the presence of free oxygen and water, and takes place in at least two stages. A ferrous compound is formed in the first instance; this is then oxidised to rust. We do not think that the presence of carbon dioxide is necessary for rusting.[1] Solutions of sodium carbonate, if they dissolve any carbon dioxide, will not hold this free, but combined as bicarbonate. Now neither bicarbonate nor carbonate of soda prevents rusting. Indeed they sometimes accelerate it. The presence of free carbon dioxide is therefore not necessary for rusting. We believe that the formation of a ferrous compound in the first stage of rusting follows the equation

$$2\,Fe + O_2 + 2\,H_2O = 2\,Fe(OH)_2$$

[1] Cushman and Gardner, "The Corrosion and Preservation of Iron and Steel," 1910, p. 35. Dunstan, Journal Chemical Society, 1905, 87, 1548).

It does not appear likely that the oxygen and water together act simultaneously on the iron. It is more probable that the iron first dissolves to a very limited extent in the water. It is known to be capable of dissolving to a small extent in water as ferrous ion, displacing at the same time an equivalent quantity of hydrogen. The hydrogen in the absence of free oxygen polarises the iron surface and the function of the oxygen is to remove the layer of polarising hydrogen. According to this view of the rusting process, iron should dissolve faster if it be in contact with a more electro-negative metal like platinum, for then the hydrogen would tend to collect more on the platinum plate than on the iron one. The acceleration of corrosion caused by contact with platinum is shown by the result of the experiment given in Table I.

Uniform steel strips weighing about 64 grams were cut from steel sheet of the composition:—Carbon 0·35, manganese 0·61, phosphorus 0·06, silicon 0·01, sulphur 0·01%. They were fully immersed in unstirred distilled water. Two of the strips were connected to strips of platinum. The surfaces of all the strips of steel were approximately the same. Also the temperature of experiment may be regarded as being the same for these comparative experiments. (Room temperature.)

Note as to the Method of Experiment.—In all the experiments given here, those in any series were placed together in one part of a room. The temperature of experiments was the temperature of the room and therefore was not constant, but it varied in the same manner for each individual test in any series. The pieces of steel in comparative experiments were always placed wholly underneath the water and at the same distance from the surface. The corrosion was determined by removing the steel after an appropriate time, scrubbing the surface well with a tooth brush, drying and weighing. Corrosion is then expressed as loss of weight.

Table I.

	Weight at Start.	Loss of Weight after 17 days.	Loss of Weight after 35 days.
Steel	64·563	0·141	0·258
Steel with platinum	64·619	0·185	0·326
Steel	65·371		0·273
Steel with platinum	63·382		0·303

(2) Influence of Composition of Steel on Corrosion.—Having in our possession slowly cooled steels of composition varying between 0·1% carbon and 1% carbon content, we exposed these to the corrosive influence of a water containing bicarbonate of soda, magnesium sulphate and sodium chloride. The results were somewhat irregular, so that few exact conclusions can be drawn regarding the influence of composition on the corrodibility. It is however very noticeable that (1) the initial rate of corrosion is very different from the rate which sets in after a few weeks. (2) a steel containing ·9 or 1% carbon corrodes less in the water used than a steel containing smaller percentages of carbon.

Table II.

Steels of varying composition exposed to the action of corrosive water containing the following:—Sodium bicarbonate 2·64, *magnesium sulphate* 0·113, *sodium chloride* 0·166 *grams per litre. Surface exposed in each case* 390 *sq. mm., weight equal* 4 *grams.*

Percentage of Carbon.	Loss of Weight after 5 weeks.	Total loss after 6 months.
0·18	0·0153	0·0408
0·23	0·0168	0·0288
0·40	0·0144	0·0296
0·62	0·0118	0·0170
0·80	0·0120	0·0178
0·90	0·0115	0·0164
1·18	0·0141	0·0184

The amounts of Si, P, Mn, S, in these steels were almost identical.

When it is remembered that a steel of ·9% carbon has the eutectic composition of "perlite," it can readily be believed that a steel containing perlite only might corrode less than a ferrite-perlite steel, [*i.e.* 0 – 0·8% carbon]. We think, however, that it will scarcely be possible to claim superiority for such a high carbon steel until further experiments have been made.

(3) **Influence of the Magnetic Condition of Steel on its Corrosion.**—It has not to our knowledge been suggested that magnetisation affects corrodibility, but to test this we performed some experiments on the steel already described in paragraph (1). The results showed in Table III indicate that magnetisation has no noticeable effect on the corrosion.

Table III.

Corrosion of steel in unstirred distilled water.

Condition of Sample.	Weight at start.	Loss of Weight after 21 days.
Magnetised ...	65·060 grams	0·236 grams
,, ...	64·746 ,,	0·221 ,,
Unmagnetised ...	63·903 ,,	0·226 ,,
,, ...	63·557 ,,	0·2111 ,,

It is known that bore casings are often found to be magnetised, so it is well that we should have proved that this has no effect on the corrosion.

(4) **Effect of additions to water on the corrosion of steel in water.**—The effect of adding small quantities of soluble matter to water is sometimes to increase and sometimes to decrease the corrosive power of water on steel. The general effect of adding an acid is to increase, and of an alkali to decrease corrosion.

The effect of adding salts has only lately begun to be studied in a systematic manner by Messrs. Hehn and Bauer.[1]

[1] International Society for Testing Materials, Report of Copenhagen Congress, 1909.

They find that many salts at a certain concentration in the solution show a maximum of corrosive power, but that on further increasing the concentration, the corrosive power rapidly decreases. We believe that the accelerative effect of salts on corrosion is explained by the greater conducting power of the solution. The decrease in the velocity of rusting with higher concentrations of dissolved salt is probably due to the decreased solubility of oxygen in the solution. The experiments described in paragraph (6) were conducted primarily with the object of testing the action of some Artesian bore waters on steel. It has been supposed for some time that the bore-waters in the Coonamble district are extra corrosive on steel or iron casings, and we have tested two of these in our experiments.

(5) **Analysis Records of Bore Waters.**—We have carefully examined the analyses of all the bore waters in the State of New South Wales, with the object of seeing whether any great variations are noticeable, which could account for any special corrosion. The analyses records are contained in a printed report kindly sent to us by Mr. L. A. B. Wade, Department of Public Works of N.S.W. We have noticed one characteristic which clearly marks off the Coonamble district as being different from the others, though we do not believe that this characteristic in itself is a direct cause of special corrosion.

There are approximately 440 bores (working) in New South Wales; 100 of these are situated in the Coonamble district; of these 51 show the presence of sulphates. There are only 18 bore-waters in other parts of the State which show the presence of sulphates. It is further noticeable that as a bore is deepened, carbonates and chlorides usually decrease in quantity, while there is a tendency for increasing quantities of sulphate to be present. The sulphates are found in Coonamble district at smaller depths than elsewhere. Twenty-two of the Coonamble bores show sulphates at a depth less than 1,500 feet. Excluding three bores (Momba, Opera and Sandy Creek, which are exceptional in other respects), no bore water in other parts of the State shows sulphate at a depth less than 2,300 feet. This peculiarity of the waters from the Coonamble district is not shown here to be directly accountable for any special corrosion, but we believe attention has not already been drawn to this singularity, and we think the matter should prove of interest to geologists who know the Coonamble district.

(6) **Corrosion Experiments.**—The steel used throughout had the composition given in paragraph (1). Steel plates were fully immersed in the water used. All experiments were started simultaneously and were kept in the same part of a room. No other special measures were adopted to keep the temperature constant. Duplicate experiments showed that the variations of temperature were sufficiently uniform in the separate experiments to be negligible. After the rusting had gone on for some time, the steel plates were brushed, and re-weighed. This gave the loss due to corrosion. The weight and surface area of all strips were very nearly equal.

Table IV.

The water was not stirred here in any way.

Solution.	Weight of Steel strip.	Loss of weight after 37 days.	Average loss of weight.
Distilled water	64·486	0·288	0·274
	63·235	0·241	
	65·913	0·296	
	65·735	0·273	
*Woodlands Bore, water containing ·03% total solids, chiefly sodium bicarbonate.	63·683	0·302	0·288
	65·649	0·278	
	64·906	0·286	
	64·847	0·284	

Table IV—*continued.*

Solution.	Weight of Steel strip.	Loss of weight after 37 days.	Average loss of weight.
*Coonamble, No. 2 Bore, water containing ·04% total solids, chiefly bicarbonate of calcium and sodium.	64·300 65·128 65·246 64·986	0·298 0·284 0·282 0·284	0·287
Water containing ·12% sodium bicarbonate, ·05% magnesium sulphate, ·07% sodium chloride.	65·640 64·850 64·490	0·240 0·269 0·267	0·258
Water containing 0·2% ferrous sulphate.	62·766 64·725	0·304 0·312	0·308
Water containing ·25% potassium hydrate.	64·561	0	0
Water containing ·25% potassium cyanide.	65·914	0·002	0·002

* *These waters contain all the carbonate present as bicarbonate. They contain besides carbonates small quantities of chlorides and sulphates of sodium, potassium and calcium. They contain a little free carbon dioxide.*

The water from Coonamble No. 2 bore was tested [by Mr. G. Wright, a demonstrator in the Chemical Department] for radioactivity by boiling out all the dissolved gases and bringing these inside a gold leaf electroscope (*in vacuo*). The radioactivity of the emanation from 1 litre of solution, after three days had elapsed from the time the sample was collected, was equal to that of the emanation obtainable from ·0005 grams uranium, from pitch blende. This corresponds on Boltwood's scale to an initial activity of 90×10^{-4} grams uranium per litre of water. As the activity of the emanation decayed to one half its value in four days it may be considered to be radium emanation. Boltwood[1] has examined a large number of waters from

[1] American Journ. of Sci,, 1904, IV 18, p. 378, *ibid.* 1905, IV 20, p. 128.

springs: the radioactivity of these is seldom quite as high as this water which has just been examined. We have tried the effect of adding radioactive salts to water to test whether this affected the corrosion, and found that the result was negative.

Table V.

Corrosion as affected by stirring the solution.

Description of Solution.	Weight of steel at start	Loss after 20 days.	Loss after 40 days.
a. Distilled water, unstirred ...	65·401	0·219	0·403
	64·581	0·207	0·376
b. Distilled water, unstirred ...	65·617		0·387
	64·223		0·403
a. Distilled water, stirred... ...	64·161	0·573	1·304
	65·215	0·565	1·341
b. Distilled water, stirred... ...	64·833		1·490
	63·792		1·490
a. Water from Coonamble No. 2	64·844	0·591	1·536
Bore, stirred	64·964	0·612	1·652
b. Water from Coonamble No. 2	64·002		1·344
Bore, stirred.	64·701		1·339

In the experiments marked (a) *the pieces of steel after being weighed at the end of twenty days were put back for another twenty, to make up the total. In the experiments marked* (b) *the steel was not disturbed for forty days.*

These experiments show (1) that the bore-waters tested here are not noticeably more corrosive than distilled water, (2) that moderate stirring of the solution has an accelerative effect on the rusting process, (3) that the initial rate of corrosion does not stand in any simple relation to the rate which sets in after some time has elapsed.

We have noticed, however, that under different conditions there are great differences in the character of the corrosion.

Comparing the corrosion by the bore water with that obtained by distilled water, the surface in the latter case, (Fig. 1) *Plate 4*, is almost quite uniformly corroded, whereas in the former (Fig. 2) there are distinct patches of oxide, and these are much darker in colour than the usual rust colour. The photographs shown in *Plate 4*, are about half the original size.

[As the corrosion at Coonamble does not arise from the water containing any dissolved corrosive substance we have analysed the steel used in these casings and find it to be of good quality and not responsible for any special corrosion. The gases which are evolved from many bores have lately been examined by Mr. Symonds, Department of Public Works, and, so far as these examinations go, the Coonamble bore appears to be exceptional in containing both oxygen and carbon-dioxide in the evolved gases.]

We think that future investigations into the corrosion and steel should be pursued to investigate these points: (1) the relation of corrosion to the surface conditions of the metal, (2) the determination of any catalytic influence at work—iron or ferrous compounds; (3) the velocity of the diffusion of substances in the liquid to and from the surface of the metal; (4) the relative corrosion rates of ferrite, perlite and cementite.

STUDIES IN STATISTICAL REPRESENTATION.

STATISTICAL APPLICATIONS OF FOURIER SERIES.

(Illustrated by the analysis of the rates of marriage, temperature, suicide, etc.)

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[*Read before the Royal Society of N. S. Wales, July 5, 1911.*]

1. Fundamental Nature of the Problem.—Whenever the whole series of fluctuations in phenomena such as are susceptible of numerical representation are, in general, exactly repeated, or may be supposed to be repeated, during equal periods of time, they may be *arbitrarily* represented by a formula of the following type.

$$(1) \ldots\ldots y = a_0 + a_1 \sin (x + \alpha_1) + a_2 \sin 2 (x + \alpha_2) + \ldots + a_m \sin m (x + \alpha_m) \ldots$$

the complete period being denoted by $x = 2\pi$. Or again, they may be represented by a similar series containing instead cosine terms, viz. $b_1 \cos (x + \beta_1)$, $b_2 \cos 2 (x + \beta_2)$, etc.; or yet again, if the series contain both sine and cosine terms the angles α_1, β_1; α_2, β_2, etc., may be omitted, the general term being $a_m \sin mx + b_m \cos mx$, in all cases m being an integer.

In the above formula $\alpha_1, \alpha_2 \ldots \alpha_m \ldots$ represent the intervals between the origins of particular elements [the complete periods of which are respectively $\frac{2\pi}{1}, \frac{2\pi}{2}, \frac{2\pi}{3}, \ldots \frac{2\pi}{m} \ldots$] and the beginning of the period under review, say the commencement of the year or month, or of the day, as the case may be. They may be called "epochal angles." The factors $a_1, a_2 \ldots a_m \ldots$ are the semi-amplitudes of the oscillation. Epochal angles are not necessary however when the series contains both sines and cosines. It may be noted that the periods $\frac{2\pi}{2}, \frac{2\pi}{3}, \ldots \frac{2\pi}{m}$ being all sub-multiples of 2π, are exactly repeated with the larger period 2π.

By way of illustration it may be said that the secular means of weekly, monthly, or quarterly variations of temperature, of rainfall, etc., may be replaced by a curve of the form indicated in (1), in such a way that the area standing on the abscissa representing any interval of time and bounded by the curve, the axis of abscissæ, and the two limiting ordinates, will give the same average result over the interval of time as was originally furnished by the data.

In many cases, however, statistical results may disclose oscillatory fluctuations of which the absolute amplitude increases as some function of the time: hence in dealing with certain classes of statistical data it may be necessary to write instead of equation (1)

(2)......$y' = f(x)\{a_0 + a_1 \sin(x + \alpha_1) + \ldots + a_m \sin(x + \alpha_m) + \ldots\}$ that is to say, the values of the fluctuating or periodic terms have to be multiplied by the factor $f(x)$, or in other words

$$(3)\ldots\ldots y = y'/f(x).$$

For example, with a growing population, the changes in the number of births from month to month shew a seasonal or periodic fluctuation, the amplitude of which however is itself growing in proportion to the total population: while the mean monthly rainfall of a country which was becoming arid, would similarly shew a periodic fluctuation, the amplitude of which was diminishing in the ratio of the diminution of aggregate annual rainfall. This method will always be satisfactory when the amplitude of the fluctuation is relatively small as compared with y, in other words, in all cases where the amplitudes vary only as $f(x)$ in (3), and are or may be considered to be, unaffected by the magnitude of the periodic term itself.

With regard to the form in which the problem may be actually presented it may be noted that data may be either in the form of *instantaneous values*—that is, values of the function with different values of x as argument,—or *group values*, viz., totals or averages between certain values of x. The latter form is that which usually occurs in statistical applications. Instantaneous values are of course directly represented by (2). For group values we have, on integrating (1),

$$(4)\ldots\ldots\ Y = \int y\,dx = a_0 x - a_1 \cos(x + \alpha_1) - \tfrac{1}{2} a_2 \cos 2(x + \alpha_2) - \ldots - \frac{1}{m} a_m \cos(x + \alpha_m)\ldots$$

Y denoting an area. Hence group values are essentially the values of this integral between the limits x_0 to x_1; x_1 to x_2;...x_{n-1} to x_n; n denoting the number of groups. In most instances practically occurring, the data do not furnish Y but $Y/\int dx$, i.e. $Y/(x_1 - x_0)$; $Y/(x_2 - x_1)$; $Y/(x_3 - x_2)$; etc., for the different limits.

2. Correction for secular change of amplitude.—If the data are in form (2) they must first be reduced to form (1), by dividing by the values of $f(x)$ which represents merely the secular change: this itself may either be periodic (with a long period) or non-periodic. Consequently when the data are in the form of rates properly calculated for equal periods it is in general not necessary to correct them for secular changes, unless the rate itself is subject to secular change.

When the function $f(x)$ is sensibly linear, say $(1+kx)$, and the oscillations are small as compared with the absolute numbers to which they refer (as is most frequently the case), then the readiest way to correct the data will be to take for the general value that of the middle of the period, and correct the monthly values by multiplying by $(1+kx)$. For example, where absolute monthly means (not rates, unless we are dealing with secularly changing rates) for a whole decennium are used, the corrections to each would with sufficient approximation be as follows:—

Corrections to reduce monthly means of a linearly growing population to the mean value for the year.

Jan.	Feb.	March	April	May	June
$+\frac{11}{24}k$;	$+\frac{9}{24}k$;	$+\frac{7}{24}k$;	$+\frac{5}{24}k$;	$+\frac{3}{24}k$;	$+\frac{1}{24}k$;
July	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
$-\frac{1}{24}k$;	$-\frac{3}{24}k$;	$-\frac{5}{24}k$;	$-\frac{7}{24}k$;	$-\frac{9}{24}k$;	$-\frac{11}{24}k$.

These fractions represent the distance of the middle of the month from the middle of the year. The general mean will then correspond to the amplitudes which would hold good for the end of the fifth year and the beginning of the sixth year, when the data are derived, as supposed, from a whole decennium. Such corrections should of course be applied after the values for the month have been equalised, as referred to hereinafter.

Example—For the decennium 1900 to 1909 in the Commonwealth of Australia the following average numbers of persons, viz., those shewn on line (1) committed suicide per diem in the successive months of the year. The rate of growth of the population assumed to be linear, was 0·0177 per unit per annum; hence the correcting factor is 1 ± 0·0177 x, where x is the interval. Making this correction the number in line (2) is obtained.

Number of Persons daily committing suicide in Australian Commonwealth, decennium 1900 – 1909.

	Jan.	Febr.	March	April	May	June
(1)	1·423	1·479	1·335	1·340	1·239	1·133
(2)	1·435	1·489	1·342	1·345	1·242	1·134
(3) *	+ ·054	− ·147	+ ·003	− ·103	− ·108	+ ·065
(4)† *	1·434	1·484	1·338	1·342	1·237	1·134

	July	August	Sept.	Oct.	Nov.	Dec.
(1)	1·200	1·303	1·230	1·416	1·300	1·390
(2)	1·199	1·300	1·225	1·409	1·291	1·378
(3) *	+ ·101	− ·075	+ ·184	− ·118	+ ·087	
(4)† *	1·202	1·301	1·227	1·411	1·292	1·379

NOTE.—* *For meanings of lines* (3) *and* (4) *see Section* 3. †(4) *denotes the monthly average of the numbers of persons daily committing suicide for months of equal duration and a constant population, viz., the mean population for the year.*

The correction is thus, $1 - kx$, in which x is interval of time from the end of 30th June, expressed as a fraction of a year and is negative if earlier than that date, positive if later. This correction can frequently be made by inspection.

3. Correction for unequal length of months.—There is another correction, however, which it is necessary to make, viz., that due to unequal length in the different months in the year. If months were equal in length then the average would be free from error, and would give either the a_0 of the formula, or a multiple thereof. The table hereunder gives the correction in days for each month of the year according as the results are:—

(i) For the ordinary year, month = 30·4167 days.
(ii) For the leap year, month = 30·5000 days.
(iii) For the decade of two leap years, month = 30·4333 days.
(iv) For the decade of three leap years, month = 30·4417 ,,
(v) One twelfth of the tropical year (365·2422) month = 30·4368 days.

The equal or uniform month in each case represents 30°, or in radians $\frac{1}{6}\pi$, or 0·52359877. The end of the uniform month of January is within the actual month itself. In every other case the end of the uniform month, when not exactly at the end of the actual month, is in the actual month following. Attention to this will obviate the need for attending to the signs of the corrections.

Differences in days between ends of uniform and actual months.

Type of Year	Jan.	Feb.	March	April	May	June
(i)	0·583	1·833	1·250	1·667	1·083	1·500
(ia)	$\frac{7}{12}$	$\frac{22}{12}$	$\frac{15}{12}$	$\frac{20}{12}$	$\frac{13}{12}$	$\frac{18}{12}$
(ii)	0·500	1 000	0·500	1·000	0·500	1·000
(iii)	0·567	1·667	1·100	1·533	0·967	1·400
(iv)	0·558	1·583	1·025	1·467	0·908	1·350

(v) may be regarded as equivalent to (iii).

Type of Year.	July	August	Sept.	Oct.	Nov.	Dec.
(i)	0·917	0·333	0·750	0·167	0·583	0·000
(ia)	$\frac{11}{12}$	$\frac{4}{12}$	$\frac{9}{12}$	$\frac{2}{12}$	$\frac{7}{12}$	0
(ii)	0·500	0·000	0·500	0·000	0·500	0·000
(iii)	0·833	0·267	0·700	0·133	0·567	0·000
(iv)	0·792	0·233	0·675	0·117	0·558	0·000

Where a rough graph has been drawn shewing the instantaneous values corresponding to and giving the group values, the proper instantaneous values corresponding to the end or beginnings of the months will be available. Inasmuch however, as the correction is very small, it will, in general, be sufficiently accurate to take the mean of the average daily values for the two contiguous months. The difference between this average value and average value for either month is one half the difference of the given averages.

Thus reverting to line (2) of the previous table, we have the differences shewn on line (3), and these are the bases of the corrections, which when applied to the values in line (2), give ultimately those of line (4). Excepting the case of leap year there are two terms in the correction for every month but January and December, and one for each of these months. In leap year there are one-term corrections for the months of January, August, October, and December.

The value of the correction may be found thus:—Let the difference of the daily averages of two successive months be denoted by $2d$, the sign being always determined by subtracting the daily average value of the preceding from that of the following month, and let M denote the length of the uniform month. Then if $2d_1$, and $2d_2$ denote the difference-values for the beginning and the end of any month we have for the corrected average value, (v')

(5)......$v' = v + c'$

v being the crude daily average and c' the correction thereto. Denoting the interval between the end of the uniform and actual months by t, and regarding t as *always positive*, we shall have for the value of c'

(6)......$c' = -\dfrac{d_2t_2}{M}$ for January.

(6*a*)......$c' = -\dfrac{d_1t_1 - d_2t}{M}$ for February.

(6*b*)......$c' = -\dfrac{d_4t_1}{M}$ for December.

(6*c*)......$c' = +\dfrac{d_1t_1 + d_2t_2}{M}$ for every other month.

The sign of all the values of d must be carefully attended to. These corrections may be at once deduced from the consideration that if the position either of the beginning or the ending of any month be shifted towards higher average values the average for the month in question will be increased: *vice versa* if the position be changed in the direction of a lower average value. Again if M is the number of days in the average month the relative weight of the correction is only t/M, where t is the number of days of the shift. Thus a new value of the average is given, viz:—

$$(7)\ldots\ldots v' = v + d.\frac{t}{M} = v + c'$$

It may be noted that for all months except January and December the correction $d(t/M)$ must be applied twice, once each for the beginning and end of the month, and, as before, the signs of the different values of d will require careful attention.

By way of example we may note that the totals of lines (1), (2), and (4) in Section 2, are respectively 15,788; 15,789; and 15·781: hence these divided by 12 give for a_0 the following values:—(1) 1·3157; (2) 1·3157; (3) 1·3151; only the last of which is satisfactory; that is, the proper mean is given only when the values for the equalised months are used.

4. Corrections for unequal lengths of quarters and half years.—The corrections for the intervals between the end of the uniform quarters and the ends of March, June, September, and December, can be found by the application of the same principles. They are given by the following equations, viz:—

$$(8)\ldots\ldots c = \frac{D_1T_1}{Q} \text{ for the 1st quarter.}$$

$$(8a)\ldots\ldots c = \frac{D_1T_1 + D_2T_2}{Q} \text{ for the 2nd quarter.}$$

$$(8b)\ldots\ldots c = \frac{D_2T_2 + D_3T_3}{Q} \text{ for the 3rd quarter.}$$

$$(8c)\ldots\ldots c = \frac{D_3T_3}{Q} \text{ for the 4th quarter.}$$

In these expressions D_1, D_2, D_3 denote the differences of the daily averages for the quarters (with the proper signs): T_1, T_2, T_3, the intervals, all being regarded as positive : and Q the length of the uniform quarter in days.

In the case of the correction for the half-year, the daily average being still the datum, we have for the correction

$$(9)\ldots\ldots c = \frac{D\,T}{S}$$

D being the difference (with its proper sign) of the daily averages for the two half-years; T the interval between the end of June and the middle of the year, reckoned positive : and S the length in days of the uniform half-year. The correction is positive for the first half year and negative for the second.

These corrections are often so small that they may be neglected. Corrections for the unequal lengths of the years in a decennium are usually quite negligible. They may, of course, be computed on the same principles.

5. Equalised months and years.—Statistical results needing analysis can also be put in a suitable form by using as original data results for equalised months and years. The scheme should be as follows:—

Inasmuch as the year 2000 is a leap year, the period of 199 years lasting from 1st January 1901 to 31st December 2099 may be regarded, for statistical purposes, as consisting of years of $365\frac{1}{4}$ days. Both months and years may then be readily equalised by making the months $365\frac{1}{4} \div 12 = 30\frac{7}{16}$ days, and considering the first of the month as falling differently in each year of the cycle of four years, according to the following scheme, viz.:—

Years.	1901 1905 1909 etc.	1902 1906 1910 etc.	1903 1907 1911 etc.	1904 1908 1912 etc.
Equalised Month.	Beginning of Equalised Months.			
January	Jan. 0	$0\frac{4}{16}$	$0\frac{8}{16}$	$0\frac{12}{16}$
February	Jan. $30\frac{7}{16}$	$30\frac{11}{16}$	$30\frac{15}{16}$	$31\frac{3}{16}$*
March	Mar. $1\frac{14}{16}$	$2\frac{2}{16}$	$2\frac{6}{16}$	$1\frac{10}{16}$
April	April $1\frac{5}{16}$	$1\frac{9}{16}$	$1\frac{13}{16}$	$1\frac{1}{16}$
May	May $1\frac{12}{16}$	2	$2\frac{4}{16}$	$1\frac{8}{16}$
June	June $1\frac{3}{16}$	$1\frac{7}{16}$	$1\frac{11}{16}$	$0\frac{15}{16}$
July	July $1\frac{10}{16}$	$1\frac{14}{16}$	$2\frac{2}{16}$	$1\frac{6}{16}$
August	Aug. $1\frac{1}{16}$	$1\frac{5}{16}$	$1\frac{9}{16}$	$0\frac{13}{16}$
September	Sept. $0\frac{8}{16}$	$0\frac{12}{16}$	1	$0\frac{4}{16}$
October	Oct. $0\frac{15}{16}$	$1\frac{3}{16}$	$1\frac{7}{16}$	$0\frac{11}{16}$
November	Nov. $0\frac{6}{16}$	$0\frac{10}{16}$	$0\frac{14}{16}$	$0\frac{2}{16}$
December	Dec. $0\frac{13}{16}$	$1\frac{1}{16}$	$1\frac{5}{16}$	$0\frac{9}{16}$
January	Jan. $0\frac{4}{16}$	$0\frac{8}{16}$	$0\frac{12}{16}$	0

* Feb. $0\frac{3}{16}$.

That is, the beginning of the equalised month or year will fall regularly into a new position each year in the cycle of four years, but this position will be repeated four years later. In allowing for change of absolute or relative numbers for each month the principles already indicated may be followed.

6. Analysis of annual fluctuations. Quadrimestral and quarterly data.—A large number of statistical results may be more or less approximately represented by fluctuations which have an annual period; the simplest instance being those whose instantaneous value is representable by

(10)...... $y = a + b \sin (x + \beta)$

the integral of which is

(10a)...... $Y = \int \{a + b \sin (x + \beta)\} dx = ax - b \cos (x+\beta)$

Since the form in which the data are usually furnished is that of average values for a period, *e.g.*, monthly, quarterly etc., the data in question are not given in the form of equation (11) but in the form

$$Y/\int dx = y'; \text{ i.e. } Y/(\tfrac{1}{6}\pi) \text{ or } Y/(\tfrac{1}{2}\pi)$$

for the cases of monthly or quarterly statistics as the case may be.

Going back to equation (10*a*), it is seen that, if the data furnish values for *half years* only, then $y' = Y/\pi$, and a is the mean between the two values of y': also either b or β may be arbitrarily assumed and the other then deduced. Ordinarily it will suffice to put $\beta = 0$.

If, however, results are given for *thirds of years*, a unique solution for a, b and β, may be obtained. Integrating (10*a*) between the limits 0 to $\frac{2\pi}{3}$, $\frac{2\pi}{3}$ to $\frac{4\pi}{3}$, and $\frac{4\pi}{3}$ to 2π, the group results are:—

$$Y_1 = \tfrac{2}{3}\pi a + \tfrac{1}{2}b(3\cos\beta + \sqrt{3}\sin\beta)$$
$$Y_2 = \tfrac{2}{3}\pi a + \tfrac{1}{2}b(-2\sqrt{3}\sin\beta)$$
$$Y_3 = \tfrac{2}{3}\pi a + \tfrac{1}{2}b(-3\cos\beta + \sqrt{3}\sin\beta)$$

Whence dividing by $\int_0^{\frac{2}{3}\pi} dx$ or $\frac{2\pi}{3}$ we get, in each of these expressions y'_k instead of Y_k, a instead of $2\pi a/3$ and $3b/4\pi$ instead of $\frac{1}{2}b$.

Hence primarily, by addition

(11)...... $3a = y'_1 + y'_2 + y'_3$; thus $a = \frac{1}{3}(y'_1 + y'_2 + y'_3)$ and

$$(12)\ldots\ldots \quad \frac{y'_1 - 2y'_2 + y'_3}{3(y'_1 - y'_3)} = \frac{a - y'_2}{y'_1 - y'_3} = \frac{\frac{3\sqrt{3}}{2\pi}}{\frac{9}{2\pi}} \cdot \frac{b\sin\beta}{b\cos\beta} = \frac{1}{\sqrt{3}}\tan\beta$$

and, β being found, we have

$$(13)\ldots\ldots \quad b = \frac{2\pi}{3\sqrt{3}}(a - y'_2)\operatorname{cosec}\beta; \text{ or}$$

$$(13a)\ldots\ldots \quad b = \frac{2\pi}{9}(y'_1 - y'_3)\sec\beta.$$

In practice, however, results are only rarely given in thirds of years. Usually they are *quarterly* or *monthly*. In the former case, if the sum of the first and third quantities equal the sum of the second and fourth, we may suppose the frequency to be of the form

(14)...... $y = a + b \sin (x + \beta)$

The data do not allow of the inclusion of more terms except by making arbitrary assumptions which can in general have no validity. [If for example in equation (14) we add one term so that it becomes

(14a)...... $y = a + b \sin (x + \beta) + c \sin 2 (x + \gamma)$

we should have only four equations to determine the five unknowns a, b, β, c, γ, and we could obtain a complete solution only by making some assumption such for example as $b = c$ or $\beta = \gamma$ or that $\gamma = 0$.] In the case of monthly statistics the frequency may be supposed to be of the form

(15)...$y = a_0 + a_1 \sin (x + \alpha_1) + a_2 \sin 2 (x + \alpha_2) +$
$a_3 \sin 3 (x + \alpha_3) + \ldots\ldots$ the final term being a_6.

It is first of all necessary that x should either be expressd in rates (calculated correctly for equal periods), so that the numbers may be independent of a secular change taking place during the period under review; or that the absolute quantities should be reduced to a common datum. For example, if the absolute number of births during a period is given, it must be reduced to birth rates or corrected so as to express what it would have been had population remained constant during the time under consideration: so that for example the final formula for absolute numbers will be of the form

(16)......$Y = Pe^{\phi(t)} \{a_0 + a_1 \sin (x + \alpha_1) + a_2 \sin 2 (x + \alpha_2) + \text{etc.}\}$

Y being the absolute number of persons, and P being the absolute number for $x = 0$.

From (14) above we have for quarterly fluctuations

$$x = 0, \frac{1}{2}\pi, \pi, \frac{3}{2}\pi, 2\pi.$$

and since

(17)... $\int \{a + b \sin (x + \beta)\} \, dx = ax - b \cos (x + \beta)$

the following are the values for the integrals between the limits indicated, viz., for the case where sum of first and third quarters equal sum of second and fourth.

$$Y_1 = \tfrac{1}{2}\pi a + b (\cos\beta + \sin\beta); \quad Y_2 = \tfrac{1}{2}\pi a + b (\cos\beta - \sin\beta)$$
$$Y_3 = \tfrac{1}{2}\pi a - b (\cos\beta + \sin\beta); \quad Y_4 = \tfrac{1}{2}\pi a - b (\cos\beta - \sin\beta)$$

Let $y'_k = Y'_k/\tfrac{1}{2}\pi$, in which $k = 1, 2, 3$, and 4, and y'_1, y'_2, y'_3, and y'_4 are the corrected quarterly *means*. Hence in these expressions we may write y'_k instead of Y_k; a instead of $\tfrac{1}{2}\pi a$; and $2\,b/\pi$ instead of b and we thus obtain

(18)... $a = \tfrac{1}{4}(y'_1 + y'_2 + y'_3 + y'_4)$;

and also

(19)... $$\frac{y'_1 - y'_2 - y'_3 + y'}{y'_1 + y'_2 - y'_3 - y'_4} = \frac{\frac{8b}{\pi} \sin\beta}{\frac{8b}{\pi} \cos\beta} = \tan\beta$$

and β being thus found, we have

(20)... $$b = \frac{\pi}{8}(y'_1 - y'_2 - y'_3 + y'_4) \operatorname{cosec}\beta$$
$$= \frac{\pi}{8}(y'_1 + y'_2 - y'_3 - y'_4) \sec\beta$$

If, as is very commonly the case, the sum of the first and third quarters is not equal to the sum of the second and fourth, we must introduce another term into the frequency, say $c \sin 2(x + \gamma)$; then making $c = b$ in accordance with the arbitrary assumption already referred to, the frequency becomes

$$y = a + b \sin (x + \beta) + b \sin 2(x + \gamma)$$

Proceeding on the same lines as before we have

$$y'_1 = a + \frac{2}{\pi} b (\cos\beta + \sin\beta) + \frac{2}{\pi} b \cos 2\gamma$$
$$y' = a + \frac{2}{\pi} b (\cos\beta - \sin\beta) - \frac{2}{\pi} b \cos 2\gamma$$
$$y'_3 = a - \frac{2}{\pi} b (\cos\beta + \sin\beta) + \frac{2}{\pi} b \cos 2\gamma$$
$$y'_4 = a - \frac{2}{\pi} b (\cos\beta - \sin\beta) - \frac{2}{\pi} b \cos 2\gamma$$

from which, as before we obtain (18), (19), and (20), and further:—

(20a)... $b \cos 2\gamma = \frac{\pi}{8}(y'_1 - y'_2 + y'_3 - y'_4)$

from which we have

(20b)... $\cos 2\gamma = \frac{(y'_1 - y'_2 + y'_3 - y'_4)}{(y'_1 - y'_2 - y'_3 + y'_4)} \sin \beta.$

7. Annual fluctuations: monthly data.—With monthly average results reduced to a uniform basis we put, [see (1) and (4)]

(21)...... $\int \{a_0 + a_1 \sin(x + \alpha_1) + \ldots\ldots + a_m \sin m(x + \alpha_m)\} dx$

$$= a_0 x - a_1 \cos(x + \alpha_1) - \ldots\ldots - \frac{1}{m} a_m \cos m(x + \alpha_m).$$

For the monthly averages, the integral is taken between the limits 0 to $\frac{1}{6}\pi$; $\frac{1}{6}\pi$ to $\frac{1}{3}\pi$; etc.
Consequently if the right hand side of (21) be divided by $\frac{1}{2}\pi$, the monthly *means* (not aggregates) are obtained as a series of twelve equations of which the first is

$$s_1 = a_0 - \frac{6}{\pi} \cdot a_1 \Big\{\cos(x + \alpha_1)\Big\}_0^{\frac{\pi}{6}} - \frac{6}{\pi} \cdot \tfrac{1}{2} a_2 \Big\{\cos 2(x + \alpha_2)\Big\}_0^{\frac{\pi}{6}} - \ldots$$

the second is

$$s_2 = a_0 - \frac{6}{\pi} \cdot a_1 \Big\{\cos(x + \alpha_1)\Big\}_{\frac{\pi}{6}}^{\pi} - \frac{6}{\pi} \cdot \tfrac{1}{2} a_2 \Big\{\cos 2(x + \alpha_2)\Big\}_{\frac{\pi}{6}}^{\frac{\pi}{3}} - \ldots$$

and so on.

Summing these vertically, we see that

$$s_1 + s_2 + \ldots\ldots + s_{12} = 12\, a_0; \text{ thus}$$

(22)...... $a_0 = \frac{1}{12} \Sigma_1^{12} s_k$

It is desirable for the purposes of computation to form the quantities $s_1 - a_0$; $s_2 - a_0$; etc., which will be denoted by r_1, r_2, etc. Thus

$$r_1 = \frac{6}{\pi}\,[a_1\{\cos \alpha_1 - \cos(\alpha_1 + 30^\circ)\} + \tfrac{1}{2} a_2\{\cos 2\alpha_2$$
$$- \cos 2(\alpha_2 + 30^\circ)\} + \tfrac{1}{3} a_3\{\cos 3\alpha_3 - \cos 3(\alpha_3 + 30^\circ)\} + \ldots]$$

$$r_2 = \frac{6}{\pi}\,[a_1\{\cos(\alpha_1 + 30^\circ) - \cos(\alpha_1 + 60^\circ)\} + \tfrac{1}{2} a_2\{\cos 2(\alpha_2 + 30^\circ)$$
$$- \cos 2(\alpha_2 + 60^\circ)\} + \ldots]$$

and so on.

These last equations reduce to

$$r_1 = \frac{6}{\pi}[a_1 . 2 \sin (\alpha_1+15^\circ) \sin 15^\circ + \tfrac{1}{2} a_2 . 2 \sin (\alpha_2+15^\circ) \sin 30^\circ + \tfrac{1}{3} a_3 . 2 \sin 3 (\alpha_3 + 15^\circ) \sin 45^\circ + \text{etc....}]$$

$$r_2 = \frac{6}{\pi}[a_1 . 2 \sin (\alpha_1+45^\circ) \sin 15^\circ + \tfrac{1}{2} a_2 . 2 \sin (\alpha_2+45^\circ) \sin 30^\circ + \tfrac{1}{3} a_3 . 2 \sin 3 (\alpha_3 + 45^\circ) \sin 45^\circ + \text{etc....}]$$

etc., etc., the angles increasing downwards 15°, 45° 75° etc., and horizontally 15°, 30°, 45°, etc.

The following results are now obvious :—

$$(23)...r_1+r_7 = \frac{6}{\pi}[a_2 \sin 2 (\alpha_2+15^\circ)+ \frac{\sqrt{3}}{2} a_4 \sin 4 (\alpha_4+15^\circ) + \tfrac{2}{3} a_6 \sin 6 (\alpha_6 + 15^\circ)]$$

$$(24)...r_4+r_{10} = \frac{6}{\pi}[a_2 \sin 2 (\alpha_2+105^\circ)+ \frac{\sqrt{3}}{2} a_4 \sin 4 (\alpha_4+105^\circ) + \tfrac{2}{3} a_6 \sin 6 (\alpha_6 + 105^\circ)]$$

etc.

It is thus evident that by making suitable combinations the whole of the values a_1, a_2, $a_3 ... a_5$ and α_1, $\alpha_2 ... \alpha_5$ can be obtained, and if α_6 be assumed to be 0, then a_6 can also be obtained.

For example we have from (23) and (24)

$$(25)...r_1+r_4+r_7+r_{10} = \frac{6\sqrt{3}}{\pi} a_4 \sin 4 (\alpha_4+15^\circ) = L_1, \text{ say,}$$

similarly

$$(25a)...r_2+r_5+r_8+r_{11} = \frac{6\sqrt{3}}{\pi} a_4 \sin 4 (\alpha_4+45^\circ) = L_2$$

$$(25b)...r_3+r_6+r_9+r_{12} = \frac{6\sqrt{3}}{\pi} a_4 \sin 4 (\alpha_4+75^\circ) . = L_3.$$

These last three equations may be written

$$(26)...L_1 = \frac{6\sqrt{3}}{\pi} a_4 (\tfrac{1}{2} \sin 4\alpha_4 + \frac{\sqrt{3}}{2} \cos 4\alpha_4)$$

$$(26a)...L_2 = \frac{6\sqrt{3}}{\pi} a_4 . \sin 4\alpha_4$$

$$(26b)...L_3 = \frac{6\sqrt{3}}{\pi} a_4 (\tfrac{1}{2} \sin 4\alpha_4 - \frac{\sqrt{3}}{2} \cos 4\alpha_4)$$

from which we obtain

$$(27)\ldots \frac{L_1 + L_3}{L_1 - L_3} = \frac{\frac{6\sqrt{3}}{\pi}\, a_4 \sin 4\alpha_4}{\frac{6\sqrt{3}}{\pi}\, a_4 \cos 4\alpha_4 \,.\, \sqrt{3}.} = \frac{1}{\sqrt{3}} \tan 4\alpha_4$$

Having obtained α_4, we have

$$(28)\ldots a_4 = -\frac{\pi}{6\sqrt{3}}(r_2 + {}_5r + r_8 + r_{11}) \operatorname{cosec} 4\alpha_4.$$

To get the terms a_3 and α_3 we form the sum $r_1 + r_5 + r_9$ and the four possible similar ones. All the terms cancel each other except a_3 and a_6 and we thus obtain

$$(29)\ldots r_1 + r_5 + r_9 = \frac{6}{\pi}[a_3.\sqrt{2} \sin 3(\alpha_3 + 15^\circ) + a_6 \sin 6(\alpha_6 + 15^\circ)] = M_1, \text{ say}$$

$$(29a)\ldots r_2 + r_6 + r_{10} = \frac{6}{\pi}[a_3.\sqrt{2} \sin 3(\alpha_3 + 45^\circ) + a_6 \sin 6(\alpha_6 + 45^\circ)] = M_2$$

$$(29b)\ldots r_3 + r_7 + r_{11} = \frac{6}{\pi}[a_3.\sqrt{2} \sin 3(\alpha_3 + 75^\circ) + a_6 \sin 6(\alpha_6 + 75^\circ)] = M_3$$

$$(29c)\ldots r_4 + r_8 + r_{12} = \frac{6}{\pi}[a_3.\sqrt{2} \sin 3(\alpha_3 + 105^\circ) + a_6 \sin 6(\alpha_6 + 105^\circ)] = M_4$$

from which the following are derived, viz.,

$$(30)\ldots \frac{M_2 + M_3}{M_2 + M_1} = \frac{\frac{6}{\pi} a_3 \,.\, 2 \sin 3\alpha}{-\frac{6}{\pi} a_3 \,.\, 2 \cos 3\alpha_3} = -\tan 3\alpha_3$$

$$(31)\ldots \text{ and } a_3 = \frac{\pi}{12}[(r_2 + r_6 + r_{10}) + (r_1 + r_5 + r_9)] \sec 3\alpha_3$$

To obtain a_2 and α_2 we proceed as follows

$$(32)\ldots\ldots r_1 - r_4 + r_7 - r_{10} = \frac{6}{\pi}[2\, a_2 \sin 2(\alpha_2 + 15^\circ) + \tfrac{4}{3}\, a_6 \sin 6\,(\alpha_6 + 15^\circ)] = N_1 \text{ say,}$$

$$(32a)\ldots r_2 - r_5 + r_8 - r_{11} = \frac{6}{\pi}[2\, a_2 \sin 2(\alpha_2 + 45^\circ) + \tfrac{4}{3}\, a_6 \sin 6\,(\alpha_6 + 45^\circ)] = N_2;$$

$$(32b)\ldots r_3 - r_6 + r_9 - r_{12} = \frac{6}{\pi}[2\, a_2 \sin 2(\alpha_2 + 75^\circ) + \tfrac{4}{3}\, a_6 \sin 6\,(\alpha_6 + 75^\circ)] = N_3;$$

thus

$$(33)\ldots \frac{N_1 - N_3}{N_2 + 2N_2 + N_3} = \frac{\frac{6}{\pi}\, 2\, a_2 \,.\, \sqrt{3} \sin 2\alpha_2}{\frac{6}{r}\, 2\, a_2 \,.\, 3 \cos 2\alpha_2} = \frac{1}{\sqrt{3}} \tan 2\,\alpha_2$$

and α_2 being thus determined we can derive a_2 from the equation

$$(34)\ldots a_2 = \frac{\pi}{12\sqrt{3}}\Big[(r_1 - r_4 + r_7 - r_{10}) - (r_3 - r_6 + r_9 - r_{12})\Big] \operatorname{cosec} 2\alpha_2.$$

The values of a_1, α_1 and a_5, α_5 can be determined from one operation as follows:—

$$(35)\ \ldots r_1 - r_7 + r_3 - r_9 = R_1 = \frac{24\sqrt{3}}{\pi}\left[a_1 \sin 15^\circ \sin(\alpha_1 + 45^\circ) - \tfrac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 45^\circ)\right]$$

$$(35a)\ldots r_2 - r_8 + r_4 - r_{10} = R_2 = \frac{24\sqrt{3}}{\pi}\left[a_1 \sin 15^\circ \sin(\alpha_1 + 75^\circ) - \tfrac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 75^\circ)\right]$$

$$(35b)\ldots r_3 - r_9 + r_5 - r_{11} = R_3 = \frac{24\sqrt{3}}{\pi}\left[a_1 \sin 15^\circ \sin(\alpha_1 + 105^\circ) - \tfrac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 105^\circ)\right]$$

$$(35c)\ldots r_4 - r_{10} + r_6 - r_{12} = R_4 = \frac{24\sqrt{3}}{\pi}\left[a_1 \sin 15^\circ \sin(\alpha_1 + 135^\circ) - \tfrac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 135^\circ)\right]$$

From (35) and (35b) by addition

$$(36)\ldots\ R_1 + R_3 = \sqrt{3}\,\frac{24\sqrt{3}}{\pi}\Big[a_1 \sin 15^\circ \sin(\alpha_1 + 75^\circ) + \tfrac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 75^\circ)\Big]$$

from (35a) and (36) we have by addition and subtraction

$$(37)\ldots R_1 + R_3 + R_2\,.\,\sqrt{3} = \frac{144}{\pi}\, a_1 \sin 15^\circ \sin(\alpha_1 + 75^\circ)$$

$$(38)\ldots R_1 + R_3 - R_2\,.\,\sqrt{3} = \frac{144}{\pi}\,.\,\frac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 75^\circ)$$

Similarly from (35a), (35b), and (35c) we deduce

$$(39)\ldots\ R_2 + R\ \ + R_3\ \sqrt{3} = \frac{144}{\pi}\, a_1 \sin 15^\circ \sin(\alpha_1 + 105^\circ)$$

$$(40)\ldots\ R_2 + R_4 - R_3\ \sqrt{3} = \frac{144}{\pi}\,.\,\frac{1}{5}\, a_5 \sin 75^\circ \sin 5\,(\alpha_5 + 105^\circ)$$

and further

$$(41)\ldots\frac{R_2 + R_4 + R_3\ \sqrt{3}}{R_1 + R_3 + R_2\ \sqrt{3}} = \frac{\sin(\alpha_1 + 105^\circ)}{\sin(\alpha_1 + 75^\circ)} = \tfrac{3}{2} + \tfrac{1}{2}\cot(\alpha_1 + 75^\circ)$$

$$(42)\ldots\frac{R_2 + R_5 - R_3\ \sqrt{3}}{R_1 + R_3 - R_2\ \sqrt{3}} = \frac{\sin 5(\alpha_5 + 105^\circ)}{\sin 5\,(\alpha_5 + 75^\circ)} = -\tfrac{3}{2} + \tfrac{1}{2}\cot 5(\alpha_5 + 75^\circ)$$

which determine α_1 and α_5; when a_1 and a_5 can be at once deduced from (39) and (40). Lastly reverting to equations (29) and (29b) we see that

$$(43)\ldots(r_1+r_3+r_5+r_7+r_9+r_{11}) = (r_2+r_4+r_6+r_8+r_{10}+r_{12}) = \frac{12}{\pi} \cdot a_6 \cdot \cos 6\,\alpha_6$$

The data are not sufficient to enable us to determine both a_6 and α_6, but with data thus restricted we may assume $\alpha_6 = 0$ and we get at once the value of the amplitude a_6.

$$(44)\ldots a_6 = \frac{\pi}{12}\left[r_1+r_3+r_5+r_7+r_9+r_{11}\right]$$

The data at our disposal do not admit of solutions for terms higher than $6x$.

8. **Quinquennial periods.**—Quinquennial periods with yearly results only are fully represented by two periodic terms. Let Y_1, Y_2... be the yearly results and q_1, q_2... the yearly means, then

$$(45)\ldots Y_1 = \int_0^{\frac{2}{5}\pi}\left[a+b\sin(x+\beta)+c\sin 2(x+\gamma)\right]dx$$

and

$$(46)\ldots q_1 = Y_1\Big/\frac{2}{5}\pi = a+\frac{5}{2\pi}\Big\{b\cos\beta\,(1-\sin 18^\circ) + b\sin\beta\cos 18^\circ + \tfrac{1}{2}c\cos 2\gamma\,(1+\cos 36^\circ) + \tfrac{1}{2}c\sin 2\gamma\sin 36^\circ\Big\}$$

with four similar expressions indicated in the table hereunder.

If sin 18° be denoted by s_1; cos 18° by c_1; sin 36° by s_2 and cos 36° by c_2; the coefficients of $b\cos\beta$, $b\sin\beta$, $\frac{1}{2}c\cos 2\gamma$, and $\frac{1}{2}c\sin 2\gamma$ inside the bracket are given by the following scheme:—

Mean.	$b\cos\beta$	$b\sin\beta$	$\frac{1}{2}c\cos 2\gamma$	$\frac{1}{2}c\sin 2\gamma$
q_1	$1-s_1$	c_1	$1+c_2$	s_2
q_2	s_1+c_2	s_2-c_1	$-c_2-s_1$	$-s_2-c_1$
q_3	0	$-2s_2$	0	$2c_1$
q_4	$-s_1-c_2$	s_2-c_1	c_2+s_1	$-s_2-c_1$
q_5	$-1+s_1$	c_1	$-1-c_2$	s_2

Primarily we have,

$$(47)\ldots\ a = \frac{1}{5}(q_1 + q_2 + q_3 + q_4 + q_5).$$

Then denoting the differences of the means from this quantity by r_1, etc., we have

$$(48)\ldots\ q_1 - a = r_1;\ q_2 - a = r_2;\ \text{etc.}\ldots\ldots$$

then $r_3 = \frac{5}{2\pi}\left[-2\sin 36^\circ . b\sin\beta + 2\cos 18^\circ . \tfrac{1}{2} c\sin 2\gamma\right]$

and $\tfrac{1}{2}(r_1 + r_5) = \frac{5}{2\pi}(\cos 18^\circ . b\sin\beta + \sin 36^\circ . \tfrac{1}{2} c\sin 2\gamma)$

from which we obtain

$$(49)\ldots\ b\sin\beta = \frac{2\pi}{5} . \frac{\tfrac{1}{2}(r_1 + r_5) - r_3\sin 18^\circ}{2\sin 36^\circ \sin 18^\circ + \cos 18^\circ}$$

Further

$$r_1 - r_5 = \frac{5}{2\pi}\left\{2\,b\cos\beta\,(1 - \sin 18^\circ) + 2(1 + \cos 36^\circ)\tfrac{1}{2}\,c\cos 2\gamma\right\}$$

$$r_2 - r_4 = \frac{5}{2\pi}\left\{2\,b\cos\beta\,(\sin 18^\circ + \cos 36^\circ) - 2\,(\sin 18^\circ + \cos 36^\circ)\,\tfrac{1}{2}\,c\cos 2\gamma\right\}$$

Consequently

$$(50)\ldots\ \frac{2\pi}{5}\left\{\frac{r_1 - r_5}{1 + \cos 36^\circ} + \frac{r_2 - r_4}{\sin 18^\circ + \cos 36^\circ}\right\} =$$

$$2\,b\cos\beta\left[\frac{1 - \sin 18^\circ}{1 + \cos 36^\circ} + 1\right] = b\cos\beta\left(2 + \frac{1}{1 + \sin 18^\circ}\right),$$

which determines $b\cos\beta$ and then from (49) we can obtain $\tan\beta$ and thence b.

9. Tabulation of terms as far as 6x.—The table hereunder gives the trigonometrical coefficients for terms up to $6x$ inclusive. In order to find, as is necessary, the several terms in the expansion of r_n, r_n having the value assigned to it in § 7, viz.,

$$(51)\ldots\ r_n = \frac{6}{\pi}\left[-a_1\cos(x + \alpha_1) - \tfrac{1}{2}a_2\cos 2(x + \alpha_2) - \ldots\ldots\right]_{\frac{(n-1)\pi}{6}}^{\frac{n\pi}{6}}$$

We may note that, ignoring the multipliers $a_1, a_2 \ldots$ and the constant $\frac{6}{\pi}$, the co-efficients of $\cos\alpha_1$, $\sin\alpha_1$: $\cos\alpha_2$, $\sin\alpha_2$: $\cos\alpha_3$, $\sin\alpha_3\ldots$: are given as far as the term involving $6x$ in the table hereunder.

TABLE OF CO-EFFICIENTS FOR SUB-DIVISION OF TOTAL PERIOD INTO TWELVE PARTS.

In the following table $l = 1 + \frac{\sqrt{3}}{2}$; $m = 1 - \frac{\sqrt{3}}{2}$; $h = \frac{\sqrt{3}+1}{2}$; $k = \frac{\sqrt{3}-1}{2}$; and $p = \frac{\sqrt{3}}{8}$.

$\cos a_1$	$\sin a_1$	$\cos a_2$	$\sin a_2$	$\cos a_3$	$\sin a_3$	$\cos a_4$	$\sin a_4$	$\cos a_5$	$\sin a_5$	$\cos a_6$	$\sin a_6$
m	$\frac{1}{2}$	$\frac{1}{4}$	$2p$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{3}{8}$	p	$\frac{1}{5}l$	$\frac{1}{10}$	$\frac{1}{3}$	0
k	k	$\frac{1}{2}$	0	$\frac{1}{3}$	$-\frac{1}{3}$	0	$-2p$	$-\frac{1}{5}h$	$-\frac{1}{5}h$	$-\frac{1}{3}$	0
$\frac{1}{2}$	m	$\frac{1}{4}$	$-2p$	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{3}{8}$	p	$\frac{1}{10}$	$\frac{1}{5}l$	$\frac{1}{3}$	0
$\frac{1}{2}$	$-m$	$-\frac{1}{4}$	$-2p$	$-\frac{1}{3}$	$\frac{1}{3}$	$\frac{3}{8}$	p	$\frac{1}{10}$	$-\frac{1}{5}l$	$-\frac{1}{3}$	0
k	$-k$	$-\frac{1}{2}$	0	$\frac{1}{3}$	$\frac{1}{3}$	0	$-2p$	$-\frac{1}{5}h$	$\frac{1}{5}h$	$\frac{1}{3}$	0
m	$-\frac{1}{2}$	$-\frac{1}{4}$	$2p$	$\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{3}{8}$	p	$\frac{1}{5}l$	$-\frac{1}{10}$	$-\frac{1}{3}$	0
$-m$	$-\frac{1}{2}$	$\frac{1}{4}$	$2p$	$-\frac{1}{3}$	$-\frac{1}{3}$	$\frac{3}{8}$	p	$-\frac{1}{5}l$	$-\frac{1}{10}$	$\frac{1}{3}$	0
$-k$	$-k$	$\frac{1}{2}$	0	$-\frac{1}{3}$	$\frac{1}{3}$	0	$-2p$	$\frac{1}{5}h$	$\frac{1}{5}h$	$-\frac{1}{3}$	0
$-\frac{1}{2}$	$-m$	$\frac{1}{4}$	$-2p$	$\frac{1}{3}$	$\frac{1}{3}$	$-\frac{3}{8}$	p	$-\frac{1}{10}$	$-\frac{1}{5}l$	$\frac{1}{3}$	0
$-\frac{1}{2}$	m	$-\frac{1}{4}$	$-2p$	$\frac{1}{3}$	$-\frac{1}{3}$	$\frac{3}{8}$	p	$-\frac{1}{10}$	$\frac{1}{5}l$	$-\frac{1}{3}$	0
$-k$	k	$-\frac{1}{2}$	0	$-\frac{1}{3}$	$-\frac{1}{3}$	0	$-2p$	$\frac{1}{5}h$	$-\frac{1}{5}h$	$\frac{1}{3}$	0
$-m$	$\frac{1}{2}$	$-\frac{1}{4}$	$2p$	$-\frac{1}{3}$	$\frac{1}{3}$	$-\frac{3}{8}$	p	$-\frac{1}{5}l$	$\frac{1}{10}$	$-\frac{1}{3}$	0

10. Illustrations of applications of sine formulæ, marriage rates.—The application of the formulæ for the fluctuations may be illustrated by the following examples. The corrected mean of the marriage rates for the Commonwealth during the years 1907-9 is given in the following table:—

Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
7·52	8·01	7·65	10·40	6·99	7·87	7·23	7·05	7·87	7·30	7·36	8·13

If we group these in four-monthly periods, the three averages for these periods are 8·40 : 7·28 : 7·67 :

The frequency is $y = a + b \sin (x + \beta)$; and

$$a = \tfrac{1}{3}(8 \cdot 40 + 7 \cdot 28 + 7 \cdot 67) = 7 \cdot 78$$

From equation (12) we have $\dfrac{7 \cdot 78 - 7 \cdot 28}{8 \cdot 40 - 7 \cdot 67} = \dfrac{1}{\sqrt{3}} \tan \beta$

Therefore $\tan \beta = 1 \cdot 186$ and $\beta = 49^\circ\ 52'$.

Lastly $b = \dfrac{2\pi}{9}(8 \cdot 40 - 7 \cdot 67) \sec \beta$ from (13a)

$$= \cdot 698 \times \cdot 73 \times 1 \cdot 551 = \cdot 79.$$

Therefore the frequency is $y = 7 \cdot 78 + 0 \cdot 79 \sin (x + 49^\circ\ 52')$

A convenient and sufficiently approximate verification may be had by Simpson's rule: for over the first four-monthly period the values of x corresponding to the first, middle, and last ordinates are 0°, 60° and 120°, and the corresponding values of $\sin (x + 49^\circ\ 52')$ are

$\sin 49^\circ\ 52' = \cdot 7645$; $\sin 109^\circ\ 52' = \cdot 9405$; $\sin 169^\circ\ 52' = \cdot 1759$

also $\dfrac{\cdot 7645 + 4 \times \cdot 9405 + \cdot 1759}{6} = \dfrac{4 \cdot 7024}{6} = \cdot 7837$

and $7 \cdot 78 + (\cdot 79 \times \cdot 7837) = 7 \cdot 78 + \cdot 62 = 8 \cdot 40$.

For the case of quarterly results which occur more frequently in practice than four-monthly results, the quarterly averages corresponding to the monthly averages given in the last example are 7·73 : 8·42 : 7·38 : 7·60.

As the sum of the first and third quarters' averages is not equal to the sum of the second and fourth, we must use equations (18) and (19); and we thus get

$$a = \tfrac{1}{4}(y'_1 + y'_2 + y'_3 + y'_4) = 7{\cdot}78$$

$$\tan\beta = \frac{y'_1 - y'_2 - y'_3 + y'_4}{y'_1 + y'_2 - y'_3 - y'_4} = \frac{-47}{117} = -0{\cdot}401$$

Therefore $\beta = 158^\circ\ 7'$.

$$\text{Also } b = \frac{\pi}{8}(y'_1 + y'_2 - y'_3 - y'_4)\sec\beta$$

$$= {\cdot}3927 \times 1{\cdot}17 \times -1{\cdot}077 = -0{\cdot}49 \text{ about}$$

$$\text{and } \cos 2\gamma = \frac{y'_1 - y'_2 + y'_3 - y'_4}{y'_1 - y'_2 - y'_3 + y'_4} \sin\beta$$

$$= \frac{-{\cdot}91}{-{\cdot}47} \times {\cdot}3727 = 0{\cdot}7216 \text{ about. Hence } 2\gamma = 43^\circ\ 50' \text{ nearly}$$

$$\text{and frequency is } = 7{\cdot}78 - 0{\cdot}49\sin(x + 158^\circ\ 7') - 0{\cdot}49\sin 2(x + 21^\circ\ 55').$$

Marriage fluctuation is of course profoundly affected by the position of Easter in the year.

11. Curves of temperature and suicide.—The application of the formula for monthly fluctuations may be illustrated by the following example. The monthly means of the mean maximum and mean minimum temperatures for the different capital cities of the Commonwealth were taken from volume 3 of the Commonwealth Official Year Book. The numbers so obtained were corrected for unequal lengths of months as explained in section 3 and then weighted by multiplying by the populations of their respective States. The numbers so obtained were added for the different months and divided by the population of the Commonwealth. The resulting numbers, which may be taken as approximately representing the monthly mean temperatures prevailing for the great mass of people in the Commonwealth. are given in the following table :—

Month	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Temp. Fah.	71·1	70·7	68·4	63·5	57·7	53·6	51·8	54·1	57·7	61·8	65·6	69·0

Turning now to equation (22) we have

$$a_0 = \frac{1}{12}(71{\cdot}1 + 70{\cdot}7 + \ldots\ldots\ldots\ldots + 69{\cdot}0) = 62{\cdot}08$$

$r_1 = 71{\cdot}1 - 62{\cdot}08 = 9{\cdot}02$, and the different values of r are given in the following table:—

r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	r_{12}
+9·02	+8·62	+6·32	+1·42	−4 38	−8·48	−10·28	−7·98	−4·38	−0·28	+3·42	+6·92

We can now make use of the equations already deduced to determine the values of a_1, $\alpha_1 : a_2$, α_2 : etc. From equation (41) we obtain at once

$$\cot(\alpha_1 + 75^\circ) + \surd 3 = 2.\frac{R_2 + R_4 + R_3\surd 3}{R_1 + R_3 + R_2\surd 3} = \frac{2[4{\cdot}60 + 2{\cdot}80\surd 3]}{32{\cdot}80 + 31{\cdot}696} = 0{\cdot}293$$

Hence $\cot(\alpha_1 + 75^\circ) = -1{\cdot}439$; thus $\alpha_1 = 70^\circ\ 12'$.

Then from (37) we have

$$a_1 = (R_2 + R_4 + R_3\surd 3)\frac{\pi}{144}\operatorname{cosec} 15^\circ \operatorname{cosec}(\alpha_1 + 75^\circ)$$

$$= 9{\cdot}450 \times {\cdot}0218 \times 3{\cdot}864 \times 11{\cdot}951 = 9{\cdot}513.$$

From (33) and (34) $a_2 = -1{\cdot}183$; $\alpha_2 = 65^\circ\ 31'$

From (30) and (31) $a_3 = +0{\cdot}155$; $\alpha_3 = 26^\circ\ 6'$

From (27) and (28) $a_4 = +0{\cdot}099$; $\alpha_4 = 34^\circ\ 30'$

From (40) and (42) $a_5 = -0{\cdot}046$; $\alpha_6 = 4^\circ\ 36'$

Lastly from (29), (29b) and (44), we have

$$r_1 + r_3 + r_5 + r_7 + r_9 + r_{11} = \frac{12}{\pi} a_6 \cos \alpha_6$$

and if we assume that $\alpha_6 = 0$; then $a_6 = -0{\cdot}047$.

The frequency is thus

$$= 62{\cdot}08 + 9{\cdot}513 \sin(x + 70^\circ\ 12') - 1{\cdot}183 \sin 2(x + 65^\circ 31')$$
$$+ 0{\cdot}155 \sin 3(x + 26^\circ\ 6') + 0{\cdot}099 \sin 4(x + 34^\circ\ 30')$$
$$- 0{\cdot}046 \sin 5(x + 4^\circ 36') - 0{\cdot}047 \sin 6x$$

which will give the group means from which they were derived, as may be readily verified.

The figures given in (4) representing daily number of persons committing suicide in the Commonwealth during the decennium 1900-09, may be taken by way of further illustration of the analysis into periodic series, and by way also of indicating the time-relation of the two series (see also § 13 hereafter).

The average population during that period was 3,995,800, hence the average daily number of suicides per million of inhabitants is obtained by dividing the figures in (4) by 3·9958. The results are shewn in the following table :—

Daily suicides per million inhabitants.—Equalised months.

Jan.	Feb.	Mar.	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
·3589	·3714	·3349	·3359	·3096	·2838	·3008	·3256	·3071	·3531	·3233	·3451

By addition, as before,

$$a_0 = \frac{1}{12}[\cdot 3589 + \ldots\ldots \cdot 3451] = \cdot 3291$$

The determination of the constants is effected as in the case of the temperature curve. The resulting frequency is

$$= 0\cdot 3291 + 0\cdot 0354 \sin(x + 72^\circ\ 4') - 0\cdot 0117 \sin 2(x + 73^\circ\ 22') + 0\cdot 0031 \sin 3(x + 12^\circ\ 49') - 0\cdot 0142 \sin 4(x + 40^\circ\ 52') - 0\cdot 0131 \sin 5(x + 0^\circ\ 16') + \cdot 0104 \sin 6x.$$

12. Reduction of epochal angle to days—It is sometimes desirable to reduce the epochal angles of an annual series to days, particularly in the calculation of "lag." See § 13.

Since an angle of 360° corresponds to 365·2422 days, the following approximate relation holds between D the number of days and g the epochal angle expressed in degrees

$$(52)\ldots\ D = g\left(1 + \frac{1}{100} + \frac{1}{200} - \frac{1}{2000} + \frac{1}{20000} + \frac{1}{100000}\right)$$

which gives 365·2416.

As many terms can be used as are necessary, and the result can frequently be written down by inspection. As a rule it is sufficient to stop at the term $\frac{1}{200}$.

Another convenient relation between D and g is

$$(52a)\ldots\ D = g\left(1 + \frac{1}{70} + \frac{2}{7000} - \frac{1}{100000}\right)$$

which gives 365·2421, and in most cases it would be sufficient to stop at the term $\frac{1}{70}$.

13. Determination of "lag" in correlated phenomena.—Given two periodic series of the same periodicity, viz., (53)... $y_m = \sin m\,(x + \alpha)$: (ii) $y'_m = \sin m\,(x + \beta)$,

then since the values of each are 0 for the value $x = -\alpha$ and $x = -\beta$ respectively, we may say that the "lag" of the second behind the first is given by

(54)... $\lambda = \alpha - (\beta + 2n\pi)$

In general we may assume that $n = 0$, in the term $2n\pi$, that is to say, in the majority of cases practically arising, the lag will be less than a whole period.

Hence if we have reasonable grounds, apart from mathematical considerations, to look on them as causally related, then the second may be regarded as an effect of the first brought about after the lapse of time λ. Thus the lag may be determined term by term when "a priori" we know the length of the period, and we should thus have for the lag of the "*m*th" term

(55)... $\lambda_m = \alpha_m - \alpha'_m$

in which the accented letter is the epochal angle corresponding to the non-accented letter.

But the resolving of a periodic oscillation under equation (1) is purely arbitrary, the periods being merely assumed instead of being known "a priori." In such a case we may with some propriety regard the whole group of the second series of periodic terms as having what may be called a "group lag" in respect of the first series. It is obvious in the first place that the "group lag" is a function of the epochal angles. Also, since the importance of any term varies with its amplitude, the influence of any epochal angle on the group lag must further be regarded as a function of the amplitude factor. If then we suppose that the weight of each epochal angle enters into the result directly as the amplitude of the term, we shall have approximately for what may be called the mean epochal angle,

(56)... $$\alpha_0 = \frac{a_1\alpha_1 + a_2\alpha_2 + \ldots}{a_1 + a_2 + \ldots} = \frac{\Sigma a_m(\alpha_m)}{\Sigma a_m}$$

and the general lag will be

(57)... $\lambda_0 = \alpha_0 - \alpha'_0$.

This expression which is empirical, however, loses significance as the similarity of the two curves disappears, and in any case can be regarded only as of the nature of a rough indication of the general time relation between them.

14. Analysis of sine and cosine curves.—When a curve is of the type of a simple sine curve, differing only in respect of absence of symmetry, it may be represented by

(57a)... $y = A + B \sin x + C \cos x$

which is identical with

(57b) $y = A + b \sin (x + \beta) + c \cos (x + \gamma)$

since it is easily shewn that

(58)... $B = b \cos \beta - c \sin \gamma$; and

(58a)... $C = b \sin \beta + c \cos \gamma$.

In all cases we have

(59)... $A = \frac{1}{n} \Sigma_1^n y_k$

If we put as before $r_k = y_k - A$, we shall have for quadrimestral division

(60)... $B = \frac{2\pi(r_1 - r_3)}{9}$; $C = -\frac{2\pi r_2}{3\sqrt{3}}$;

for quarterly division

(61)... $B = \frac{\pi}{8}(r_1 + r_2 - r_3 - r_4)$; $C = \frac{\pi}{8}(r_1 - r_2 - r_3 + r_4)$

and for division into five parts

(62)... $B = \frac{4\pi}{25 + 5\sqrt{5}}(r_1 + r_2 - r_4 - r_5)$; $C = \frac{2\sqrt{2}\,\pi r_3}{5\sqrt{(5 - \sqrt{5})}}$

the coefficients of which may also be written

$$\pi / \{5(1 + \cos 36^\circ)\} \text{ and } 4\pi/(5 \sin 36^\circ).$$

Where the form in (57a) satisfactorily represents the data, it is occasionally necessary to determine the point where the curve has a maximum or minimum value or equals the average value (A).

The points where $y = A$ are given by

$$B \sin \theta + C \cos \theta = 0.$$

θ being the value of x for $y = A$, that is:—

(63)... $\tan\theta = -\dfrac{C}{B}$.

and the maximum and minimum values of x, μ say, are given by

$$dy/dx = B\cos\mu - C\sin\mu = 0, \qquad \text{that is}$$

(64)... $\tan\mu = \dfrac{B}{C} = -\cot\theta$.

In comparing two curves of this type, we must have recourse to such corresponding phases as θ and μ.

The value of the ordinate at this point, viz. the maximum or minimum is

(65)... $y = A + \sqrt{B^2 + C^2}$.

In other cases than that referred to, the determination involves the solution of an equation of the fifth degree, and need not be considered.

Where there are more divisions than five it will in general be desirable to represent the frequency by an equation of the form

(66)... $y = a + b\sin x + c\cos x + d\sin 2x + e\cos 2x$.

The integral of this is

(66a)... $\int y\,dx = ax - b\cos x + c\sin x - \frac{1}{2}d\cos 2x + \frac{1}{2}e\sin 2x$

and if it be taken between the limits 0 to $\frac{\pi}{6}$; $\frac{\pi}{6}$ to $\frac{\pi}{3}$; etc... and if y_1, y_2...denote the monthly means we have

$$y_1 = a + \frac{6}{\pi}\Big\{ - b(\cos 30^\circ - \cos 0^\circ) + c(\sin 30^\circ - \sin 0^\circ)$$
$$- \tfrac{1}{2}d(\cos 60^\circ - \cos 0^\circ) + \tfrac{1}{2}e(\sin 60^\circ - \sin 0^\circ)\Big\}.$$

As before denoting $y_k - a$ by r_k...we get a series of equations of which the first is

$$\frac{\pi}{6}r_1 = b(\cos 0^\circ - \cos 30^\circ) + c(\sin 30^\circ - \sin 0^\circ)$$
$$+ \tfrac{1}{2}d(\cos 0^\circ - \cos 60^\circ) + \tfrac{1}{2}e(\sin 60^\circ - \sin 0^\circ)$$

Denoting $1 - \dfrac{\sqrt{3}}{2}$ by m: $\dfrac{\sqrt{3}-1}{2}$ by l: and $\dfrac{\sqrt{3}}{2}$ by k, the equations become

$$\frac{\pi}{6}r_1 = mb + \tfrac{1}{2}c + d + \tfrac{1}{2}ke,$$

the coefficients of b, c, d, e in the successive terms r_1, r_2, etc., being represented by the following scheme

r	b	c	d	e	r	b	c	d	e
1	$+m$	$+\frac{1}{2}$	$+\frac{1}{4}$	$+\frac{1}{2}k$	7	$-m$	$-\frac{1}{2}$	$\frac{1}{4}$	$+\frac{1}{2}k$
2	$+l$	$+l$	$+\frac{1}{2}$	0	8	$-l$	$-l$	$\frac{1}{2}$	0
3	$+\frac{1}{2}$	$+m$	$+\frac{1}{4}$	$-\frac{1}{2}k$	9	$-\frac{1}{2}$	$-m$	$\frac{1}{4}$	$-\frac{1}{2}k$
4	$+\frac{1}{2}$	$-m$	$-\frac{1}{4}$	$-\frac{1}{2}k$	10	$-\frac{1}{2}$	$+m$	$-\frac{1}{4}$	$-\frac{1}{2}k$
5	$+l$	$-l$	$-\frac{1}{2}$	0	11	$-l$	$+l$	$-\frac{1}{2}$	0
6	$+m$	$-\frac{1}{2}$	$-\frac{1}{4}$	$+\frac{1}{2}k$	12	$-m$	$+\frac{1}{2}$	$-\frac{1}{4}$	$+\frac{1}{2}k$

From these necessary combinations may be obtained for determining the constants b, c, etc.

The most probable values of these constants may be obtained from the whole of the equations by making use of the method of least squares.

Multiplying the equations in turn by m, l, $\frac{1}{2}$, etc., (*i.e.*, by the different co-efficients of b) we obtain, since the sum of the co-efficients of c, d, e all total to zero,

$$(67)\ldots \frac{\pi}{6}\left\{mr_1 + lr_2 + \tfrac{1}{2}r_3 + \ldots\ldots\right\} = 6\,(2-\sqrt{3})\,b.$$

Similarly the following equations can be deduced

$$(68)\ldots \frac{\pi}{6}\left\{\tfrac{1}{2}r_1 + lr_2 + \ldots\ldots\right\} = 6\,(2-\sqrt{3})\,c,$$

$$(69)\ldots \frac{\pi}{6}\left\{\tfrac{1}{4}r_1 + \tfrac{1}{2}r_2 + \ldots\ldots\right\} = \frac{3}{2}\,d,$$

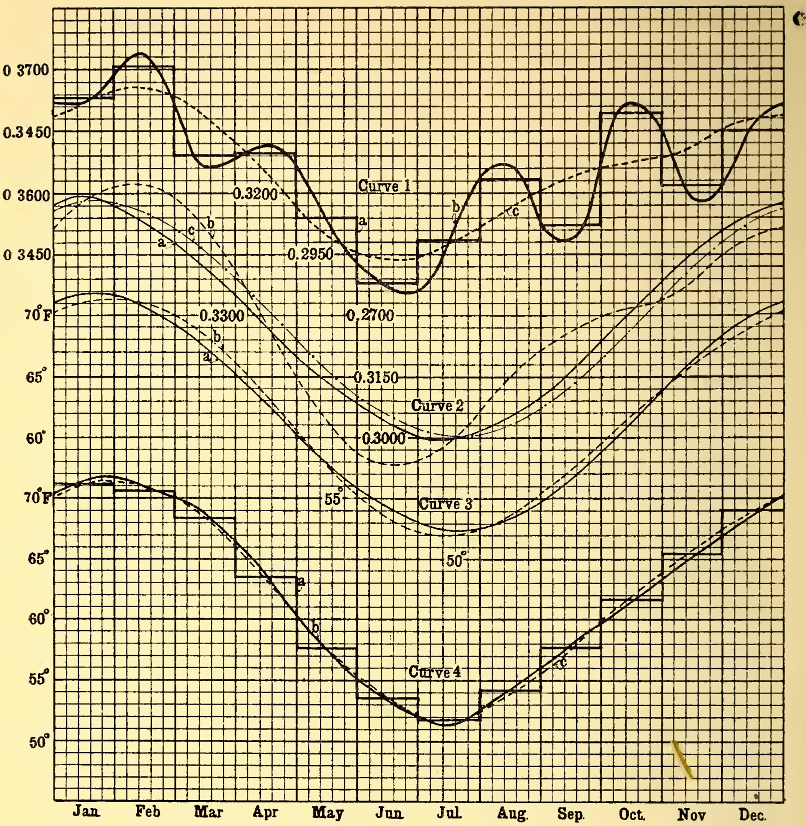
and

$$70)\ldots \frac{\pi}{6}\left\{\tfrac{1}{2}kr_1 + 0 + \ldots\ldots\right\} = \frac{3}{2}\,e.$$

which give the values of b, c, d, and e.

In the case of the "temperature curve" already examined, see § 11, $r_1 = 9{\cdot}02$: $r_2 = 8{\cdot}62$, etc., and we derive the values $a = 62{\cdot}08$; $b = 3{\cdot}227$; $c = 8{\cdot}965$; $d = 0{\cdot}337$; $e = -\ 0{\cdot}890$.

The second (small) co-efficients d and e denote merely small oscillations about the main curve defined by the first pair of co-efficients (large) viz., b and c.



For the suicide curve the co-efficients are :—

= 0·3291 ; = 0·0054 ; = 0·0285 ; = 0·0097; = 0·0064.

It will be seen that the general trend is fairly well represented by the sine and cosine in x only.

In the diagram the different curves shew the following:—

CURVE 1—*Suicides.*

(a) The group results are shewn by firm rectangular lines.

(b) The complete curve in sin x to sin $6x$ giving these group results is shewn by firm curved lines.

(c) The curve given by sine and cosine of x and $2x$ by dotted curved lines.

The ordinates to the curve denote the number per diem per million committing suicide in the Commonwealth of Australia.

CURVE 2—*Suicides.*

(a) The curve shewn by firm lines denotes the solution in terms of sine and cosine x only.

(b) The curve in dotted lines denotes similarly the solution in terms of sine and cosine $2x$ as well as x. and shews the effect of the introduction of this second series. This is the same as the dotted line in curve 1, (c). The ordinates denote the number per diem per million committing suicide in the Commonwealth of Australia, but are plotted to a larger scale than in curve 1.

(c) The curve in broken lines with dots is the suicide curve, as empirically deduced by formula (71) § 16 hereinafter, from the temperature curve 3a.

CURVE 3—*Temperature.*

(a) The curve in firm lines denotes the solution in terms of sine and cosine x only.

(b) The curve in dotted lines similarly denotes the solution in terms also of sine and cosine $2x$, as well as x.

CURVE 4—*Temperature.*

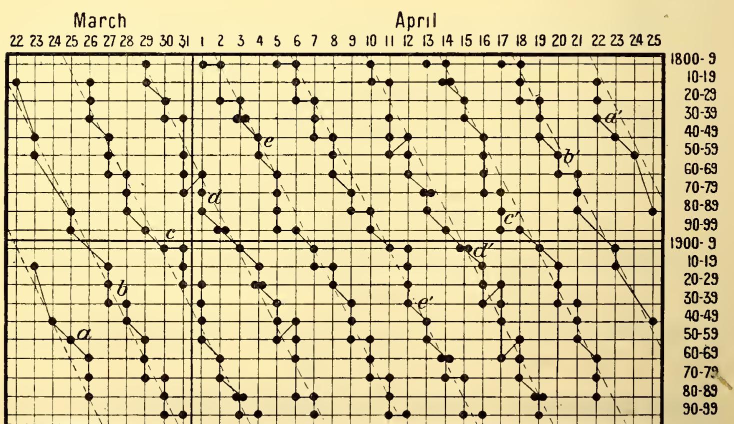
(a) The monthly means shewn by firm rectangular lines are obtained from the monthly means of the maximum and minimum temperatures of the capital cities of the States taken over a long series of years, weighted according to the population of the States. It may be considered as the curve of temperature affecting the population of the Commonwealth as a whole.

(b) The firm line shews the complete curve in sin x to sin $6x$ giving the group results.

(c) The dotted line shews the curve given by the terms in sine and cosine of x and $2x$, only.

15. Periodicity affected by movable feasts.—The periodicity of marriage and of migration etc., is affected by the "movable feast" Easter. As ecclesiastically defined Easter day is the first Sunday after the 14th day of the paschal "Calendar Moon," a fictitious ecclesiastical moon, which is from one to three days later than the real moon (See De Morgan's article in the Companion to the Almanac 1845). The average position of Easter for the century 1800 to 1899 is April 8·55 days, and for the century 1900 to 1999 is April 8·89 days, or say for the whole period of 200 years April 8·72 days. In the illustrative figure herewith, the whole of the Easters in each decade are shewn on a single line for the years 1800 to 1999 inclusive. It will be seen that an inspection of the diagram will disclose the fact that the points lie approximately on a series of 10 slanting lines, four days apart, these lines progressing at the rate of one half day per decade, and further that they are inversely symmetrical. For lines *a*, *b*, *c*, and *e* and *a′*, *b′*, *c′*, and *e′* the symmetry is perfect; for lines *d* and *d′* however the symmetry is not absolutely perfect. It is evident that no means derived from two decades nor from periods of 19 years, nor from centuries are exactly comparable.

Position of Easter.



Since the tropical year = 365·2422 days and the synodic lunar month = 29·530588 days, the Metonic cycle, *19 tropical years is 6939·6018 days, and 235 complete lunations equal 6939·6882 days, differing only ·0864 day from the nineteen years.

The following table exhibits the peculiarities for successive decades.

*Mean Position of Easter.**

1800.					1900.				
Decade.	Mean.	Easters in March.	Mean of March Easters	Mean of April Easters.	Decade.	Mean.	Easters in March.	Mean of March Easters	Mean of April Easters.
	April					April			
0–9	9·46	1	29	9·56	0–9	10·56	2	30·5	13·12
10–19	8·16	3	25·67	13·57	10–19	8·36	3	27	12·86
20–29	8·86	2	28	11·50	20–29	8·06	2	29	10·25
30–39	7·86	3	29	11·43	30–39	9·66	2	27·5	12·62
40–49	9·06	2	25	12·50	40–49	8·96	2	26	12·12
50–59	8·56	3	27	13·57	50–59	7·56	2	27	10·38
60–69	7·96	3	28·67	11·86	60–69	9·66	2	27·5	12·88
70–79	9·36	2	29·5	11·88	70–79	8·66	3	28·33	13·14
90–89	9·46	2	25·5	12·62	80–89	8·66	2	28	11·25
90–99	6·76	2	27	9·25	90–99	8·76	2	30·5	10·88
Means	8·55	2·3	27·48	11·70	Means	8·89	2·2	28·09	11·94

* The complete cycle of Easter restoring both the day of the week and of the month is 4 × 7 × 19 = 532 years, the "Dionysian" or "Great Paschal" period.

To find the position of Easter day (Sunday) we have for any years subsequent to 1582

- Y denoting the date (year of the Christian era)
- N denoting the golden number
- E denoting the epact, or moon's age at the beginning of the year (expressed positively)
- C denoting the number of centuries in the date
- P denoting the number of days from the 21st March to the 15th day of the "paschal moon"
- L denoting the number of the dominical letter of the year

To obtain a normal periodic fluctuation it would be preferable, were it practicable, to combine the results, each for a series of years such as would give Easter an identical distribution. In the period such a series is, however, impracticably long. Hence in the case of marriage, migration etc., we must consider the actual effect on the periodic fluctuation studied. The effect of Easter is to reduce the

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l denoting the letter belonging to the day on which the 15th of the "paschal moon" falls

p denoting the *number of direction* or number of days from 21st March to Easter day

then a subscript r following brackets denoting that the *remainder* only is to be taken, and a subscript w in a similar position denoting that only the whole number in the quotient is to be taken, we shall have

$$N = \left(\frac{Y+1}{19}\right)_r ; \quad a = \left(\frac{C-17}{25}\right)_w$$

$$E = \left(\frac{N + 10\,(N-1)}{30}\right)_r \quad - (C-16) + \left(\frac{C-16}{4}\right)_w + \left(\frac{C-15-a}{3}\right)_w$$

$$L = 7m + 6 + \left\{ -Y - \left(\frac{Y}{4}\right)_w + (C-16) - \left(\frac{C-16}{4}\right)_w \right\}$$

in which m is an integer such as will give a product not more than 6 greater than the number following in the brackets.

When $E < 24 : \begin{cases} P = 24 - E \\ l = \left(\frac{27-E}{7}\right)_r \end{cases}$ $\qquad E > 24 : \begin{cases} P = 54 - E \\ l = \left(\frac{57-E}{7}\right)_r \end{cases}$

$$p = P + L - l.$$

Hence the number of days from the beginning of the year is:—

$81 + p$ for leap years, and $80 + p$ for common years :

common years being such as are not exactly divisible by 4, or being divisible by 4 are also divisible by 100 but not by 400; excepting that years divisible by 4000 are also common years. Leap years are years exactly divisible by 4, unless divisible also by 100 and not by 400; and further if divisible by 4000 they are common years.

number of marriages in the Lent period (6 weeks) preceding, and to augment them in the preceding and following periods.

It may be noted that for the fluctuations of annual period in the marriage frequency, the great length of the Lent period, viz., 6 weeks, has the effect of throwing the increase of frequency as far back as February. The migration frequency is frequently thrown back into March. Thus as is evident from the preceding table and the diagram, decennial means will clearly be nearly but not exactly comparable. The data for a thorough study of periodic fluctuation would in these cases have to be weekly groups.

16. Connection between periodic series.—Correlation between statistical results may be of two kinds, viz., (*a*) rational, and (*b*) empirical. In the curves 2 and 3 in the figure, where the fluctuations of suicide and temperature are analysed by the expression in sin x and cos x only (which in the nature of the case probably really represents the general trend) the striking similarity is evident. That suicide is accentuated in the summer and falls off in winter, is thus indicated, and in the Northern Hemisphere the same holds, that is to say the maximum period differs about six months from that in the Southern Hemisphere. On comparing the two curves in sin x and cos x only, we find the following results hold

Temperature curve	max.	71·61	at	19° 48′
	min.	52·55	difference	19°·06
Suicide curve	max.	0·3581	at	10° 44′
	min.	0·3001	difference	0·0580

Since the mean for the suicide curve is 0·3291 and of the temperature curve is 62·08°, and since moreover 0·0580/19·06 = 0·00304 we have the suicide curve almost exactly produced from the temperature curve by the formula

$$(71)\ldots\ q = 0{\cdot}3291 + 0{\cdot}00304\ (t - 62{\cdot}08^\circ)$$

in which q is the frequency of suicide per diem per million in the Australian Commonwealth and t is the temperature in Fahrenheit degrees. This curve is plotted as curve 2 (c) and it will be seen from the diagram, that if it be moved about 9 or 10 days to the left ($19° 48' - 10° 44' = 9° 04'$) it is practically coincident with the temperature curve. This identity is purely empirical. The discussion as to whether this relation can be rationalised is really an extra-mathematical one, and is outside the scope of the present paper.

17. Conclusion.—The formulæ given for deducing the constants of the several equations will enable periodic series to be conveniently applied to the discussion of appropriate statistical results, without involving a prohibitive amount of labour, and will yield expressions that reproduce the data exactly, while giving instantaneous values throughout their whole range. The illustrations are intended only to exhibit the mode of application of these formulæ.

ECHINORHYNCHUS POMATOSTOMI, (N.SP.) A SUBCUTANEOUS PARASITE OF AUSTRALIAN BIRDS.

By T. HARVEY JOHNSTON, M.A., D.Sc., and J. BURTON CLELAND, M.D., Ch.M.

(From the Government Bureau of Microbiology, Sydney.)

[*Read before the Royal Society of N. S. Wales, July 5, 1911.*]

IN three species of *Pomatorhinus* and in three other Australian birds which were associated in each case with members of this genus, a number of larval individuals of a species of *Echinorhynchus* was obtained by one of us from three different portions of Australia, each separated from the other by a distance of many hundred miles. As the occurrence of larvæ of this genus in vertebrates is rare, and is so far unrecorded for Australian Birds, it seemed to us advisable to describe this parasite as fully as the material will allow. From its association in each case with members of the genus *Pomatostomus (Pomatorhinus)*, we have given it the specific name of *E. pomatostomi.* The following information as to the discovery of these parasites may be interesting more especially to those ornithologists who have facilities for examining fresh carcases of Australian birds.

In the latter part of the year 1907 one of us had an opportunity of securing some birds midway between Port Hedland and Marble Bar in North West Australia. On one occasion *Pomatostomus rubeculus*, Gould, and *Climacteris wellsi*, Grant, were shot together in the same patch of scrub on the banks of a dry water-course (the Shaw River), together with a few other birds. On preparing the skins later, a number of small white bodies like very small grains of rice were found embedded in the subcutaneous tissue of the necks of these two birds. These were easily shelled out and then proved to be small larval worms. In May, 1910, about twelve miles south of Adelaide *Pomatostomus superciliosus*, Vig. and Horsf., and *Aphelocephala leucopsis*, Gould, were shot near the same patch of scrub together with several other small birds and a hawk. In the *Pomatostomus* and *Aphelocephala* were a number of larval worms similar to those in the North Western birds, distributed in the subcutaneous tissues of the neck and thorax, sometimes being more deeply placed between the muscles especially those of the chest or even within the muscles. In November, 1910, two specimens of *Pomatostomus frivolus*, Lath. (syn. *P. temporalis*, Vig. and Horsf.) together with several other birds were shot near Collarenebri in the north of New South Wales. Both the *Pomatostomi* showed scattered larval worms in the same situations as in the birds obtained near Adelaide. The country here was open black soil plains with a few scattered gum trees. We have recently received from Mr. J. W. Mellor through Mr. L. Harrison, a number of similar parasites from the subcutaneous tisssue of *Hylacola pyrrhopygia*, Vig. Horsf., shot near Adelaide.

It will be seen from the foregoing, that this small parasite is widely distributed geographically in Australia, having been obtained at three places sundered by many hundred miles from each other. Lines joining these three points would form roughly a triangle with its apex in Southern Australia, one angle in North Central New South Wales, and the other angle in North West Australia. The types of country of these three localities are absolutely distinct from each other, so that no particular type of country can have much influence on the development of the parasites. It is a significant fact that in each of the three localities birds of the genus *Pomatostomus* were infested. Several hundred birds have been examined by us from various parts of Australia, but the parasites have not been detected in any of these save in those above mentioned. It therefore seems highly probable that the ordinary host for the larvæ consists of birds of the genus *Pomatostomus*, and that these have been the dispersing agents throughout Australia, but that occasionally other small birds such as *Climacteris*, *Hylacola*, and *Aphelocephala*, living in the neighbourhood of *Pomatostomi* can also harbour the larvæ. It may be presumed however that the infestation of these other birds is more or less accidental, and that from their habits or the nature of their food, they do not so readily acquire the ova as does *Pomatostomus*. If many species of Australian birds acted as the ordinary host of the larvæ we would have expected to find more instances of invasion in other species, and also cases of birds being infected in neighbourhoods where *Pomatostomus* was not present. It will be interesting to see whether species closely allied to this genus can also act as distributing agents. If any such birds are found to act in this way it would support their position as relatives of the genus *Pomatostomus*. It is possible that the adult worm may be an inhabitant of the intestine of some birds of prey, and that in this way the life cycle is completed.

The parasites usually resemble small maggots, about 3·33 mm. long, with a maximum breadth of about 1·26 mm., the surface of the body being transversely wrinkled. The posterior end is bluntly rounded, the anterior extremity being truncate and rather wider. Retracted within the latter lies the rostellum. The lemnisci are nearly 1·25 mm. in length. No other internal structures are recognisable. In one specimen (taken from *P. superciliosus*) the rostellum is everted, the worm being fully twice as long as the form usually met with, reaching 7·4 mm., but its maximum width is only 0·93 mm. In this specimen the cuticle is quite smooth. There is a gradual tapering towards each end, the posterior end being rounded off, while the anterior terminates in the prominent rostellum. The latter is 0·74 mm. in length (measuring the whole eversible portion), and 0·55 mm. in width. The hook-bearing part is practically spherical, a somewhat narrower neck succeeding it. The hooks appear to be arranged in eight transverse rows, there being about forty altogether. Those situated anteriorly are much more powerful than those located further back. Each is surrounded by a kind of collar which projects prominently around the basal region. These hooks, which may reach 0·205 mm. in length, bear a marked resemblance in general shape to those of the large Taeniae. The dorsal root is short but thick and rounded, the ventral root being relatively massive. The claw or blade which is the only portion seen in ordinary preparations, is also prominent. On its inner side near the tip, there is a distinct notch or barb which no doubt adds considerably to the adhesive power of the hook.

The type slide of *Echinorhynchus pomatostomi* (from *Pomatostomus superciliosus*) will be deposited in the Australian Museum, Sydney.

Explanation of Figure.

Echinorhynchus pomatostomi.

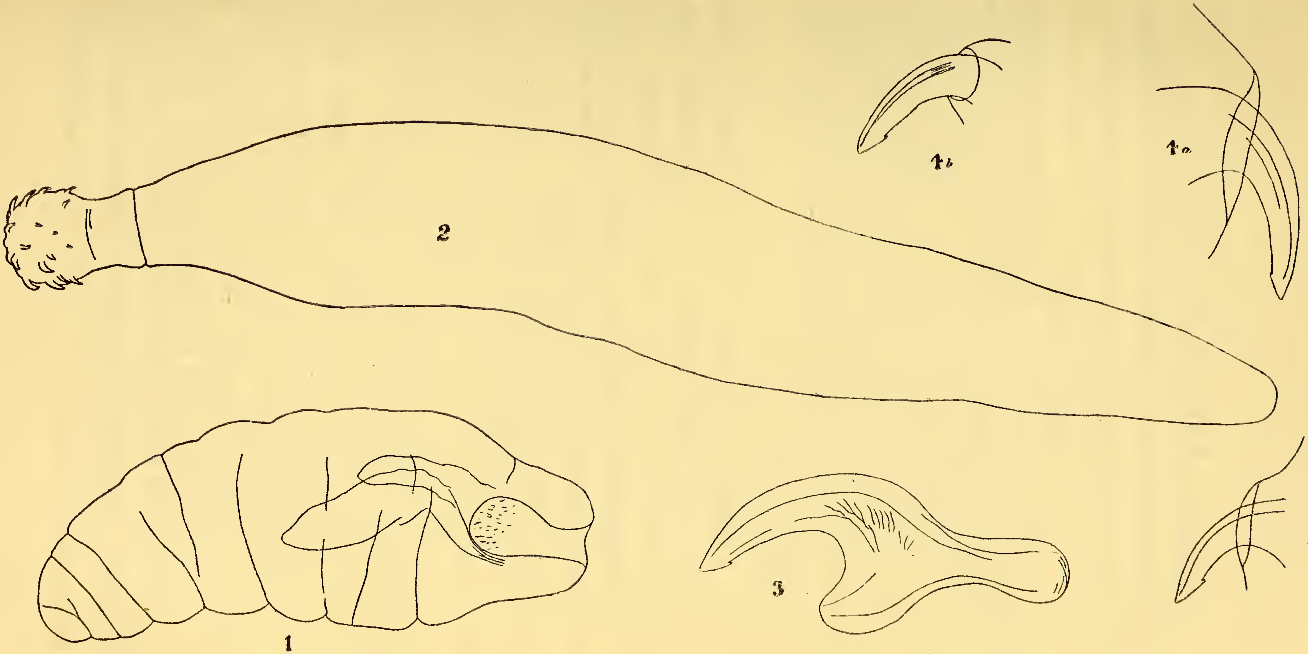
Fig. 1. Usual form with rostellum retracted, from *Pomatostomus frivolus*.

Fig. 2. Specimen with rostellum protracted, from *P. rubeculus.*

Fig. 3. Hook from rostellum, from *P. rubeculus.*

Fig. 4. Portions of hooks from (*a*) Anterior series; (*b*) middle series; (*c*) posterior series, drawn to same scale—showing collar—from *P. superciliosus.*

Addendum.—In May, 1911, one of us obtained further specimens of this parasite in *Pachycephala gilberti*, obtained near Blanchetown in South Australia. Pomatostomus was in the neighbourhood.



Echinorhynchus pomatostomi, (n.sp.)

EROSION AND ITS SIGNIFICANCE.

By E. C. ANDREWS, B.A., Department of Mines, Sydney.

[*Read before the Royal Society of N. S. Wales, August 2, 1911.*]

Introductory.

THE present note is an attempt to coordinate our knowledge of stream processes, and to assign them their proper place in the sculpturing of land forms. It is rapidly coming to be seen that in order to explain the origin of certain common but important "facts of form" one must grasp the real significance of the operation of certain highly variable factors, not only when acting individually but also when acting in combination.

To take a single illustration, it is well known that wherever there are high plateaus in the temperate and tropical regions there one finds great fault scarps, deep narrow senkungsfelder,[1] and great numbers of minor fault scarps, arranged apparently in the most capricious fashion. On the other hand similar plateau blocks occur in the mountains of Western America, in Alaska, in southern New Zealand, in the Swiss Alps, in Norway and in the Antarctic, and it is almost certain from a consideration of mechanical principles, that in these regions also deep senkungsfelder were formed, nevertheless the intense glaciation to which they have been subjected in more recent times has so modified the preglacial profiles as to obscure them and to make it almost impossible to directly prove their origin by faulting, by stream action, or by a combination of these two activities. It is a remarkable fact, however, that so soon as one leaves the region of intense glaciation in such areas, one has the evidence of strong recent fault-

[1] A senkungsfeld is a sunken, or dropped, block of the earth's crust.

ing [*e.g.* Colorado, Utah, Arizona, and California]. To the case of the New Zealand Alps and the Californian Sierras reference will be made later.

A personal experience may perhaps be of interest in this connection. During a great number of cross-country journeys undertaken some years ago in New England (New South Wales), the writer had observed the existence of a magnificent plateau level varying from 3,000 to 3,400 feet in height. One peculiarity of this grand land surface lies in the fact that it is separated into a northern and a southern portion by a plateau about 1,000 feet higher, the two surfaces being connected by long rambling spurs whose bases are not arranged after any regular pattern. Furthermore, wherever examined the lower plateau was observed to be dissected by very broad and shallow valleys, as to its central portions, and by deep profound cañons on its eastern (and western) portions. Various other plateau remnants also diversified the main surface, their heights varying from 200 to 1,200 feet above the general level. Ridges and peaks likewise rose from these higher plateau blocks. The walls of the broad plateau valleys were rarely rectilinear, but were interrupted by jogs and large re-entrants. In the year 1903 these surfaces were described as the products of several cycles of erosion.[1]

In 1908 the writer accepted an invitation from Dr. G. K. Gilbert to visit the Sierras of California in connection with the question of the efficiency of ice as a powerful corrasive agent. The trip was carefully planned by him so as to lead the observer gradually to a scenic and physiographic climax in the Yosemite National Park. The way led first across the Great Californian Valley to Shafer viâ Fresno, thence up a fork of the San Joaquin to the Upper Evolution Valley

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[1] "Tertiary History of New England," Rec. Geol. Surv. N.S. Wales, 1903, p. 140.

and to the summit of Mount Darwin (13,870 feet). The descent thence was made of the great east fault front of the Sierras. The base of this giant scarp was then skirted to Mono Lake. The Sierras were here ascended at Bloody Cañon. Mount Dana (13,000 feet) was visited, and the Yosemite was approached by way of Tuolumne and Cloud's Rest. Trips also to the Grand Cañon of Arizona and to the Wasatch Range of Utah were taken at Dr. Gilbert's suggestion, and Pike's Peak and Cripple Creek areas were also studied. To Dr. Gilbert, our master in physiographical science, the writer is under a peculiar debt of gratitude for the trouble taken by him in pointing out all points of interest in this wonderland, and for supplying an explanation of the greater "facts of form" there seen.

The general account of the wonderful topographic and volcanic forms seen on that trip will doubtless be written by Dr. Gilbert and Mr. Willard D. Johnson who have both made a close study of them.

As a result of that trip the writer wrote a paper on "Corrasion by Gravity Streams."[1] But after the preparation of that paper it was seen that the application of the principles therein deduced suggested the complete dismantlement of one raised peneplain surface during the development therein of another peneplain at a lower level, if both such surfaces had been excavated in rocks comparable in hardness and resistance to the forces of erosion. This leads to the main thesis of the present note, namely, that in areas of homogeneous rocks or of rocks comparable in hardness, such as dense sandstones, quartzites, granites or crystalline schists, the existence of two peneplain surfaces in association but separated by youthful topography must be explained by activities other than those of ordinary corrasion.[2]

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[1] This Journal, Vol. XLIV, 1910, p, 204.

[2] A joint paper on the physiographic criteria of faulting in Eastern Australia is in preparation by Mr. C. A. Süssmilch and the writer.

It was evident after the production of this note on corrasion that although the main plateau level of New England and the broad mature valleys in the main plateau level and the mighty cañons dissecting them might be referred to the forces of erosion, nevertheless the various levels lying above the great lower plateau surface must be explained in some other manner. It may be stated, however, that when the earlier papers on New England were written, such explanation of origin as is there outlined was in harmony with the conceptions of modern physiographers.

Land Sculpture by Streams.

Scope of note.—An attempt is here made to present in briefest outline the various steps in the formation of the peneplain, and then to make several important applications of such reasonings to geological problems.

The following notes do not conflict with the published views on erosion by Gilbert, Powell, Davis, Penck, Dutton, Lawson, Tarr, Salisbury, and others, but seek simply to add to them and to call attention to the important consequences of accepting such principles.

The forces of erosion.—Let us consider the reduction of a high mountain or plateau mass by the forces of erosion, the action of the sea being neglected in this connection.[1]

On the one hand we have a plateau or uplifted plain, either high or low, either simple or complex in rock structure, either simply warped or intensely faulted, either resistant or weak. Such a feature is evidently a challenge to the forces of erosion. On the other hand as destructive forces we have the action of gravity in bringing streams down to the lowest points of a region, and we have still

[1] The action of the sea appears to be very limited unless helped by relative subsidence of the land. This is easily seen from a consideration of the slight depth only at which wave base can be developed below sea-level, and the slope of the profile of the shore thence to the shore-line, along which the sea must possess strength sufficient to transport its burden as a whole.

another action of an insidious nature, gradually breaking down the chemical and mineralogical structures so that the action of the descending streams may be hastened. These are the forces of corrasion and of weathering, the former being dependent upon the transporting power of the streams. The attack of the streams themselves on the rock structures (corrasion) may be considered as analogous to a direct muscular assault in the animal kingdom, while the effects of weathering on the rocks may be taken as analogous to the diseases among animals. It will be seen that the corrasive attack is the dominant one in the earlier stages of peneplanation, while the attack by weathering is the dominant one during all but the earlier stages of land reduction. Special attention is directed to these processes.

Transportation.—Geikie and Gilbert both insist on the geometrical increase of transportation upon simple increase of velocity for the case of ordinary streams. We quote first from Geikie (Geology 1893, p. 380).

"Mr. David Stevenson's table of power of transportation of different velocities of river currents.

Inches per Second.	Miles per Hour.	
3	0·170	Just work on fine clay
6	0·340	Lift fine sand
8	0·4545	Lift sand coarse as linseed
12	0·6819	Will sweep along fine gravel
24	1·3638	Will roll along rounded pebbles one inch in diameter
36	2·045	Sweep along slippery angular stones size of egg."

"The effects of abrasion upon the loose materials on a river bed are but a minor part of the erosive work performed by the stream. A layer of debris, only the upper portion of which is pushed onward by the normal current, will protect the solid rock of the river channel which it covers, but is apt to be swept away from time to time by violent floods."—(Geikie, Geology, p. 385.)

"More work may thus be done by a stream in a day than could be accomplished by it during years of its ordinary condition."—(*Ibid.*, p. 381.)

The case however for ordinary streams was first stated scientifically by Gilbert in 1883 (The Topographic Features of Lake Shores, U.S. Geol. Survey, Fifth Ann. Report, 1883-4 p. 89). ". . . It gives to the exceptional flood a power greatly in excess of the normal or annual flood. Not only is it true that the work accomplished in a few days during the height of the chief flood of the year is greater than all that is accomplished during the remainder of the year, but it may even be true that the effect of the maximum flood of the decade or generation or century surpasses the combined effects of all minor floods. It follows that the dimensions of the channel are established by the great flood and adjusted to its needs."

Floods.—This leads us to a definition of the term flood. It is common to hear of "floods" in rocky mountain gorges, of the "sheet flood erosion" of broad valley bottoms and the "floods" in areas of deep alluvium. It is evident that two distinct processes are here implied, the one implying corrasion, the other bringing about an actual deposition of material. We are here mainly concerned with the meaning of the term flood as it is related to corrasion, nevertheless both cases are considered.

In physiographical studies the term corrasion implies the mechanical abrasion, quarrying and sapping of the sides and the bases of stream channels; that is, the corrasion of channel structures implies "work" done on them by external forces. For channel structures, such external forces arise as the result of stream action. It is thus evident that a stream which moves the upper layer only of the débris in its channel is not attacking the channel structures, but on the other hand the débris in such a case actually protects its channel profiles. Stated in terms of mechanics, then such a stream is not doing "work" on its channel structures. Thus a glacier which overrides its ground moraine, or an ordinary stream which enters a deep hole in its course without stirring the pebbles and boulders at the bottom, or a torrent which forms a great alluvial fan on the floor of a senkungsfeld are all magnificent examples of streams which at such points are not corrading but are aggrading their channel structures.

In periods of great stream volumes in mountainous areas the channel débris overlying any particular point is carried over that point as a whole, while during a period of "fresh" or ordinary "flood" the channel débris is only moved as a whole in a few places. In times of such moderate stream volume the débris in the deeper holes and on the edges of the larger cutting curves is not moved as a whole, and the stream accomplishes but little work on the channel structures. The word flood may then be defined in terms of mechanics for mountain tracks; in the case of the rock channel it is that stream volume which accomplishes "work" on its channel sides and base by moving the channel débris as a whole over any point of such channel structures. In this case the curve of corrasion is concave to the sky. The time factor is here not taken into consideration.

A stream again in its course of development may have been affected by the development of a deep senkungsfeld across its path. In this case it will attempt to construct a bridge across the senkungsfeld along which it may transport its load. Thus the senkungsfeld base becomes heavily aggraded. In this case, even during periods of heaviest flood, corrasion is only accomplished on the upfaulted block while the downthrown block is actually protected. During the heaviest flooding the débris will be arranged on the senkungsfeld area in a continuous curve convex to the sky. Smaller floods will destroy the uniformity of this convex curve. Such a phase of stream action is usually very short lived.

Thus the term "flood" is seen to possess a dynamical significance for both degrading and protective stages.

It is necessary thus to carefully examine present day stream channels to understand whether they become flooded or not at periodical intervals. For only by appreciating the action of a flood can the formation of a stream channel be understood. To understand the work of the Upper Amazon in flood, one should have knowledge of it during such period or at least one should have knowledge of other large streams when in flood. Again, if glacial cirques are stream channels, then they in turn must have been formed during periods of greater ice volume than at present, because the "Ice Age" has only just gone, and the high level glacier marks may be seen on the cirque walls. But to-day the ice in such situations is relatively meagre in volume; it is in a state of tension, whereas in channels formed by streams, the streams themselves should have been in a condition of compression when accomplishing their task. This arises from the conception of flowage by pressure as weight.

All the foregoing account of flood action is dependent on the condition that floods are of such frequent occurrence that weathering has no opportunity to obliterate such flood profiles by its action during interflood periods.

Form of channel.—It is evident that the stream corrades not so much by its own material as by the load of earth débris it transports, unless indeed its own mass is so great as to exceed the ultimate crushing strength of the rock structures it traverses or so as to be enabled to detach rock masses from their unstable moorings on declines. It is also evident that a stream must so work as to be enabled to handle its load in the easiest manner, so as to minimise friction and nevertheless so as to take the line of quickest descent. To handle its rock load as a whole, the stream volume must greatly exceed that of its load. The stones by their superior weight will also occupy the more basal portions of the streams. The individual pebbles and other classes of channel débris will all attempt to take the line of quickest descent, but from considerations of friction and transportation the channel can not be V-shaped. On the other hand the stream is forced to concentrate its volume as much as possible, so as also to minimise friction. Inasmuch then as the stream load is small as compared with the stream volume, as the stream channel is designed so as to minimise friction, and as the streams take the lines of quickest descent, so the channel floor, in homogeneous structures as a whole, must be flattish nevertheless possessing a gentle slope to one deepest point, and its sides must be steep as compared with the floor. The reason for the last condition is plain. The individual boulders and pebbles of the load by minimising of friction tend to roll smoothly over each other, and yet to occupy only a small portion of the stream volume. They thus abrade the rock structures and form a flattish floor and sap the walls of the channel which are also abraded in a minor degree by the sand and smaller pebbles of the higher flood waters. The width and depth of a stream channel are thus functions of the volume, the velocity, and the load of the stream. This applies in the main to all streams alike. Thus if a glacier has excavated a valley as its channel, and such channel be examined at a moderate distance from its head then its base may be wide and fairly flat. If now the slowly moving glacier disappear and a much smaller mobile waterstream occupy its valley, then the new stream cannot occupy the whole glacial floor from considerations of volume and friction, but will excavate a somewhat similarly shaped channel in its floor as opportunity offers.

Depths of canons in plateaus.—If one knew the details of stream corrasion well, then having given the volume, the load, the steepness of the thalweg, and the strength of the rock structures acted upon, one could tell to what exact depth the streams could cut their bases into any plateau. For it is evident that the channel bases will be cut down towards base level so long as the stream is enabled to carry its load as a whole over its channel structures. In the absence of such exact knowledge it may be helpful to describe several cañon types:—

In Eastern Australia a peneplain has been raised in late geological time to form a high plateau. In this surface streams such as the Shoalhaven, Hawkesbury, Clarence and Barron have cut gorges, and they may be seen to be still growing by headward recession.

The Tallong Plateau through which the Shoalhaven flows is 2,000 feet in height, and 50 miles from the sea the gorge of the stream is 1,600 feet in depth.

The Wollondilly, at a distance of 200 miles from the sea flows in a gorge through a plateau 2,600 feet high, yet its base is only 600 feet above sea level at this point.

The Barron is an extremely short river possibly not more than 60 or 70 miles in length. It has recessed its front for a distance of about 10 or 15 miles. The base of the gorge under the giant waterfall (750 feet) where it leaves the upland is said to be only about 200 feet above sea level. Similarly for other streams of Eastern Australia.

The Merced Gorge in California flows through a lofty plateau for many miles, nevertheless at El Portal, its base is only 1,850 feet above the sea.

The Colorado River at El Tovar, Arizona, flows through a plateau 7,000 feet in height, yet the base of the gorge is only 2,500 feet above the sea.

Numerous other examples might be cited in illustration.

In all these examples it may be seen at a glance that the streams are still able to carry their loads as a whole easily over their channel bases when in flood. In each case the channel structures consist of dense rock structures. In other words, provided the rainfall in these regions does not sensibly decrease in amount, the streams under consideration will cut their bases much more closely to sea level before they become incompetent to carry their loads as a whole over any given point of the fresh rock structures of their channel bases.

Transitional stage.—But for all streams a slope of channel base is reached at some time along which the load that is delivered to the main channel cannot be moved as a whole over any specified point of the channel base, even during periods of heaviest stream volume. This stage at which the corrasion of fresh rock structures ceases to be the dominant factor in peneplanation may be called the Transitional Stage. Henceforth weathering and transportation become the dominant factors in land sculpture by erosive processes.

Width of canons.—Tributary streams cut their way into the plateau at the same time that the main stream does. In the early stages these side streams will be hung up.[1] By the repeated branching of such streams, the plateau in the vicinity of the main stream becomes riddled with a network of gorges. In hard rocks, such as granites, the writer has observed that the lips of the cañon are about one mile broad when once the cañon exceeds a depth of

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[1] E. C. Andrews, Proc. Linn. Soc. N.S. Wales, 1906, Vol. xxxi, pp. 419 –516. pl. xl,

1,500 feet. Exceptions to this rule occur near the heads of the gorges, where cañons 1,500 feet deep are not much more than 200 or 300 yards across at their brinks. At a considerable distance downstream the cañons may become much wider, sometimes attaining a width of 10 miles, and nevertheless retaining their marked cañon characters.

Sapping and the action of storm waters have been credited with most of the work of cañon widening. The examination of an ordinary side thalweg in such a cañon, and which receives only the drainage of the cañon side, is interesting however in this connection. In areas of dense geological complexes acted upon by a considerable rainfall, the floor of the channel will be found to consist of steep rocky ledges and waterfalls, here and there cumbered with heavy rock fragments. The whole stream course thus bears signs of extreme youth. To leave the thalweg involves a scramble or a difficult climb up an excessively steep spur to the sides of which cling ferns, shrubs, jungle growths or even great trees. The rocks are much shattered, granite blocks may be easily detached; they appear to have been wedged apart; slates creep; and fresh scars of land and rock slides are common, the latter showing the influence of great master joints. Notwithstanding all this the spurs are frequently heavily grassed, and their crests are often convex to the sky. At the headwaters of the thalweg, that is, at the angle where two spurs meet at the lip of the cañon (or at a point down the cañon side) an amphitheatrical enclosure may be seen often of appreciable size. Here there is no catchment for rain waters, the rocks are seen to be rotten, slates creep when present; the material is weathered, and by sapping from corrasion at a point some distance down the thalweg the gravitative or amphitheatrical head is formed by the action of material falling freely towards a common point. This amphitheatrical head slopes downward to a narrow and steeply inclined thalweg.

This then, the force of weathering, becomes a great factor in peneplanation when once the transitional stage has been reached. For the channel structures of the deep valley bases are attacked by the insidious force of weathering and lose their coherence, and thus the streams which could not corrade the fresh rock structures are enabled to gradually transport their weathered fragments.

The important point to remember about this is that once the transitional stage has been reached, henceforth the signs of youthful topography gradually and continually decrease, never more to be revived unless by some much more potent stream action or by some powerful earth movement.

Corrasion above the canon walls.—If a peneplain be slightly tilted as well as locally faulted or sharply flexed, then two valleys will be carved out of the upland at the same time, one a cañon receding from the face of the fault or flex, and one a broad and shallow valley formed headwards of the cañon growth. For during the peneplain stage which preceded the uplift, weathering activities extended to considerable depths below the peneplain surface, but the streams could only feebly transport such weathered material during the advanced old age stage of erosion. Upon slight tilting of the uplifted peneplain, however, the streams would have their velocity increased sufficiently to corrade this weaker material, and thus a broad and shallow valley would extend headwards of the cañon growth. Even if the plateau were not tilted, the very excavation of the cañon would yield enough stream fall to enable a new valley to be formed in the weathered material above the falls. Such a valley will necessarily become rapidly mature and will usually be very shallow indeed owing to the downward limits set upon effective weathering.

The cañon will recede along this shallow mature valley and in the divide it will assume a fairly broad amphitheatrical shape, the depth and breadth of the form so produced being strongly influenced by the height of the plateau, and both by the rainfall and the distance of the divide from the sea or from the nearest heavy fault or flex scarp. At the actual divide the curve of the surface should be convex to the sky, because in such places weathering runs ahead of corrasion—because of lack of catchment area—and the material tends to sink down hill under both its own weight and the influence of rains, thus tending to the parabolic curve convex to the sky.[1] This feature needs attention to be directed to it, inasmuch as it illustrates the influence of weathering, even in this early stage in plateau dissection.[2]

Subsequent stages of reduction.—The incapacity of the stream to directly scour its fresh rock structures at a certain definite critical stage (varying in time from point to point in its history) is not so much because of the absolute efficiency of weathering processes, as that the streams have reduced the slopes of their thalwegs to such an extent that their velocities in turn have been much reduced. This again implies an almost incredible decrease in power of transportation, and this it is which furnishes the real check to the initial rapid corrasion of the uplifted peneplain.

The influence of such a factor on the rate of sedimentation will be dealt with later.

This stage when weathering is so powerful a factor, and when lateral wear is in excess of vertical wear, is probably that which Davis describes as "the balance between erosion and deposition,"[3] and that to which Gilbert[4] refers in his statement "that downward wear ceases when the load equals the capacity for transportation."

[1] Corrasion, p. 216.
[2] Convexity of Hill Tops, G. K. Gilbert, Journ. Geol. 1909, pp. 340 – 350.
[3] Journ. Geol,. 1902, pp. 86-87. [4] Henry Mountains, 1877, pp. 126-127.

It must, however, be distinctly understood that though the stream has now no opportunity (except on narrow ridges) to effect much corrasion of live rock structures, nevertheless, as the rocks themselves become broken up by the action of the weather, so little by little the stream removes the incoherent mass so produced towards the sea. Thus the channel bases ever approach the main sea level. Because of the relative greater relief of the interstream areas, however, the latter will be more rapidly worn down to the general level of reduction by erosion than the main channel bases themselves. Thus the country tends ever more and more to the plain stage, and the youthful topographic form becomes less and less possible. The convex profiles which characterise the actual crests, even in the youthful stage of dissection, ever grow wider and wider, and become ever more and more important features of the landscape, until, as in the case of the majority of the inland country of New South Wales, the summits of the gentle hill slopes can only be seen from points at some distance from their bases owing to their convexity of slope. This is the slow aggradation of the hillside, owing to the supremacy of weathering agencies over those of corrasion and transport.

Davis' vivid picture of the death of the plateau shows how its features diverge more and more from those of youthful attack.[1] It may be noted, however, that in subarid New South Wales, as at Cobar, numerous narrow and steep ridges or peaks with steep rocky thalwegs dot the great plain of denudation. These represent the action of fierce thunderstorms on resistant rock ridges in an area which is not much influenced by weathering.

We have then by this slow but fairly safe route reached the following important conclusion:—

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[1] Journal of Geology, 1902.

Whenever two peneplain or [old age] surfaces are found associated in resistant rock structures, such as granites, crystalline schists, and dense quartzites or sandstones, and the two such surfaces are situated the one above the other, and the two are separated by a youthful or mature topography, it may be considered that they were formerly continuous, but are now discontinuous, owing to earth processes other than those due to erosive activities. Such earth processes may be either warping or faulting. This is absolutely irrespective of any irregularity of plan possessed by the youthful topography separating the two peneplains.

Applications.

Several important corollaries may now be deduced from the main principles of stream erosion :—

(1) *Height of peneplain above sea level.* The profile of corrasion in the ideal case is a function of stream volume. At each point corrasion varies both as the stream volume and as the cube of the velocity thus derived. The thalweg may be considered as receiving equal increments of volume at points equidistant from each other. These produce a definite increase in velocity, but this in turn implies a much higher increase in kinetic energy. Therefore the profile of corrasion should steepen with relative rapidity as it is traced headwards.

After the limiting profile of corrasion of fresh rock structures has been formed, weathering ensues and the work is carried on by transportation of the rock material thus broken down. There is practically no limit to this action. The final stages of corrasion, however, will apparently be a low plain generally convex to the sky and not much raised above sea level. The convexity of profile to the sky will be assumed long before the reduction of the surface to very low levels, and a peneplain may well be conceived as having a general height at its centre of several hundreds of feet, provided the divide be situated at a considerable distance from the sea.

(2) *Computations of the age of the earth based upon the estimated rate of denudation at the present day.*

It is common to find the age of the earth's sedimentary record based on the assumption that denudation of the land occurs at a fairly uniform rate.[1]

The study of erosive processes does not bear out such assumption for the following reasons :—

(*a*) The mountains of the present day are doubtless comparable in size with those of any Post-Archæan Age.

(*b*) The mountain valleys of the present day are quite youthful, and their loads are enormous by reason of their great transporting and corrasive power. Such transporting and corrasive power is related in a rapidly increasing geometrical ratio to the simple increase of stream velocity.

(*c*) Mountains are only transient forms in a landscape during the cycle of erosion necessary for the production of a peneplain.

(*d*) The time necessary to reduce a continent or plateau from a height of 1,000 feet to a peneplain of 500 feet in height at its centre involves practically the same length of time as the reduction of a plateau 20,000 feet in height to a similar stage when all other things are equal. This is simply an application of the known laws of geometrical decrease of corrasive and transporting powers upon the great reduction of stream channel and land slope.

(*e*) Many great peneplains or surfaces or erosion have been formed at various periods in the earth's history.

It would thus appear that estimates of the earth's age based on the assumption of uniform denudation are altogether too small.

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[1] A. R. Wallace, Island Life, 1892, pp. 210 – 240.

Estimates of the earth's age from a consideration of the thickness of the sedimentary deposits are also valueless for a similar reason.

Estimates also as to the earth's age based on the salinity of the ocean apparently need modification, because all the factors do not appear to have been considered. Thus during an ephemeral mountain period, such as the present one, the volume of rock accessible to wandering waters which yield up their harvest of salts to the rivers is much greater than that during the incomparably longer life of the low lying plain of erosion.

(3) *Peculiarities of certain topographies.*—Controversy has raged round the origin of certain topographic features for many years. Thus the Yosemite Valley of California has been explained variously as the result of stream, of fault, or of glacial action. The fiord and lake basins of New Zealand have also been explained in the same manner, so also the forms of the Scottish Highlands, of the Norwegian fiords, and of the Alpine valleys and lakes of Switzerland. While all these processes have doubtless been active in all the regions mentioned during recent times, it is necessary to decide as to what share each has had in moulding the landscape. In this connection brief mention only is made of the Yosemite and several New Zealand forms.

Yosemite.—It is certain that glaciers have occupied the lower 2,000 feet of the valley in recent time and it is highly probable that they have produced the peculiar "steps" and "treads" at the Nevada and Vernal Falls. On the other hand there are no moraines in the valley worth serious consideration, and the upper valley slopes are certainly those due to sapping action. The most difficult thing to explain on the assumption of the origin of the Yosemite profiles by ice corrasion alone is the position of the Bridal

Veil Falls and the peculiar re-entrant in the wall immediately downstream of El Capitan (See Matthes' Topographic Map). On the other hand this part of the valley could be easily explained by faulting action with later modification by ice-stream action. An interesting fact of observation in this connection is that the Yosemite Valley lies in a region of intense faulting and warping action in late Tertiary or recent time. Glacial action, however, has certainly exercised a marvellous influence on the preglacial Yosemite profiles.

Preservation Inlet, [New Zealand].—Here a long broad and fairly shallow inlet dotted over with islands runs up along its lower portions into a plateau about 1,000 feet in height, while its upper portions run amongst much higher plateau remnants. The various topographies thus enumerated are separated by rough youthful forms. Heavy glaciers have passed down the inlet or sound, leaving moraines and other signs of ice action in various places.

The most feasible explanation (from a consideration of the present note) is that earth forces raised a peneplain here in recent times to form two high plateaus and dropped a centre block to form the inlet, which has since been modified by ice erosion.

Lake Te Anau is a large body of water bounded by plains and lake terraces on the south and south-east, while its western and main eastern walls are composed of high plateaus of varying heights, and trenched by three or four profound fiords. The base of the lake lies many hundreds of feet below sea level. The topography to the west and north-east is singularly wild, rugged, and magnificent, while the approach from the south is tame and monotonous, except for the high and rugged Takitimu Range which bounds this low lying land block to the east.

On the same wide and low lying block as that which holds Lake Te Anau lies Lake Manapouri, and both lakes have their deepest portions in situations along which the greatest stream scour could not have taken place. On the other hand the locations of maximum stream (ice or water) scour have been along channels whose bases lie above or near lake level. In a word, the lakes lie on an old age surface, and such wide surface is separated from other dismantled old age surfaces by the wildest topography imaginable.

The region has been intensely glaciated in recent times. It is difficult to assign the exact share that earth movements and erosive activities have had in producing this magnificent topographical feature, but it is evident that corrasion has had only a minor share in producing the total result. The lake in quite recent times was much larger than at present, and from a consideration of the principles discussed in the present note it appears to represent the filling by water of a great senkungsfeld having the mountainous country on the western portion of the lake proper as one wall, the eastern wall of the lake for another, and the rugged and youthful Takitimu Range for another wall.

The beginning of the fiords which break its western and northern walls may also have been in heavy cross faulting, but it is certain that the fiords have been intensely glaciated during the recent Ice Age, and that the long and profound cañons discharging into the fiords may be easily explained by erosive processes alone.

Similar reasoning may be extended to the case of Lake Wakatipu where faulting appears to have been most pronounced especially about Arrowtown, The Crown Terrace, and the great west front of The Remarkables. Heavy erosion by ice, however, is evidenced on the lower hills, the thickness of the ice stream having been several thousands of feet. It is probable that the Tertiary strata found in the valley have been let down by Late Tertiary faulting.

Similarly for all the large Alpine lakes and most of the magnificent fiords of the west coast. In each case most intense ice action is evidenced, but there are also signs of formative activities other than those of streams. In some cases, for example, Dusky Sound, Doubtful Sound, Lake Manapouri and Lake Wanaka, it is highly probable that the basins have originated in heavy faulting action with the production thus of senkungsfelder, and that the senkungsfeld valleys have in later time been modified and extended headwards as cañons, first by ordinary streams and then by ice action. The evidence for this conclusion is simply an application of the principles dealt with in this note and consists of the intimate association of topographical surfaces in quite different stages of development in dense resistant geological complexes. Some of the lake and sound basins, such as those of Wanaka, Hawea, Wakatipu, Manapouri, Te Anau, Doubtful, Breaksea and Dusky Sounds are situated also where one could not expect them to be, if they had been the products of stream corrasion, and their maximum depths moreover, occur in places where the maximum stream scour could not have taken place. On the other hand the cañons which open out into them are generally such as might have originated in stream action.

It may be that certain large Alpine lake basins in other regions may be due also both to dislocations and to intense water and glacial action during a still later period.

NOTES ON THE GEOLOGY OF WEST MORETON, QUEENSLAND.

By R. A. WEARNE, B.A., and W. G. WOOLNOUGH, D.Sc., F.G.S.

[Read before the Royal Society of N. S. Wales, August 2, 1911.]

I. Introduction.—The area designated in this paper as the West Moreton District extends from the Brisbane River on the north, to the McPherson Range on the south, and from the Logan River on the east to the Main Dividing Range on the west.

Dr. H. I. Jensen, in his paper on the Alkaline Rocks of Southern Queensland, at the Brisbane Meeting of the Australasian Association for the Advancement of Science, referred to the Main Dividing Range as the Little Liverpool Range. In the following remarks the title Little Liverpool Range is applied to the spur of the Main Range that runs from Mount Castle northwards, and is crossed by the Brisbane–Toowoomba Railway Line between Grandchester and Laidley.

II. Work of Previous Observers.—The northern border of the area under discussion has formed the subject of a monograph by Cameron.[1] In this report the general sequence of the Ipswich Coal Measures is worked out, but no description is given of the volcanic series which forms the subject of the present paper.

Jensen[2] has studied the volcanic series. He describes a number of rock types, particularly from Mounts Flinders

[1] Cameron, W. E.—Geology of the West Moreton or Ipswich Coalfield. Geol. Survey of Queensland, Rep. 1899.

[2] Jensen, H. I.—Notes on the geology of the Mount Flinders and Fassifern Districts, Queensland, Proc. Linn. Soc. N.S.W., Vol. xxxiv, 1909, pp. 67–104; also The Alkaline Rocks of Southern Queensland, Rep. Aust. Assoc. Adv. Science, Brisbane, 1909, pp. 249–258.

and French. These he assigns to a variety of alkaline lavas. He is of opinion that "the volcanic rocks of the Fassifern Scrub are all Post-Triassic and probably Post-Cretaceous." He describes the area under consideration as a senkungsfeld and gives a detailed account of the tectonic geology.

Marks[1] is of opinion that the age of the volcanic series in the neighbourhood of Beaudesert is Trias-Jura, in which idea he follows Rands.[2]

In an account of Mount Lindsay in the Macpherson Range Andrews[3] describes the eruptive trachytes as Trias-Jura in age.

It will be seen then that considerable diversity of opinion exists in connection with this important question.

III. Physiography.—The contour of the Main Dividing Range which separates West Moreton from the Darling Downs reveals the fact that two successive uplifts occurred, the first an uplift of about 2,000 feet, and the second of about 2,700 feet. The summits of the Main Range—Mounts Castle (3,700 feet), Cordeaux (4,100 feet), Mitchell (4,000 feet), Spicer (4,100 feet), Huntley (4,150 feet), Roberts (4,350 feet), and Wilson (4,060 feet) are practically at a uniform height above sea level. They represent the denuded remnants of an uplifted peneplain. The uniform level of this uplifted peneplain can be seen from the summit of Mounts Spicer and Mitchell gently sloping westwards across the Darling Downs.

Four well defined "air gaps" occur between Spring Bluff and Bald Mountain, Mounts Cordeaux and Mitchell, Mounts

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[1] Marks, E. S.—Coal Measures of South East Moreton, Queensland Geol. Survey, Publ. No. 225, p. 52, Brisbane 1910.

[2] Rands, W. H.—Report on the Albert and Logan District, Qeensland, Parl. Papers. C.A. 5, p. 2, Brisbane, 1889.

[3] Andrews, E. C.—A Preliminary Note on the Structure of Mount Lindsay. Rec. Geol. Surv. N.S.W., Vol, vii, 1903, pp. 328 – 240.

Mitchell and Spicer, and Mounts Roberts and Wilson. They represent the U-shaped mature river valleys eroded to base level, which have since been elevated to a height of about 2,700 feet above sea level. Cunningham's and Spicer's Gaps still preserve a perfect U-shaped contour, the latter being one and three quarter times the size of the former. A magnificent view of these "gaps" can be obtained from the western side of "Jump Up," a high ridge which runs to the north of Mount Alford about six and a half miles to the west of the township of Boonah. The gap between Spring Bluff and Bald Mountain has been faulted to a depth of about 500 feet below the uplifted peneplain, whereas Cunningham's, Spicer's and Wilson's Gaps are on the edge of the escarpment. These gaps have at the present time an important influence upon the meteorology of the eastern coastal plain.

In Cainozoic times the Water Divide existed far to the east of its present position, and four important western flowing streams carved the U-shaped valleys of the aforesaid gaps to base level. The most northern of these rivers followed somewhat the course of the Lockyer and Murphy's Creeks and flowed through the Spring Bluff gap near Toowoomba. Its tributaries on the left bank carved the aggraded U-shaped valleys through which Blenheim Creek and Laidley Creek now meander, and the rich agricultural lands of the famous Lockyer District are the result of their work. The second river flowed west through Cunningham's Gap, and one important tributary on the right bank is represented by the magnificent V-shaped gorge of Reynold's Creek, which cleaves Mount Edwards. This gorge is at present about two miles long, its sides slope at an angle of 40°, and the summit of the V on the east is 1,000 feet above the bed of Reynold's Creek, and that on the west 1,800 feet. It much resembles the famous Upper Shoalhaven River

Gorge of New South Wales in appearance. The third stream ran roughly parallel to the second, divided from it by Mount Greville, and flowed through Spicer's Gap. The fourth stream followed the upper valley of the Teviot, flowed through Wilson's Gap, and thence along the upper course of the Condamine through the gorge known locally as "Sydney Heads."

IV. Earth Movements.—In Cainozoic times the district was reduced to a peneplain level. It was next elevated to a height of about 2,000 feet, and the mature river valleys referred to above were worn to base level in the volcanic products. This is proved by the uniform depth of the U's below the summit level. A second uplift of about 2,700 feet next occurred in late Cainozoic time, as proved by the fact that the uniform level of the 'air gaps' is at the same height above sea level. The comparative recency of the movement is indicated by the very slight alteration in form suffered by the uplifted valleys since their elevation.

Extensive trough faulting then occurred between Indooroopilly near Brisbane and the Main Range. The first faulting probably resulted in the production of what we call the *Lockyer Fault Block*, bounded on the west and south by the Main Dividing Range, and on the east by the escarpment of the Little Liverpool Range. This block is traversed by four meridional ridges:—the Little Liverpool Range, the Mount Mistake Range, the Hip Roof, and another of unknown name, with horizontal crest lines rising to a uniform level of about 2,000 feet. Immediately to the east of Toowoomba this faulting carried down a portion of the old mature valley about 500 feet below its original level. The faulting here was somewhat complex, and this fault is associated with one or more others increasing the total throw.

The second period of movement produced the *Fassifern Block* lying to the east of the Little Liverpool Range and the approximate collinear portion of the main range to the south of the junction. This fault probably amounted to about 900 feet. The throws of these faults have been calculated from the following evidence :—

i. The mature topography of the main range near Toowoomba is continued to the east near Spring Bluff at a lower level of about 500 feet.

ii. At the main range near Toowoomba basalt caps the coal measures at an altitude of 1,700 feet above sea level. It can be clearly seen from the railway line at the ninety-three mile post from Brisbane. Throughout the Lockyer Block a similar flow of basalt up to 600 feet in thickness caps the coal measures in each of the four ridges at a height of 1,200 feet above sea level.

iii. At Mount Walker, a peak belonging to the Fassifern Block, basalt also caps the coal measures, but at a height of only 300 feet above sea level.

This evidence is supported by the appearance of the sandstones and grits of the coal measures in the railway cuttings along the main range and the Little Liverpool Range. At the ninety-one mile post near Spring Bluff the slickensided surface of the fault scarp can be clearly detected. Between the first and second railway tunnels in the Little Liverpool Range a marked change in the dip can be noticed along the line of fault, and slickensided surfaces were found in the grits and sandstones. One mile to the west of Ipswich the coal measures are tilted at an angle of 80°, and the Bremer River follows the line of fault for a distance of over two miles from Berry's Lagoon to Coal Falls.

V. Geology—(I) Sedimentary Rocks.

(a) *Permo-Carboniferous Rocks.*—An inlier of Permo-Carboniferous rocks is to be found immediately to the north-west of Mount Barney, a high double peaked mountain, which is situated about six miles to the north-north-west of Mount Lindsay. These rocks have been previously considered as of Trias-Jura age, but the discovery of a definite specimen of *Fenestella fossula*, Lonsd., submitted to Mr. W. S. Dun for identification places them in the Permo-Carboniferous. This is the first record of Permo-Carboniferous fossils in the West Moreton District.

(b) *Trias-Jura Rocks.*—The representatives of the Trias-Jura rocks met with in the area under consideration are to be referred to the Welloon stage. They consist of conglomerates, grits, sandstones, and shales with thin seams of coal. The coal measures form rather poor soil, and the surface ridges are mostly used for grazing purposes.

(II) Eruptive Rocks.

Four distinct periods of volcanic eruption can be traced in the West Moreton District by the occurrence of:—

1. Trachytes.
2. Andesites and Dacites.
3. Rhyolites.
4. Basalts.

1. Trachytes.

Trachyte eruptions occurred along a zone running from the main range to Mount Cordeaux in an easterly direction to Redbank Plains, about eight miles south-east of Ipswich. These eruptions produced a number of cones, whose denuded remnants may now be seen at the summits of the main range and at Mounts Matheson, Greville, Edwards, French, Flinders, and the ridge to the south of Redbank Plains. The flow of this period attained a thickness of about 2,000 feet.

Mount Flinders.—The trachyte series at Mount Flinders (2240 feet) can be subdivided into three distinct sub-periods of eruption. The first produced the dark basic looking trachyte (pantellarite of Jensen). It has a characteristic greasy looking lustre much like phonolite. The lower hills on the the northern side of Flinders are composed of this rock. The second sub-period produced the light alkaline felspar porphyry which composes Flinders and a number of the neighbouring peaks. Two distinct dykes of this light trachyte run from Flinders through the pantellarites, one to the north-west of that mountain, 20 feet wide, shewing well defined horizontal prismatic structure. The third sub-period produced a pitchstone porphyry containing phenocrysts of sanidine embedded in a black glassy matrix. (See petrographical descriptions.)

Mount Blaine about two miles to the north of Mount Flinders is composed entirely of this material *with inclusions of light and dark trachyte.* One inclusion of the light variety measured 6″ × 4″, and another of pantellerite 5″ × 4″.

Ivory's Rock which can be seen about three miles to the east of the Rockton Railway Station, standing like a large obelisk above the plain, is about 1,300 feet high, and is composed entirely of trachyte breccia. At a point 400 feet from its summit the angular masses of breccia are cemented in a matrix of trachyte glass which seems to have forced its way from the centre of eruption through the porous masses of scoria.

Main Dividing Range.—The main range near Cunningham's Gap is composed of alkaline trachyte capped by olivine basalt. *Mount Matheson* (2,660 feet) appears to have been the main focus of the trachyte eruption of this district. Its summit consists of vesicular trachyte surrounded on all sides by huge masses of trachyte tuff, breccia and conglomerate containing angular masses three feet in diameter. A steep escarpment exists to the north and west, and a ridge connects this mountain on the southern side with the lower slopes of Mount Mitchell. Johnston Creek and Clayton Gully rise in the elbow thus formed. A perfect view of the well defined U-shaped mature valley of Cunningham's Gap can be seen from the summit of Mount Matheson.

Mount Mitchell (4,000 feet).—A splendid section of the volcanic series and the associated sedimentary rocks is revealed in Gap Creek (the eastern one of this name) and the wonderful escarpment of Mount Mitchell itself. The Walloon stage of the Ipswich coal measures is distinctly intruded and capped by trachyte, and these in turn by basalts. A fairly thick seam of coal outcrops about one mile below the "Second Falls." It is intruded by a dyke of basalt which has opened out into a sill along the seam. Several basalt dykes occur running roughly north and south at right angles to the creek, and each in turn causes the formation of a pretty waterfall.

Cunningham's Gap consists of a perfectly shaped U situated between Mounts Cordeaux and Mitchell, the trough being 1,500 feet below the summits of those mountains. It presents one of the finest examples of an Air Gap to be seen in any part of Australia. At the lowest point of the gap trachyte breccia is met with. The base of Mount Mitchell is composed of alkaline trachyte, tuff and breccia for a thickness of about 1,500 feet, and this in turn is capped by about 1,000 feet of basalt. The entire thickness is made up of a very considerable number of independent beds of volcanic material, each one practically horizontal. The summit of Mount Mitchell consists of a narrow ridge running north and south. Viewed from the east it shows a broad rounded summit with a vertical escarpment of about

2,000 feet. From the south it appears as a huge inaccessible pinnacle. The narrowest part of the summit is not more than nine feet across, and a stone can be dropped on the eastern side for a depth of at least 1,500 feet before striking the rock face, while on the western side there is a similar cliff of about 500 feet. From the summit of the mountain an excellent view of the low lying Fassifern Block can be obtained, and beyond the hills around Ipswich, which bound the block on the east, the waters of Moreton Bay are visible.

Mount Greville (2,700 feet) the sentinel of "The Gap," situated about five miles to the east of the Main Range, is composed of grorudite, and its present contour is probably due to the erosion of the mature rivers that formerly flowed through Cunningham's and Spicer's Gaps. The northern slope corresponds in contour with the southern slope of the former, while the southern contour recalls the outlines of the northern slope of the latter.

The eastern side of Mount Greville is cleft by fissures from 6 feet to 20 feet wide with precipitous walls from 100 feet to 200 feet in height. They have been formed by basalt dykes which being less resistant than the grorudite have been completely eroded. These clefts are studded with magnificent palms, ferns, and orchids, and form one of the most picturesque spots in Southern Queensland.

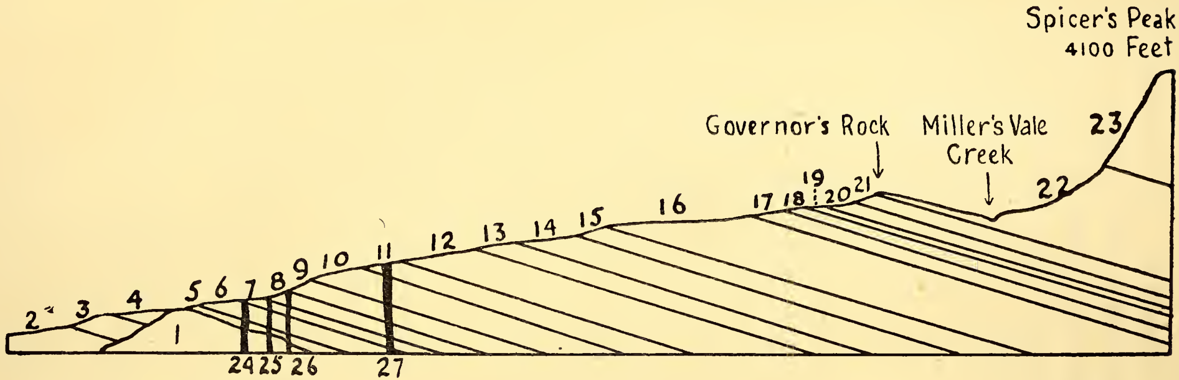
Mount Edwards (2,300 feet) is composed of trachyte intruded by basalt, and *Mount French* (1,800 feet) is composed of comendite, tuffs and breccias.

Spicer's Peak (4,100 feet) presents a section almost identical with that of Mount Mitchell, and like the latter has a vertical escarpment on the east.

2. Andesites and Dacites.

A parasitic cone of andesite occurs along the old Warwick Road which runs through Spicer's Gap (See Fig. 1). Here

Fig. 1—*Section of Main Range along Old Warwick Road,*



Horizontal Scale ———— 1000 Yards : Vertical Scale —— 1000 Feet

1. Trias-Jura sandstone and quartzite
2. Trachyte tuff and breccia
3. Trachyte
4. Tuff
5. Tuff
6. Trachyte
7. Tuff
8. Trachyte
9. Coarse trachytic agglomerate
10. Basic trachyte
11. Trachyte tuff
12. Basic trachyte
13. Amygdaloidal trachyte
14. Tuff
15. Trachyte
16. Trachyte tuff and breccia
17. Basic trachyte
18. Trachyte
19. Basalt sill
20. Trachyte
21. Trachyte tuff
22. Trachyte tuffs
23. Olivine basalt
24. Phonolite dyke
25. Basalt dyke
26. Basalt dyke
27. Andesite (probably parasitic cone)

there is distinct evidence that the andesite intrudes and caps the trachyte.

Mount Alford (2,200 feet) about three miles to the east of Mount Greville is composed of andesites, quartz-diabases and devitrified obsidians, etc., intruded by rhyolite dykes. This mountain presents a fine field for research work and holds the key to the volcanic sequence. It is hoped that a detailed examination will be made later.

Mount Maroon (3,300 feet) about 12 miles to the E.S.E. of Mount Alford is composed entirely of rhyolite. Two features are here worthy of note (1) the occurrence of huge vertical prisms 150 feet high on the northern side of the summit, and (2) the presence of two small but very deep elliptical lakes near Mr. Rose's Farm on the mount side. These lakes are surrounded by rhyolite breccia and tuffs, and have never been known to be dry. The larger one is 150 yards long by 75 yards wide.

Mount Barney the culminating peak of southern Queensland, 4,625 feet high, is also composed of rhyolite, intruded by basalt dykes. It is situated between Mount Maroon and the McPherson Range.

3. Rhyolites.

A large rhyolite dyke intrudes trachyte at Johnston Creek, about one mile to the west of Mr. Anderson's house "Marraboola," in portion 92 V, Parish of Clumber.

Glennie's Pulpit consists of the plug of rhyolite on the north-western side of Mount Alford. It stands about 120 feet above the contour of Mount Alford, and is composed of practically horizontal hexagonal prisms, pointing to a vertical conduit for the molten magma. It is surrounded by acid tuffs and breccias and represents a centre of rhyolite eruption.

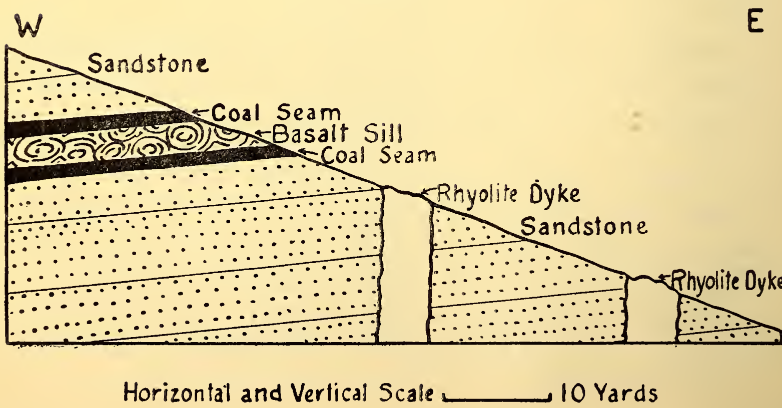
4. Basalts.

Basalt intrudes and caps trachyte along the Main Dividing Range near "The Gap." Basalt dykes intrude trachyte at Mounts Greville, Edwards, French and Flinders. Basalt dykes intrude andesite at Mount Alford, and basalt dykes intrude rhyolite at Mount Barney.

A striking difference is presented between the relationship of the basalt dykes to the streams near the Main Range and at Mount Barney. At the former locality the dykes cross the streams at right angles, whereas at Mount Barney the streams are subsequent and follow the course of the dykes. Basalt seems to have been extruded throughout the whole district by fissure flows.

At the Main Range near Toowoomba two distinct dykes of large dimensions can be seen along the eastern escarpment—one at the 93 mile post on the railway line from Brisbane, 200 yards in thickness, and the other at the 91 mile post exposing a width of 600 yards in the railway cutting. Intrusive sills of basalt occur on the Main Range along the old Warwick Road at an altitude of 2,040 feet, and at the "Jump Up" see figs. 1 and 2.

Fig. 2.



Limestone Hill (Ipswich) has been formed by a fissure flow of basalt and it consists of a brown decomposed basalt, white trap, silicified breccia which has been rebrecciated, and basalt.

Red Hill forms the western portion of the same flow, the fissure running through the Golf Park.

Age of Volcanic Rocks.

Trachyte and basalt intrude and cap the Trias-Jura Coal Measures throughout the whole of the volcanic zone from the Main Range to Redbank Plains and portions of the Trias-Jura rocks can be found embedded in the volcanic breccias at Mount French and Ivory's Rock. Thus at first sight one would naturally conclude that the whole of the volcanic eruptions were Post Trias-Jura.

After very careful search along the Blenheim Creek valley and also in the deep gullies at the base of Mount Flinders and Mount Alford, waterworn volcanic pebbles were found embedded in an extensive bed of conglomerate which occurs near the top of the Walloon Series. This conglomerate is capped by grits and sandstones for a thickness of about 150 feet.

At the "Hip Roof" referred to above, a large piece of volcanic tuff was found associated with basalt containing fossil imprints of Trias-Jura plants. One specimen submitted to Mr. W. S. Dun for identification was stated to be *Taeniopteris Daintrei*. There seems thus to be conclusive evidence that at least some of the volcanic eruptions of West Moreton were of Trias-Jura age. This agrees with the evidence published by Andrews and Marks.

Field evidence seems to support the conclusion that there have been two distinct and separate series of volcanic eruptions in the West Moreton District:—

(1), of Trias-Jura Age contemporaneous with the Walloon stage of the Ipswich Coal Measures and including the more normal trachytes of the Main Range, Mounts Edwards and Flinders and the basalts of the Main Range near Cunningham's Gap, and

(2), of Tertiary Age including the more alkaline trachytes of Mounts French and Greville, the rhyolites of Mounts Maroon and Barney, and the basalts of the Toowoomba Range.

Summary.

1. At least two levels of erosion are to be recognised in West Moreton, standing respectively at an altitude of 2,600 feet and 4,000 feet.

2. Extensive block faulting has occurred, giving rise to what we have termed the Main Range Fault, the Lockyer Block, and the Fassifern Block.

3. An area of fossiliferous Permo-Carboniferous is shewn to exist near Mount Barney.

4. The volcanic sequence is:—

   i. Trachyte
   ii. Andesites and dacites
   iii. Rhyolites
   iv. Basalts

5. The ages of the volcanic eruptions believed to belong,

   i, to the Walloon stage of the Trias-Jura Coal Measures, etc.

   ii, to the Tertiary Period.

Petrographical Notes.

Granophyre, Mount Alford.—Allotriomorphic granular rock with very conspicuous granophyric structure. Essential constituents, plagioclase, anorthoclase, quartz, alteration products of ferromagnesian minerals, ilmenite and apatite. Exclusive of the granophyric fibres, the average grainsize of the rock is even, about 1 mm., though individual crystals rise to about 2 mm. in length. The plagioclase is subidiomorphic in form and includes the largest crystals in the rock. It is twinned on the albite law and occasionally on the Carlsbad law as well. Here and there a little pericline twinning is developed also. The composition is that of an acid labradorite. There is also abundant felspar quite allotriomorphic, untwinned or very hazily twinned, with refractive index less than, or equal to that of Canada balsam, and less than that of quartz. This appears to be anorthoclase. It is granophyrically intergrown with quartz. In some instances there is a large grain of the felspar with a fringe of granophyre ; in others the granophyric structure extends to the centre of the crystal; while in others there is a nucleus of quartz with a fringe of granophyre, but this last arrangement is not common. Some independent grains of quartz occur, but this mineral is mostly intergrown with anorthoclase as above described.

The arrangement of the ilmenite is one of the most remarkable features of the slide. It is abundant in thick tabular sections, sometimes simple, sometimes intergrown with the ferromagnesian mineral, and *sometimes forming a perfect granophyric intergrowth with quartz and felspar.* The ferromagnesian mineral (probably augite) is completely altered, and is represented by an aggregate of fibrous uralite, dark green and pleochroic. Apatite is fairly abundant in thin needles. Order of consolidation :—

Apatite
Ilmenite
Augite
Plagioclase
Anorthoclase
Quartz

Granophyre, near base of Mount Alford on the northern side.—The rock is granophyric with pseudo-porphyritic nuclei of quartz, orthoclase, anorthoclase(?), and haematite. Individual grains of the various minerals are up to 4 mm. diameter, but mostly are much smaller. Haematite is always enclosed in the other minerals and probably represents the alteration product of original magnetite. Felspar is considerably kaolinized. Some is definite orthoclase, but some appears to have higher refractive index and shows very fine and hazy albite twinning. Sometimes quartz, sometimes felspar forms the nucleus round which a granophyric intergrowth is formed.

Mount Alford.—There is a marked variation in texture within the limits of the microscope slide but the line of demarcation is not very sharply drawn.

The finer grained portion is cryptocrystalline and spherulitic with occasional granophyric patches, very much clouded by decomposition products. There are occasional phenocrysts of plagioclase, and grains of magnetite up to 0·5 mm. diameter.

The coarser portion has a fine base composed of untwinned felspar (orthoclase ?), with a little quartz, chlorite and magnetite and very little trace of granophyric structure. In this part occur abundant plagioclase phenocrysts and grains of titaniferous magnetite very irregular in shape and much intergrown with the ferromagnesian constituent. The latter is represented by green fibrous uralite.

The plagioclase phenocrysts appear to be the same in both portions. They are idiomorphic, twinned after albite and Carlsbad laws mostly, with occasional patches showing pericline lamellæ, and must be referred to acid labradorite.

In the coarser portion there occur, fairly abundantly, rounded grains of quartz and also one little nest of quartz and calcite. This latter is undoubtedly an inclusion of calcareous sandstone and the isolated grains of quartz appear to have a similar origin. The whole rock is much impregnated with calcite.

It is probable that the coarse and fine portions represent "schlieren" in a non-homogeneous magma.

Foot of Mount Greville.—Porphyritic rock with an even-granular base averaging about 2 mm. The base contains quartz and orthoclase in about equal amounts together with alkaline amphiboles in considerable abundance and apparently of several varieties. Among these amphiboles we have:—

i. Ophitic patches of strongly pleochroic dark green to brilliant indigo riebeckite. This encloses idiomorphic quartz and felspar grains.

ii. Irregular prisms with ragged ends and sides, pleochroic in dark brown to bluish-green tints. It is most difficult to obtain suitable sections for optical examination. The extinction is nearly straight, but, in the larger grains, is not very perfect owing to strong dispersion. The elongation is negative, but the mineral is too opaque to yield figures in convergent light. It is probably arfvedsonite and belongs certainly to an older generation than the ophitic patches of riebeckite above described.

iii. Prisms and patches of a somewhat pleochroic brown to yellow mineral, possibly cossyrite. This sometimes forms the centre of a thin prism, the outer zones of which consist of the green-brown mineral (arfvedsonite ?).

Phenocrysts of quartz (1 mm.) and of sligtly decomposed orthoclase (2 mm.) are not very abundant. There is a good deal of haematite staining throughout the rock.

Summit of Mount Greville.—A very similar rock to the last, but decidedly more trachytic in character, the felspars being more lath-shaped. The cossyrite (?) is much darker than in the rock from the base, probably owing to separation of haematite. In both rocks the amphibole is the last mineral to crystallize, enclosing quite idiomorphic quartz.

Great dyke on Mount Alford.—The rock has an extremely fine grained base of lath-shaped orthoclase, considerably decomposed, with a little interstitial quartz. Here and there a spherulitic structure is suggested. There are very occasional phenocrysts of quartz and thoroughly glassy sanidine.

Devitrified obsidian, Mount Alford (not in situ).—An extremely fine grained rock consisting of a colourless base crowded with green needles. The base consists of a mosaic of untwinned orthoclase, having all the appearance of having been formed by the devitrification of a glass with the composition of a felspar. The green fibres are long but excessively thin, strongly pleochroic brownish-green to opaque, and with straight extinction; they are probably ægirine. Their arrangement is variolitic, with occasional bunches in which the fibres are more radially arranged.

Obsidian, Mount Alford (not in situ).—Vitrophyric rock. The base consists of nearly colourless glass, very clear and free from crystallites or other elementary forms. The glass is slightly perlitic, but this structure is very imperfectly developed. There are abundant phenocrysts of clear fresh felspar very sharply idiomorphic. Some of the sections are broad, suggesting a tabular habit, others are rhomb shaped as if the mineral were prismatic. Mostly the sections are untwinned or twinned after the Carlsbad law, but here and there very hazy *moirée* structure can be seen. The refractive index is less than that of Canada balsam. The felspar is probably anorthoclase. These phenocrysts contain inclusions in the form of very striking negative crystals filled with glass.

Pitchstone, Spicer's Gap.—A nearly colourless glass, crowded with minute microlites of felspar in the form of excessively thin idiomorphic plates. Sometimes these are arranged one above the other in sets of three, with the axes of the three plates inclined to one another. At other times they have a kind of *echelon* formation. These overlaps give the appearance of twinning but the plates are really simple.

There are a very few larger phenocrysts of sanidine, idiomorphic and twinned after the Carlsbad law and somewhat corroded by the base.

Olivine-basalt, near the summit of Mount Mitchell.—The base is pilotaxitic with a very marked flow structure. It consists of plagioclase, augite, magnetite, ilmenite, and apatite.

The plagioclase is labradorite (Ab_9 An_{11}) in lath shaped crystals up to 0·5 mm. in length, twinned after Carlsbad and albite laws.

Augite is purplish and faintly pleochroic from brown to purple and is ophitically arranged.

Magnetite in small octahedra and ilmenite in thin plates appear to be quite independent of one another. There is a good deal of dark green chlorite throughout the slide, also large quantities of apatite in very fine needles.

Olivine is fairly abundant in idiomorphic crystals up to 1 mm. by 0·5 mm., much altered to dark green fibrous serpentine. A few irregular cavities are filled with analcite.

Coarse olivine-basalt, South-east corner of Portion 121, Parish Clumber (near the base of Mount Mitchell.—Coarsely pilotaxitic in structure. Two generations of plagioclase are present. The individuals of the first set are large prismatic crystals with square cross sections and reach 4 mm. by 0·5 mm. They consist of labradorite Ab_3 An_4 and are quite fresh and twinned after the Carlsbad and Albite laws. The felspars of the second generation differ only in size, ranging about 0·5 mm. by 0·1 mm.

Olivine is remarkable as occurring in *two distinct generations*, a phenomenon quite unusual for this mineral. The earlier formed crystals are magnificent idiomorphic forms, 3 mm. by 2 mm., with notably good cleavages. Along the cracks there is a good deal of alteration into serpentine, the fibres standing at right angles to the cracks. Another remarkable feature about these large olivines is that peripherally they are moulded on the felspars of the second generation. The olivines of the base are of small dimensions and almost completely serpentinized.

Augite is in brownish-grey grains and imperfect prisms 0·2 mm. long. It is entirely interstitial in character but is not ophitic (granulitic according to Judd).

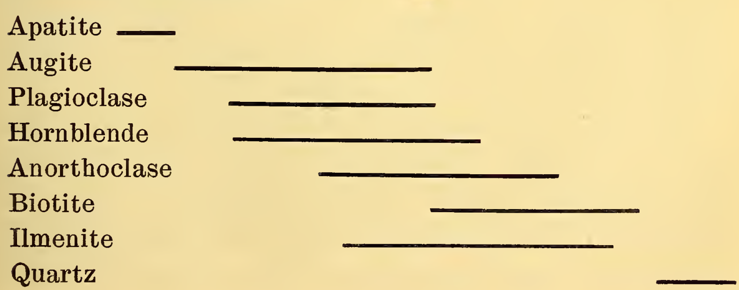
Ilmenite occurs in plates and irregular grains enclosing felspars but themselves moulded by augite. Also enclosed in olivine and augite are a few octahedra of magnetite, but most of the iron ore of the rock has the irregular habit of ilmenite.

There is much apatite in thin needles of a faint but decided greenish tint. This is enclosed in all the felspars, but not a single example of its inclusion in olivine was noted. The abundant chlorite is distributed in such a way as to suggest the infilling of numerous microlitic spaces. There is a good deal of zeolite filling small irregular spaces. It is of two kinds, (i.) cloudy brown almost opaque material which is indeterminate, and (ii.) a clear fibrous mineral answering to stilbite.

Quartz syenite, Mumbilla-Engelburg Road.—Hypidiomorphic granular rock of rather variable grainsize. The most abundant mineral is anorthoclase in prismatic sections. It is perfectly fresh and is simple, shows twinning after the Carlsbad law. The refractive index is always less than that of Canada balsam or quartz, and the symmetrical extinctions of the two halves of the Carlsbad twins give readings of 9°. On untwinned sections the extinction is + 10°. In addition to this dominant felspar there is a small quantity of oligoclase in subidiomorphic sections with well marked peripheral outgrowths of anorthoclase in crystal continuity. Quartz is not abundant, it occurs interstitially in irregular grains.

The coloured constituents are subordinate in amount. Augite is in stout prisms, greenish-brown in colour, averaging about 0·2 mm. by 0·1 mm., but very many are much more slender. These have a peripheral border of dark green hornblende and very frequently quite considerable terminal extensions of the same mineral. This latter occurs also in independent crystals but not abundantly.

Scattered through the slide are ragged and subidiomorphic flakes of exceptionally dark brown biotite. The vibrations at right angles to the cleavage give a dark brown colour, those parallel to the cleavage are completely absorbed. There are plentiful thin flakes of ilmenite up to 0·2 mm. by 0·01 mm. Apatite is exceptionally abundant in excessively thin needles up to 0·3 mm. In some of the felspar crystals there is a perfect tangle of such fibres. The order of consolidation is as follows :—



Olivine basalt, Summit of Mount Mitchell.—The rock is hyalopilitic. The great bulk of it is made up of minute singly twinned felspar microlites with very perfect fluidal arrangement. At first sight these appear to be sanidine, as their extinction is almost straight, and there are no albite lamellæ visible. The refractive index however is greater than that of cooked Canada balsam, so that the mineral is oligoclase. There is very plentiful magnetite in minute idiomorphic crystals.

Much less abundant is augite in yellowish-grey subidiomorphic grains, interstitial between the felspar laths. A little ilmenite in very thin plates can be made out.

There is quite abundant interstitial glass, brown to brownish-green in colour and quite isotropic.

Scattered small crystals of olivine up to 0·5 by 0·2 mm. give the rock a porphyritic appearance on a small scale.

A very few plagioclase crystals of the same order of size also occur. Some of these are untwinned and look extremly like nepheline, but yield a biaxial figure in convergent light.

Some of the magnetite grains rise to porphyritic dimensions.

Rounded masses of small size of fibrous secondary material occur, apparently natrolite.

Porphyritic olivine basalt, Summit of Spicer's Peak.—The rock has a pilotaxitic base of oligoclase microlites, tiny octahedra of magnetite, needles of augite and small pseudomorphs of serpentine after olivine. The arrangement is strongly fluidal; no glass is present.

Scattered phenocrysts of acid labradorite up to 5 mm. by 2 mm. occur. These are very clear and free from decomposition and show perfect examples of Carlsbad, albite and pericline twinning. They contain fairly abundant inclusions of augite granules and long subparallel streaks of a colourless mineral with low refractive index and weak double refraction. This is probably another felspar intergrown with that of the large crystal, but the material was insufficient for precise determination.

Quite scarce are pseudomorphs of brown serpentine after olivine. The shape and internal structure of the original are preserved.

The secondary material is strongly pleochroic, and its double refraction is quite strong for serpentine.

There is much apatite in tiny needles. Small spaces, up to 1 mm. in diameter, mostly quite irregular in shape are filled with zeolites, some with analcite, some with stilbite.

PRELIMINARY NOTE ON THE GEOLOGY OF THE KEMPSEY DISTRICT.

By W. G. Woolnough, D.Sc., F.G.S., Lecturer in Applied Geology and Mineralogy, University of Sydney.

[With Plate V.]

[*Read before the Royal Society of N. S. Wales, August 2, 1911.*]

The author hopes to have an opportunity, in the very near future, of spending sufficient time in the field on the Macleay and Manning Rivers to enable him to lay before the Royal Society a fairly complete account of their geological history. The results obtained during a brief visit in January and February of this year seem, however, of sufficient interest and importance to justify an immediate statement, which may serve as a guide to other observers should it be impossible for the author to carry out his intended investigation.

Geology of the Macleay River Area.

Approaching Kempsey from the New England Tableland viâ Armidale, the dominant formation met with on the Upper Macleay is an intensely jointed slate. No fossils have been met with in this slate series, so the age is uncertain. The dips are at very high angles; and jointing in several directions, also steeply inclined to the horizontal, splits the slates into long prismatic pieces like large slate pencils. These rocks may be as old as Silurian, to which system they were referred by Clarke. Bands of conglomerate occur at intervals, (as *e.g.*, near Bellbrook) and may be of value as a clue to the age of the beds, and as persistent horizons for working out their distribution.

These Silurian (?) rocks are strongly intruded by a mass of biotite granite, extensively developed near the junction of George's Creek and the Macleay.

At Anderson's Peak near Bellbrook, there occurs a capping of basalt some hundreds of feet in thickness resting upon an isolated peak composed of slates.

On the east, the Silurian rocks are bounded by a series of contorted and cleaved quartzites and slates which we may refer to as the Kempsey slates. The boundary appears to be near Hickey's Creek, where a heavy conglomerate is met with. In the road sections between Hickey's Creek and Kempsey, the slaty rocks exhibit dips in all directions and there does not seem to be any well defined axis of folding.

On the coast between Smoky Cape and South West Rocks, what appear to be the equivalents of the Kempsey slates occur in broad undulations but with an approximately horizontal disposition as a whole. They are black in colour and intensely hard, as the result of contact metamorphism. This effect is produced by two masses of intrusive rock. The bold promontory of Smoky Cape consists of a porphyrite of most handsome appearance; the groundmass is light grey, and through it are scattered very abundant phenocrysts of white felspar up to one-third of an inch diameter and less conspicuous crystals of dark hornblende. When polished it should make one of the most beautiful building stones imaginable.

Connected with this mass are numerous sills of light-coloured, fine-grained felsitic rock, intruding the black sediments lying to the north of the Cape. At Arakoon there is a small boss of granite whose junction with the dark sedimentary rocks to the south of it is a very conspicuous feature in the cliff section. The granite varies from grey to pink, the latter colour being produced by an abundance of large idiomorphic, flesh-coloured, crystals of orthoclase. In the quarry face at the Trial Bay Prison the granite is seen to be crowded with large angular blocks of intensely altered sedimentary rock, and, as the junction line is approached, these masses become larger and more numerous till they attain dimensions up to 40 feet in length. The granite mass is quite a small one and does not extend as far as South West Rocks where the slaty rocks again put in an appearance. At the New Entrance to the Macleay the quarries for materials for the breakwater expose a remarkable conglomerate. In general appearance and in the sporadic distribution of its pebbles it suggests a glacial till, but I have no distinct evidence for or against such an idea. Between this isolated mass of highland and Kempsey stretch the alluvials and swamps of the Lower Macleay.

Another coastal headland further south, Crescent Head, deserves mention. The headland itself consists of greyish shales and sandstones dipping in a northerly direction.

During the time at my disposal I searched for fossils but found only undeterminable plant remains, probably *Equisetaceæ* of some kind.

About two miles inland from Crescent Head, and separated from it by a belt of swampy land, is a steep escarpment consisting of very massive conglomerates. The form of the escarpment is very strongly suggestive of a fault parallel to the coast. The lithological character of the conglomerate is similar to that of the rocks of Camden Haven, which have been determined by Carne as Trias-Jura. The conglomerate extends inland for a considerable distance, but is mostly hidden by the marshy alluvials which are so strongly developed in this area.

On the southern side of the Macleay River above Kempsey there occur rocks of very great importance from the point of view of Australian stratigraphy, and it is to these I wish to direct attention especially.

Crossing the river at Sherwood we come almost immediately upon conglomerates interstratified with the Kempsey slates, but in this neighbourhood their relationships are not at all clearly defined.

Following the road to Moparrabah and Willi Willi, in a general west-north-westerly direction, an extensive series of chocolate and olive-green crumbly shales are encountered. These have a fairly uniform dip of N. 30° W. at 15°.

At Portion 109, Parish Kullatine, a massive belt of crinoidal limestone crosses the track, but the rocks immediately associated with it are not exposed. Inclusive of the occurrence just noted, the track crosses similar belts of limestone three times between this point and Moparrabah. In each instance the beds seem to be passed in descending sequence, though this is not certain. There may be several bands of limestone, or lenticular masses of this rock upon different horizons, or one and the same band may have been displaced by a series of step faults, throwing in a general easterly direction. Which of these explanations is the correct one must be decided by detailed mapping of the district; at present I am inclined to favour the idea of dislocation of a single bed by faulting. The limestone belt extends more or less continuously in a general E.S.E. to W.N.W. direction for upwards of 22 miles, and may be even more extensive inland. At various points limestone caves are developed, as at Yessabah, Moparrabah and Sebastopol. None of those examined by me are of great extent or conspicuous beauty, but I was informed that some of the caverns to the west of Sebastopol are finer than any of those I saw. In one place on Tait's Creek there is said to be a fine natural bridge across the valley.

The most extensive development of limestone is at Sebastopol, where a magnificent escarpment of this rock rises about 1,000 feet above the valley of Tait's Creek. The main mass of limestone is about 250 feet in thickness, and forms a vertical wall of cliff at the summit of the steep slope above mentioned. The rock is very dense and somewhat crystalline, but an abundant and fairly well preserved fauna has been obtained from it, proving its age to be Permo-Carboniferous. The facies of the fauna suggests that the horizon of the limestones here may be the same as that of the limestones at Pokolbin in the type district of the Hunter River. The bed dips N. 10° W. at 25° to 28° and the slope in that direction from the summit of the cliff is fairly gradual.

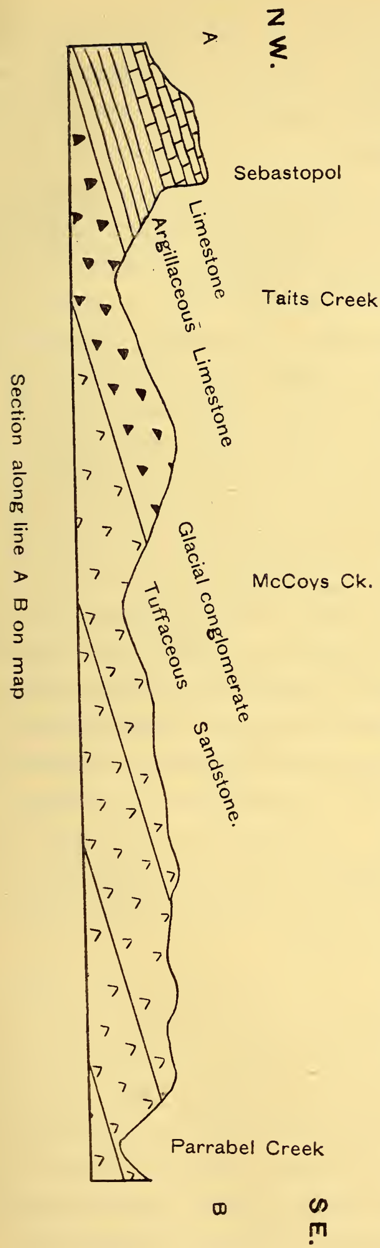
Towards its base the massive limestone reef passes into flaggy argillaceous limestone and this into chocolate and blue calcareous shales, which support a dense subtropical "brush" on the southern side of Sebastopol. This "brush" hides the continuation of the section at this spot, but in the clearer timbered country to the east it is found that the shales pass downwards into chocolate mudstones strikingly like those of Lochinvar on the Hunter, and, like the latter, containing numerous erratics, some of which are of considerable size. Some of these are distinctly glaciated and no doubt, a careful search would reveal many such.

At Stony Creek, about Portion 156, Parish Kullatine, the road cutting exposes a splendid section of the same formation. Here the chocolate groundmass is crowded with sharply angular rock fragments, mostly of small size, but contains abundant large erratics, scattered through it, singly or in groups. These erratics consist mostly of granites and reddish quartzites, and do not, so far as I have observed, show any examples of the hard tuff to be described presently. One of the erratics from this locality, a boulder of quartzite about 12 inches long by 8 inches in diameter is beautifully glaciated. This occurrence of till lies in the same position with respect to the limestone belt as that at Sebastopol.

There can be no reasonable doubt that we are here dealing with a new and very extensive development of the Lochinvar Glacial Beds of the Hunter Valley, described by Professor David.[1] In the type district these Glacial Beds form the base of the Permo-Carboniferous System, and rest unconformably on Rhacopteris Beds belonging to the Carboniferous System.

The great interest and importance of the Upper Macleay Permo-Carboniferous is that the Glacial Beds do not appear to be the basal beds of the system, but seem to be underlain by a great, but at present undetermined, thickness of conformably bedded tuffs. In Parabel Creek these dip N. 10° W. at 25°. The continuity of the section is not all that could be desired, as the wide valley of Parabel Creek intervenes between the Glacial Beds and the nearest outcrop of the tuff to the south, but the first beds of the latter which are met with in that direction conform pretty closely

[1] Discovery of Glaciated Boulders at Base of Permo-Carboniferous System, Lochinvar, N.S.W., Prof. T. W. E. David, this Journal, Vol. XXXIII.



in direction and amount of dip to the definite Permo-Carboniferous sediments. As already stated, the latter are by no means uniform in their dip and the divergence between the inclinations of the tuff and the limestones is not so great as the differences found in the dip of the latter. While this slight element of doubt as to the continuity of the section exists with respect to the Moparrabah area, a comparison with the Manning River formations to be described later, throws the balance of probability strongly in favour of conformity of the entire series. At the time of my visit Parabel Creek was in heavy flood, so that the measurement of the section could not be continued southwards, but even within that portion examined, a very considerable thickness of sub-glacial tuffaceous beds is revealed.

These rocks vary from bluish fine grained flaggy beds to coarse tuffaceous sandstones of a greenish or purplish colour.

Between the Macleay and Manning Rivers no detailed examination was attempted, though the formations developed and the relationships between them are of very great interest and importance.

On the Manning River several excursions were taken with Taree as a centre, and considerable collections of rocks were made by enthusiastic residents.

About two miles east of Taree a thick bed of limestone dipping N.E. at 43° crosses the main road. At this point the limestone is bluish-grey, rather crystalline, and contains no fossils except a few crinoid stems. What appears to be the same bed of limestone was picked up at intervals for a distance of about seven miles, in a general west-north-westerly direction to a point near Wingham. At the Taree Rifle Range the limestone is dark greyish-brown and distinctly oolitic. At Ahearn's (five miles from Taree on the Cedar Party Creek Road) it passes into a handsome reddish marble, while at Wingham it is a greenish crystalline limestone. At Ahearn's there are numerous pebbles of slaty and schistose rock up to four inches diameter, embedded in the limestone in a way which suggests the "dumping" of small erratics by icebergs. At Wingham well preserved specimens of large *Aviculopectens* occur, indicating that the bed is of the same age as, and probably identical with, the limestone of the Macleay River.

No very decisive evidence of the existence of the Lochinvar glacials on the Manning has been obtained so far. A strong bed of conglomerate occurs below the limestone at Taree in the correct position for the glacial bed, but I was unable to satisfy myself definitely as to its glacial character. At Ahearn's, immediately below the limestone there is a bluish gritty bed, almost a breccia in places, but here again no very conclusive proof of glacial origin is forthcoming.

Stratigraphically below the limestone, and undoubtedly conformable with them there is an immense series of greenish tuffs and tuffaceous slates, considerably contorted and faulted, so that its exact thickness cannot be estimated at present. This series is closely similar in lithological character to the sub-glacial tuff of the Macleay River, and I feel quite confident as to the identity of the two formations. A very important fact is that certain horizons (or a certain horizon) in the Manning area is richly fossiliferous. In the railway ballast quarry at the Devil's Elbow (about five miles along the line from Taree towards Wingham) there is exposed a massive bed of greenish tuff which contains abundant casts of *Pachydomus*, which Mr. Dun recognises as being very similar to a form occurring in the Gympie Series at Gympie in Queensland. Very numerous specimens of this fossil are to be obtained from the railway ballast derived from this quarry. What is probably the same bed occurs in a railway cutting west of Kiliwarra Railway Station, and here again *Pachydomus* is abundant. If these two occurrences are parts of one bed it should provide a most useful persistent horizon in geologically mapping the district.

The discovery of this fossil determines the age of the beds as Permo-Carboniferous, and, taken in conjunction with the evidence of the Macleay beds, indicates a vast thickness of subglacial beds of that age. A comparison of the lithological characters of this subglacial tuffaceous series, with those of the gold bearing rocks of Gympie itself, shows a very striking similarity between the two formations, and I venture to suggest that we may tentatively assume, as a working hypothesis, that the Gympie System of the Queensland geologists includes the subglacial portions of the Manning and Macleay beds. If this is so, a detailed survey of the areas described in this note is likely to clear up many of the points which now present difficulties in correlating the geological formations of New South Wales and Queensland.

Rocks of undoubted Carboniferous age occur in the Manning River area. At Crowdy Head are tuffaceous rocks, not essentially different lithologically from the subglacial tuff above referred to. But while the latter beds dip mostly northerly or north-easterly, the Crowdy Head beds dip southerly, this suggests an unconformity. The presence in the Crowdy Head beds of *Knorria* and very abundant plant impressions indicates their Carboniferous affinities. The Cape Hawke beds, to be described in a paper by Messrs. Briggs and Watson, conform in direction of dip to the Crowdy Head beds. Between Krambach and Gloucester the dips are mostly southerly, and at Copeland, where lithologically similar beds are developed, *Lepidodendron* has been met with.[1] The correlation of the *Lepidodendron* beds with those containing *Pachydomus* is a work of first rate importance in Australian stratigraphy, and it is the intention of the author to endeavour to carry out this work in the near future.

My thanks are due to the many residents of the Kempsey, Taree and Gloucester districts who assisted me by advice, hospitality and transport. I wish to express my gratitude also to Messrs. Briggs and Watson, students at the Sydney University, for their loyal and unselfish assistance under far from pleasant conditions of field work. Professor David and Mr. Dun have been ever ready with advice and help at all points, and to them my best thanks are gratefully rendered.

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[1] Ann. Rep. Dept. of Mines for 1889, p. 230, and Min. Prod. N.S. Wales 1887, p. 60.

THE EFFECT OF HEATING AND ANTISEPTIC TREATMENT ON THE SOLUBILITY OF FERTILISING INGREDIENTS IN SOILS.

By H. I. JENSEN, D.Sc.,
Chemist's Branch, The Department of Agriculture of New South Wales.

[*Read before the Royal Society of N. S. Wales, August 2, 1911.*]

IN the end of 1909 Russell and Hutchison[1] announced the interesting discovery that when a soil is heated to 95° C. it produced two, three or four times as much crop as a portion of the same soil which had not been so heated. They also found that the treatment of a soil with volatile antisceptics (toluene, carbon bisulphide and other substances) led to an increase in crop varying from 20% to 50%. They concluded that treatment of the soil by these means led to an accumulation of ammonia in the soil and an increase of unstable nitrogen compounds. This increase was not at the expense of the humus, but a slight increase in humic nitrogen was also noted. The change in total nitrogen after partial sterilisation is not great, there being an increased amount of ammonia and a diminished amount of nitric nitrogen present.

Partial sterilisation therefore seems to increase the activity of ammonia-producing bacteria, and Russell and Hutchison explain the increased bacterial activity as being due to the destruction by partial sterilisation of amœbæ and like organisms which feed on bacteria.

Pickering[2] showed in December 1908 that soil heated or treated with antiseptics contains more water soluble salts

[1] The Journal of Agricultural Science, Vol. III, part 2, Oct. 1909.
[2] *Ibid.*, Vol. III, part 1, Dec. 1908, also *ibid.*, Vol. III, part 3, Sept. 1910.

and more water soluble organic matter than untreated soils. The increase of soluble matter in the treated soils is not great but it is definite. His tables show that the increase of water soluble organic matter greatly exceeds the increase of water soluble salts.

In 1910[1] and Jan. 1911[2] Dr. Greig-Smith read papers in which he maintained that the increased fertility of treated soils is due to heat and antiseptics having the effect of removing from the soil particles an organic fatty substance, termed by him 'agricere,' which he supposes to waterproof the particles and to prevent the assimilation of plant food.

If this is the correct explanation of increased fertility due to heating or antiseptic treatment of soil there should be a marked increase in soluble plant food of heated and treated soils as compared with untreated ones.

Pickering shows a slight increase in the water soluble material of heated and treated soils as compared with the same soils not treated, but his figures hardly show sufficiently marked increases to account for the great increase in fertility noticed by Russell and Hutchison.

If Dr. Greig-Smith's theory be correct the increase in the amounts of fertilising constituents should be even more marked when stronger solvents than distilled water are used, for the agricere would tend to protect the soil particles from the action of citric acid, hydrochloric acid or nitric acid. At any rate one would expect noticeable results from the citric acid treatment.

Analyses were undertaken with a view of testing whether this is the case or not, and the results are given in the following tables. It was expected that if agricere pro-

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[1] Proc. Linn. Soc. N.S.W., 1910.
[2] Austr. Assoc. for Adv. Sci., Sydney Meeting, 1911.

tected the soil particles from solution, by waterproofing them to a sufficient degree to affect fertility, the treated soils should contain at least from 30% to 50% more plant food than the untreated. This should be especially the case where citric acid is used as a solvent, since this acid is supposed to extract only available plant food. According to the work of Pickering, more marked increases should be obtained from heated soils than from those treated with antiseptics.

The following are the soils examined :—

1. A red sandy loam from the Grafton Experiment Farm—very fertile and containing 8% volatile matter.
2. A red heavy loam derived from andesite and ironstone on the Bundarra road five miles from Armidale—rather sour and infertile ; 9% volatile.
3. A red loam derived from conglomerate on the Bundarra road, four miles from Armidale—sweet and fertile, containing 12% volatile matter.
4. A black basaltic soil from Kelly's Plains, near Armidale—very rich and fertile, and containing 12% volatile matter.
5. An alluvial soil from the Gloucester River, North Coast—very rich and fertile and containing 13% organic matter.
6. A drift soil from the old Nepean alluvials south-east of Penrith—very poor barren country, containing 2% volatile matter.

In the following tables (a) *denotes determinations made with special precautions to ensure absolutely pure precipitates, such as repaated precipitations of the iron to remove traces of lime, and the removal of manganese from the lime precipitate etc.; whereas* (b) *denotes determinations made without such special precaution.*

Table I. *Estimation of Fertilising Ingredients (per cent.) taken up by boiling in HCl, Sp. Gr. 1·1.*

No.	Locality.	Quality.	Colour.	Lime.			Potash.		Phosphoric Acid.	
					Untreated.	Heated.	Untreated.	Heated.	Untreated.	Heated.
1	Scrub Soil, Grafton Experiment Farm.	Fertile, about 8% organic matter.	Red	(a)	·101	·110	·063	·059 / ·057	·245	·272
				(b)	·086 / ·096	·110			·230	·210
2	Ironstone and Andesite Soil, Armidale District	Sour, c. 9% organic matter,	Red	(a)	·196	·198	·078	·089	·223	·211
				(b)	·208 / ·186	·248	087			
3	Ironstone Conglomerate Soil, Armidale District.	Fertile, about 12% organic matter.	Red	(a)	·318	·355	061	051	·399	·311
				(b)	·366 / ·361	·480 ?	·087	·091	·123	
4	Black Basaltic Soil, Kelly's Plains, Armidale District	Very fertile, 12% organic matter.	Black	(a)	·500	·486	·109	·120	·123	·133
							·106			
5	Alluvial, Gloucester River.	Very fertile, 13% organic matter.	Black	(a)	·536	·540	·175	·163	·141	·141
6	Drift, Warragamba Area.	Hungry, 1% of organic matter.	Light	(a)	·130	·128	·029	·022	·020	·020

Table II. *Estimation of Mineral Plant Food Soluble in 1% Citric Acid.*

No.	Lime.		Potash.		Phosphoric Acid.	
*	Untreated.	Heated.	Untreated.	Heated.	Untreated.	Heated.
1	·066	·066	·022	·016	·037	·042
2	not determined.					
3	·273	·259	·017	·009	·032	·032
4	not determined.					
5	·251	·275	·026	·016	·027	·028
6	·0148	·0136	·007	·010	·003	·003

* For particulars see Table I.

Table III. *Estimation of Mineral Plant Food Soluble in N/5 Nitric Acid.*

No.	Lime.		Potash.		Phosphoric Acid.	
*	Untreated.	Heated.	Untreated.	Heated.	Untreated.	Heated.
1	(a) ·084	·084	·051	·045	·064	·041
	(b) { ·096	{ ·102				
	·096	·085				
2	(a) ·252	·228	·052	·058	·067	·077
	(b) { ·258	{ ·240			{ ·064	
	·258	·222			·064	
3	(a) ·339	·353	·050	·048	·060	·079
	(b) { ·417	{ ·414				
	·342	·406				

* For particulars see Table I.

From the figures obtained it is clearly evident that treatment by heat or antiseptics makes no appreciable difference in the solubility of the mineral fertilising ingredients in acids. The differences obtained are not very great nor in a constant direction, and are probably due to accidental inaccuracies.

It may be taken for granted from Pickering's researches that there is a distinct increase in the water soluble organic matter of heated and treated soils. This difference is however, not large enough to account for the differences in fertility described by Russell and Hutchison.

The evidence is therefore decidedly in favour of the view taken by Russell and Hutchison, that the increased fertility is due to the destruction of the protozoa and nitric acid producing bacteria and a quick revival of the ammonia forming bacterial flora.

While the work done fails to give any support to Dr. Greig-Smith's theory of 'waterproofing,' there is still a strong possibility that 'agricere' or 'agrostearol' is a toxic substance whose poisonous action is somewhat reduced by heating or by the use of volatile antiseptics to remove it to the aerated soil crust.

In a recent paper by G. S. Fraps of the Texas Agricultural Experiment Station it is stated that the acid soluble soil phosphate is increased by ignition of the soil. Our work has failed to give any evidence of the truth of this statement, and Mr. Hargraves, Chief of the Chemical Agricultural Laboratory of South Australia, verbally informed me that in his department investigations had been made which proved that ignition did not increase the amount of any of the fertilising ingredients of soils extracted by acids.

Mr. Fraps[1] shows that certain natural phosphate minerals are rendered more acid soluble by ignition, but probably these minerals are not abundant in our soils. In one respect we can confirm the work of Mr. Fraps, namely, when he states that the acid soluble iron and alumina of a soil is increased by ignition. This has been frequently noticed in

[1] Journal of Industrial and Engineering Chemistry, May 1911, Vol. III, No. 5.

the course of the present work. Possibly the definite increases noticed by Pickering in the water soluble material of treated soils consist mainly of increased silica, iron and alumina rather than of fertilising constituents.

Unsatisfactory as the results are, this work has served the purpose of once more independently testing the various methods of soil analysis as measures of fertility.

The same soils were analysed by the hydrochloric, citric, and $N/5$ nitric acid methods, and in none of the estimations were excessive differences noticed between the treated and untreated soils.

Since the work of Russell and Hutchison has quite established an increase in fertility due to such treatment, it follows that neither the citric acid nor the $N/5$ nitric acid method is a better guide to fertility than the hydrochloric method.

In other words while existing methods of soil analysis give us some idea of the amount of mineral plant food in a soil in different stages of solubility, they do not tell us whether a soil is fertile or infertile, or what treatment will make a soil more fertile. In fact, it is vain to expect a soil analysis to indicate the state of present fertility, a condition depending on meteorological, biological and physical considerations to a much greater extent than on chemical composition.

In conclusion I wish to thank Mr. F. B. Guthrie for his continual cooperation in this work which was undertaken at his suggestion. Throughout the course of this research I have been liberally assisted by Mr. Guthrie with advice and references to literature, for which I desire to express my cordial thanks.

PRELIMINARY NOTE ON THE NEPHELINE-BEARING ROCKS OF THE LIVERPOOL AND MOUNT ROYAL RANGES.

By W. N. BENSON, B.Sc.

With Plates VI, VII.

[*Read before the Royal Society of N. S. Wales, August 2, 1911.*]

About two years ago, when first in the Nundle district, the writer noticed the great abundance, in the gravels of the Peel River, of pebbles of a remarkable coarse-grained basic rock with large dark purple-brown phenocrysts of augite. An examination of slices of these under the microscope showed that the augites were strongly zoned, sometimes having the hour-glass structure, and were highly titaniferous, while there were a number of large apatite prisms. The general facies strongly recalled the famous nepheline dolerite of the Löbauer Berg in Saxony. Nevertheless no nepheline was detected, the salic mineral being labradorite. Similar rocks were found later at Crawney, probably *in situ*, some fourteen miles further up the river than Nundle. Want of time prevented the investigation of their field relationships. While on a brief visit to Goonoo Goonoo, a small pipe of the rock was found forming a slight elevation (Currajong Hill) about a mile south-east of the station. A further large extension of these rocks was suggested by the following observation made by Mr. E. C. Andrews:—"At the Hunter and Manning River headwaters two distinct basaltic types occur, one a holocrystalline rock with large augite crystals so abundantly scattered throughout its mass as to obtain for it locally the name of 'plum pudding stone.' Other types found here are dense fine-grained vesicular olivine basalts."

[1] Tertiary History of New England, Rec. Geol. Surv. N.S.W., Vol. VII, pt. 3, p. 63, 1903.

Some months later on examining a collection of rocks given by Mr. Eustace Wilkinson of Pokolbin near Maitland to Mr. R. E. Priestley, F.G.S., a similar porphyritic rock was found, and, on sectioning, abundant nepheline was clearly visible. In letters from Mr. Wilkinson I learn the following particulars: The rocks occur in a large series, stretching from Stewart's Brook to the Barrington Trigonometrical Survey Station, a distance of 10 miles. They appear everywhere to overlie a dense normal olivine basalt, and this in turn overlies steeply dipping cherts, sandstones, and shales, carrying such typically Carboniferous forms as *Orthotetes crenistria*, *Spirifera striata*, *Orthonychia*, *Capulus* cf. *Oehlerti*, De Kon., with abundant crinoid stems. The fossils were kindly determined by Mr. W. S. Dun in specimens forwarded by Mr. Wilkinson.

The section exposed on the Barrington Trig. as observed by Mr. Wilkinson, is shown in fig. 1. He remarked, however, that it was drawn from memory, and that it had been possible to devote but a short time to its examination. And further, that as it was chiefly rocks of rather unusual appearance that he collected, normal basaltic rocks were sometimes passed over. Nevertheless he is emphatic on the highly important observation that the coarse-grained dolerites overlie normal olivine basalts.

A final visit proved that rocks of this type occurred near Nundle. They cap Square Top Hill, which lies three miles to the west of the township, and under the microscope prove to contain abundant nepheline.

There is evidently here a field of great extent geographically, (Stewart's Brook and Nundle are more than forty miles apart), and of considerable interest petrographically, see fig. 2. In view of the writer's approaching departure for England, it was thought well to collect into a brief note the scanty data available on these rocks to direct attention to their occurrence.

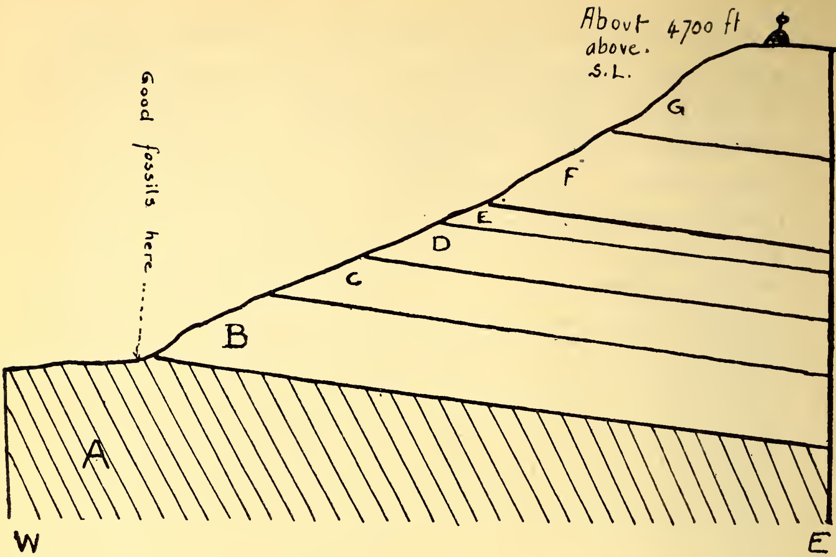

Fig. 1. *Sketch section of Barrington Trigonometrical Station Hill based on observations and collections made by Mr. Eustace Wilkinson.*

A. Carboniferous sandstone slates, shales and conglomerates, dipping in a general easterly direction at from 20° to 86°

B. Dense olivine basalt with large phenocrysts of olivine ; about 500 feet thick (Rock No. 1).

C. Olivine dolerite (Rock No. 2) with natrolite. The most persistent rock of the district, always overlying the basalt. It merges into the theralites. About 300 feet thick.

D. Theralite of varying grain size and degree of zeolitisation (Rocks No. 3 and 4). It always overlies the finer grained No. 2 rock. About 200 feet thick.

E. Olivine dolerite (No. 2 Rock). About 100 feet thick.

F. Basalt, very decomposed, with vesicles filled with natrolite and analcite. Made up of numerous flows. About 500 feet thick.

G. Olivine dolerite with a little theralite.

Fig. 2.

Petrologically the rocks may be termed dolerites, using the term in its widest possible sense. They are holocrystalline aggregates of augite and plagioclase with large ilmenite crystals occasionally developed, but owing to the presence or absence of olivine, orthoclase, and nepheline, and the variation in texture, they may fall into the more strictly defined divisions of the olivine dolerites, the essexites, the theralites and the basanites. The most remarkable rocks are the theralites (Nos. 3 and 4 of Mr. Wilkinson's figure) that occur on the slopes of Barrington Trig. These two rocks differ only in grain size and amount of zeolite developed. They are very coarsely granular with exceedingly well marked zonary structure in their deep purple augites. The predominant salic mineral is a labradorite in tabular crystals, and there are also large crystals of ilmenite and prisms of apatite. In addition to this, there is a certain amount of clear nepheline. All these different minerals can readily be distinguished with the naked eye in the slide of No. 4, of which *Plate* 6, fig. 1 is a photograph. In addition, there is a small amount of zeolite developed by alteration of the nepheline.

The most interesting feature, perhaps, is the occurrence of a second generation of augite of a more greenish tint than that of the phenocrysts, and this forms a granophyric intergrowth with the nepheline, either in little hooked-like pieces fig. 3 (a), or in peculiar arrow-head shapes fig. 3 (b).[1]

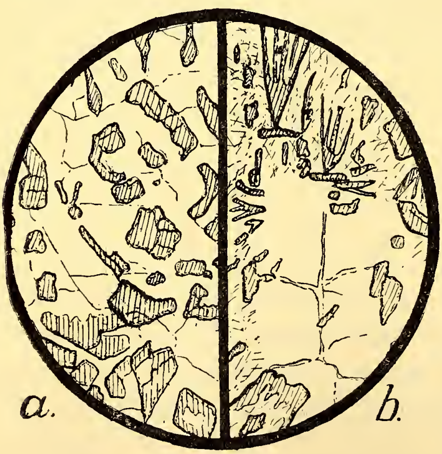

Fig. 3. *Graphic intergrowths of augite shaded, and nepheline clear, in theralite.*

(*a*) from Stewart's Brook, magnified 80 diameters.

(*b*) from Barrington Trigonometrical Station hill, magnified 22 diam.

This is an enlarged drawing of the large nepheline grain visible in the centre of fig. 1, *Plate* 6.

[1] *Cf.* Fig. 89 B, A. Harker, The Natural History of Igneous Rocks, p. 271.

This intergrowth of augite and nepheline, though not unknown, is a very rare petrological feature. It is developed in the Löbauer Berg rock above mentioned to a finer degree than here figured. In the Stewart's Brook rock there are small aggregates of chlorite, probably pseudomorphous after olivine, but these are absent from the Barrington rock. This type of rock seems best classed as a theralite. The low percentage of silica suggested by the abundance of nepheline is confirmed by the fact that a determination of silica showed the presence of 42·54% only.

No. 2 of the Barrington series, which Mr. Wilkinson remarks appears to pass by transitions into the other types (3 and 4), has a very different fabric, the tabular plagioclases having a more parallel arrangement (fig. 2, *Plate 6*). There seems to be no definite nepheline, but there are present, interstitially, cloudy areas of a very low refractive index, which may represent altered orthoclase, though the occasional presence in them of spherulites of natrolite suggests the possibility of the derivation from nepheline. The augite occurs in large irregular grains with a slight development of the ophitic structure. The presence of numerous small inclusions of olivine and felspar gives it a curiously pitted appearance. Olivine also forms numerous large idiomorphic crystals. Ilmenite is abundant in small plates, but apatite is rare.

In the majority of the doleritic pebbles of the Peel River gravels, the structure is rather intermediate between those of the rocks described above. The tabular felspars have not much parallel arrangement, the augites are varied in the extent to which they show ophitic structure or idiomorphism, but are always purple. Olivine is abundant, ilmenite frequent in small grains, and apatite is not very common. In one instance orthoclase is present, forming interstitial intergrowths with plagioclase, and occasionally occurs in individual grains. It is in very small amount however. Nepheline does not seem to be present in any of the slides I have examined.

Two extreme types call for special notice. The exceedingly coarse-grained rock illustrated in *Plate 7*, is composed of large crystals of augite up to two centimetres in diameter, with smaller crystals of olivine and plagioclase. There are also small crystals of ilmenite and apatite. Between the large crystals is a little fine-grained ground-mass composed of tiny felspar laths, some of them possibly sanidine, and pale yellow-brown masses of a platy zeolitic material, the precise nature of which must be left for future examination. Here and there are aggregates of very minute graphic crystallisations and rods of brown-grey augite of the second generation. This is very similar in many respects to the augite that is intercrystallised with the nepheline of the rocks described above. The rock must provisionally be classed as a porphyritic olivine dolerite. The same name is to be applied to a rock of a very different appearance, namely, that figured in fig. 3, *Plate 6*. It consists of large phenocrysts, up to 4 millimetres in diameter, of augite and olivine, set in an almost basaltic ground-mass composed of abundant small grains of ilmenite and purple augite with felspar laths. A little of the yellowish zeolite is present, and a very few small olivines. There appears to be a third generation of minute brown-grey arrow-heads and needles of pyroxene developing interstitially.

The only definitely nephelinic rock yet found near Nundle is that from Square Top. It forms a capping two hundred feet thick on the summit of the hill, but its mode of occurrence was not proved. There were apparently no underlying Tertiary gravels. In hand specimens the rock is dark grey, with dark purple-brown augites, and on weathered surfaces white felspar laths can be distinguished. Its microscopical appearance is shown by fig. 4, *Plate 6.* It is seen to contain large, perfectly developed, phenocrysts of purple augite which have often an exterior zone full of minute inclusions of ilmenite, olivine, and scraps of plagioclase, giving a very pitted appearance. Usually the colour changes from strong purplish pink on the inner portion of this zone, to greenish-grey on the outer portion. These phenocrysts are up to three millimetres in diameter. There are numerous smaller phenocrysts of olivine. The ground-mass consists of short felspar laths, many of which are sanidine, and abundant hexagonal prisms of nepheline. A good deal of this has been changed into natrolite. As this rock has a much finer grain than any of the others and a far more volcanic habit, it may be termed a nepheline basanite. The small amount of plagioclase present prevents it from falling directly under the nepheline basalts, using the term in its strict sense.

A mile south-east of Goonoo Goonoo Station and about twenty miles north-west of Nundle is a small knoll, Currajong Hill. On a very hasty examination it appeared to be a neck about ten yards (from memory) in diameter composed of a coarse grained rock of granite texture with dark purple black pyroxene. On section, this proves to be also closely related to the rocks above described. It is a remarkably fresh rock, and contains large purple augites, clear olivines, large labradorite tabulae, with a fair amount of interstitial orthoclase. Numerous small crystals of ilmenite are present, often surrounded by bright red-brown pleochroic biotite. Apatite prisms are well developed. The rock is best termed an essexite.

Here attention should be drawn to the similarity, several times remarked upon by Dr. Jensen,[1] between these rocks and the essexites, described by him, which occur as rolled

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[1] Proc. Linn. Soc. N.S. Wales, Vol. xxxii, p. 883, 1907.

pebbles in Bullawa Creek in the Nandewar Mountains, over one hundred miles N.N.W. of Nundle and Goonoo Goonoo.

With the exception of Mr. Wilkinson's important discovery that these rocks overlie the normal Tertiary olivine basalt, and the writer's discovery of them at Nundle capping a high hill, we have little direct evidence of their mode of occurrence. Nevertheless an observation made by Dr. Woolnough is of importance in this question. He ascended Mount Warrawalong thirty miles W.S.W. of Newcastle and over a hundred miles south of the occurrences described above. He there found the Tertiary basalt cap penetrated by dykes of coarse-grained olivine dolerite. He has generously handed specimens of this rock to me for description.

Microscopically the rock is seen to contain large elongated ophitic crystals of dark purple augite up to two centimetres in length, with felspar tabulæ and interstitial white zeolite. The microscope shows that the augite is strongly titaniferous, and has the hour-glass structure developed to some extent. A peripheral zone of a greenish colour is sometimes developed, the colour-change being usually gradual, though in some instances quite sharp, as though the crystal had grown by secondary enlargement during a later epoch of pyroxene crystallisation. The felspar is chiefly orthoclase, in large or smaller prismatic crystals, idiomorphic against a yellowish zeolitic ground mass. It is mostly glassy and untwinned, but decomposition is commencing along the cracks. Plagioclase tabulæ are also present. The refractive index is distinctly above that of the Canada balsam. There are large crystals of olivine, irregular plates of ilmenite, slightly leucoxenised, and numerous large apatite prisms. Interstitially there is a considerable amount of an almost isotropic yellowish zeolitic material, (analcite ?), like that in the northern rocks. Imbedded in this are minute graphic fragments of green augite, similar to that on the periphery of the phenocrysts. There are also, interstitially, patches of minute plagioclase laths with ophitic green pyroxene. This feature also is exhibited in some of the northern rocks. There are a few large patches of a zeolite of moderate birefringence. This rock is clearly an essexite. A second rock from the same locality and occurrence differs in the almost complete absence of orthoclase. The plagioclase is labradorite, and there is a little yellowish interstitial material with minute felspar laths and augite of the second generation; apatite is rare. This is an olivine dolerite. It is possible, of course, that the essexite is not a distinct occurrence, but that the section examined chanced to pass through a locality of orthoclase segregation in the essexitic dolerite.

It will be seen that the specimens bear features strongly recalling the northern rocks and may be considered to belong to the same series. Their intrusive character into Tertiary basalts supports Mr. Wilkinson's statement that the latter overlie these at Stewart's Brook. The extreme coarseness of grain of the majority of the rocks makes it in the highest degree improbable that they were flows. Might it not be suggested that they will be found to form sills in the Tertiary basalt, and to be comparable to the dolerite sills in the Tertiary igneous series of Skye? It may further be pointed out that the range of mineralogical composition of these rocks is almost paralleled by that of the Tertiary basalts themselves. Some are purely felspathic, some strongly nephelinic.

I have to thank Mr. Eustace Wilkinson for the pains he has taken in supplying me with information and specimens from Stewart's Brook and the Barrington Trig., and Dr. Woolnough for the opportunity of examining the Warrawalong material. To Mr. A. B. Walkom, B.Sc., I am indebted for kindly consenting to correct the proofs in my absence.

Explanation of Plates.

Plate VI, fig. 1—Theralite from Barrington Trigonometrical Station. Note the zoned augite, large ilmenites, cloudy felspar and clear white nepheline × 4. An enlarged drawing of this white patch is shown in text fig. 3.

" 2—Olivine dolerite from the above locality, with plagioclase, augite, olivine, and natrolite × 12.

" 3—Olivine dolerite from the Peel River gravels showing basaltic ground-mass × 11.

" 4—Nepheline basanite, Square Top, Nundle, showing augite phenocrysts, with peripheral zone full of inclusions, olivine, and hexagonal nepheline crystals in the ground mass × 18.

Plate VII, Specimen of porphyritic olivine dolerite from the Peel River gravels near Nundle, with large phenocrysts of titaniferous augite. Scale one half natural size.

Corrigendum to paper entitled "The Volcanic Rocks of Hornsby and Dundas," this Journal, Vol. xliv, pp. 495 – 555, 1910. The analysis of the Hornsby basalt, pp. 544 – 545 was made simultaneously with analyses of several other rocks, and it has since been discovered that the wrong figure for titanic oxide was entered through oversight, in the Hornsby analysis. A redetermination has been completed and the correction must be made as under.

Pages 544 and 545, substitute for the figures given:—

Al_2O_3 17·94% TiO_2 2·64%,

and the following recalculated norm.:—

Orthoclase	13·34	Magnetite	4·64
Albite	31·44	Ilmenite	5·02
Anorthite	24·74	Apatite	1·34
Nepheline	1·14	CO_2	·71
Diopside	9·95	Water	4·12
Olivine	4·54		100·98

On the OCCURRENCE of EXPLOSIVE or BOOMING NOISES (Barisàl Guns) in CENTRAL AUSTRALIA.

By J. Burton Cleland, M.D.

[Read before the Royal Society of N. S. Wales, September 6, 1911.]

The object of this short paper is to call attention to, and to ask for suggestive explanations of, certain loud explosive noises, resembling the booming of distant artillery, which have been heard by myself and others in various parts of central and north-western Australia. My personal experience of this remarkable phenomenon may be quoted from my diary when encamped on the Strelley River in North-west Australia, about Lat. 20° S., sixty miles east of Port Headland.[1] "*Friday, August 9, (1907)*...At half-past eight this evening (8·35), as we lay in our tent, we suddenly heard a dull roar lasting several seconds, increasing in loudness and then decreasing. Every one heard it and looked round. The sky was quite clear and not a sign of thunder. There was no apparent tremor. I thought it came from the S.E., others from the N.E. Some suggested it was the rumble of a herd of cattle galloping over a clay pan with hollow ground below as they hear it in the Kimberly district. Mr. Giles and I wonder if it is a volcanic eruption somewhere, as at Krakatoa in the eighties. *Sat. Aug. 10.* A comet, with a long but not very brilliant tail, in the east early this morning. Some of the men camped twenty miles (west) from here enquired if we had heard the rumble last night; it appears their Afghan jumped up and said, 'Buggy coming.' Whatever the sound was, it was not caused by cattle galloping." This country consists

[1] Vide Nature, June 4, 1908, Vol. LXXVIII, p. 101.

of extensive plains of spinifex *(Triodia)*, crossed by occasional broad but usually dry rivers, with occasional low isolated hills jutting up. Some fifteen miles or more from the camp, a moderate sized range of hills was discernible.

Sturt, during his exploration, heard similar sounds on three occasions. The first was when camped on the newly discovered Darling River, near Bourke, in February 1829. He says[2]:—"About 3 p.m. on the 7th, Mr. Hume and I were occupied tracing the chart upon the ground. The day had been remarkably fine, not a cloud was there in the heavens, nor a breath of air to be felt. On a sudden we heard what seemed to be the report of a gun fired at the distance of between five and six miles. It was not the hollow sound of an earthly explosion, or the sharp cracking noise of falling timber, but in every way resembled a discharge of a heavy piece of ordnance. On this all were agreed, but no one was certain whence the sound proceeded. Both Mr. Hume and myself had been too attentive to our occupation to form a satisfactory opinion; but we both thought it came from the N.W. I sent one of the men immediately up a tree, but he could observe nothing unusual. The country around him appeared to be equally flat on all sides, and to be thickly wooded; whatever occasioned the report, it made a strong impression on all of us; and to this day, the singularity of such a sound, in such a situation, is a matter of mystery to me." The second and third occasions on which Sturt heard this singular phenomenon are recorded as follows[3]:—"When Mr. Browne and I were on our recent journey to the north, after having crossed the Stony Desert (*i.e.*, in September), being then between it and Eyre's Creek, about nine o'clock in the morning, we

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[2] Sturt, Two Expeditions into the Interior of South. Austr., 2nd Edit., 1834, Vol. I, p. 98.

[2] Sturt, Narr. of an Exped. into Central Austr., 1844-6, Vol. II, p. 24.

distinctly heard a report as of a great gun discharged to the westward, at the distance of half a mile. On the following morning, nearly at the same hour, we again heard the sound; but it now came from a greater distance, and consequently was not so clear. When I was on the Darling, in Lat. 30°, in 1828, (a mistake, in 1829), I was roused from my work by a similar report; but neither on that occasion or on this, could I solve the mystery in which it was involved. It might, indeed, have been some gaseous explosion, but I never, in the interior, saw any indication of such phenomena."

William Howitt, in his work 'The History of Discovery in Australia'—a book with many errors of transcription—attributes these reports to the bursting of meteors, and refers to Sir Thomas Mitchell (incorrectly given by him as Kennedy) who, on August 20, 1846, when on the Belyando, was startled about 10 at night by a very extraordinary meteor. "First a rushing wind from the west shook the tents; next, a blaze of light from the same quarter drew attention to a whirling mass, or revolving ball of red light, passing to the southward. A low booming sound accompanied it, until it seemed to reach the horizon, after which a sound like the report of a cannon was heard, and the concussion was such that some tin pots, standing reversed on a cart-wheel, fell to the ground, and the boat on the dray vibrated for some minutes."[1]

In 1889, F. D. Johnson[2] wrote a paper entitled 'Notes on some Rumbling Sounds heard at Gill's Bluff." In this article he records no less than seven instances in which he heard these sounds in that locality. They are as follows:—
"July 9, 1888, 10·30 p.m.—Rumbling sound like blowing off of steam from a large boiler, lasting about forty seconds.

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[1] Mitchell's Tropical Australia, p. 280.
[2] Trans. Proc. and Rep. Roy. Soc. S.A., Vol. xii, 1889, p. 157.

July 22, 7 p.m.—Heard a similar noise. July 30, 10·50 p.m. —Rolling sound from the same quarter as on the previous occasions; lasted about thirty seconds. October 22, 10·30 p.m.—Rolling kind of noise for a few seconds. November 21, 8 p.m.—Slight rumbling sound. This was heard also by Mr. Rose, a prospector, who got up and questioned some natives camped alongside, who replied, 'That one alonga ground.' February 14, 1889, 10·40 p.m.—Loud rumbling sound for half a minute. The evenings were invariably calm and gave no indications of any atmospheric disturbance."

Mr. R. H. Mathews, who mentions that these mysterious noises are well known to bushmen in western New South Wales, who speak of them as the 'desert sound,' has kindly called my attention to the following reference which had escaped my notice. It occurs in Taplin's 'The Narrinyeri' (Adelaide, 1874, p. 48), a work dealing with the tribes of aborigines inhabiting Lake Alexandrina, near the Murray mouth in South Australia. "The natives also dread a water spirit called Mulgewanke. The booming sound which is heard frequently in Lake Alexandrina is ascribed to him, and they think it causes rheumatism to those who hear it. . . . I have often wondered myself what the noise is really caused by, which they ascribe to Mulgewanke. I have heard it dozens of times, and so have many other persons. It resembles the boom of a distant cannon or the explosion of a blast. Sometimes, however, it is more like the sound made by the fall of a huge body into deep water. It cannot be the peculiar sound made by the Murray bittern, as I have often heard that too, and it is not at all like the noise in the lake. At first I ascribed it to people blasting wood on the opposite side, but since then I have been convinced that this cannot be the case. One peculiarity of the sound ascribed to the Mulgewanke is, that although it is sometimes louder than at others, yet it is never near, always distant. I have no doubt but that some time or other the natural cause of it will be discovered, but I have never yet heard the phenomenon explained."

Mr. D. G. Stead has kindly forwarded me the following note on the occurrence of these sounds in western New South Wales. His suggestion as to their cause is of much interest. "In regard to mysterious rumbling or explosive sounds:—When I was on the Dry Bogan during August of last year, I stayed for two nights on Mr. Barton's Station at Mooculta. While there, and while I was discussing various natural phenomena with Mr. Reginald Kirkwood, Mr. Barton's manager, the former told me that, not infrequently, at the end of the very hot days, just about and a little after sundown, were to be heard coming from the direction of Mount Oxley (which I could see from there, and which is distant about fourteen or fifteen miles), rumbling and explosive sounds, sometimes loud, sometimes muffled, according to the state of the atmosphere and the direction of the wind. I suggested that it would probably be caused by bursting rock which had become intensely heated during the day, and was undergoing a rapid cooling process. He agreed that this was extremely probable, but could not say from actual observation. He also told me that the summit of Mount Oxley had numerous peculiar crater-shaped conical depressions; these were only about the summit. This was most interesting to me, and I specially noted it in my book at the time. Upon making a close enquiry later, I found that similar sounds had been heard coming from Mount Gunnerbooka, which I have also seen, and which is about forty miles S.S.W. from Mount Oxley. Now both of these short ranges stand up like islands in a veritable 'ocean' of plain country, the radiation from which must be enormous."

References to these sounds in other parts of the World.

In an article in *Nature* (Oct. 31, 1895, p. 650), Prof. G. H. Darwin, F.R.S., contributed a short article on 'Barisàl Guns' and 'Mist Pouffers.' He said:—"In the delta of the Ganges, dull sounds, more or less resembling distant artillery, are often heard. These are called 'Barisàl guns,' but I do not know the meaning of the term.' The object of this note is to draw the attention of the readers of *Nature* to this mysterious phenomenon, and to the similar 'mist pouffers' of the Belgian coast. My attention was for the first time drawn to the subject some days ago by a letter from M. van der Broeck, Conservator of the Museum of Natural History of Belgium. He writes of certain 'curious aerial or subterranean detonations, which are pretty commonly heard, at least in Belgium and in the north of France, and which are doubtless a general phenomenon, although little known, because most people wrongly imagine it to be the sound of distant artillery.

"I have constantly noticed these sounds in the plain of Limburg since 1880, and my colleague of the Geological Survey, M. Rutot, has heard them very frequently along the Belgian coast, where our sailors call them 'mist pouffers' or fog dissipators. The keeper of the lighthouse at Ostend has heard these noises for several years past; they are known near Boulogne, and the late M. Houzeau spoke of them to my friend M. Lancaster. More than ten of my personal acquaintances have observed the fact.

"The detonations are dull and distant, and are repeated a dozen times or more at irregular intervals. They are usually heard in the day-time when the sky is clear, and especially towards evening after a very hot day. The noise does not at all resemble artillery, blasting in mines, or the growling of thunder."

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[1] T. D. La Touche, Brit. Assoc. Rep. 1890, p. 800.

M. van der Broeck, after referring to the 'Barisàl guns,' says that he was disposed to regard the noises as due to some peculiar kind of discharge of atmospheric electricity. "But my colleague M. Rutot believes the origin to be internal to the earth. He compares the noise to the shock which the internal fluid mass might give to the earth's crust."

M. Clement Reed has informed M. van der Broeck that he believes similar noises are heard on Dartmoor, and in some parts of Scotland. I was not previously aware of anything of the kind in these islands." Professor Darwin then asks for further information from correspondents on the subject.

The article by La Touche, referred to by Sir George Darwin, is entitled "On the Sound known as 'Barisàl Guns' occurring in the Gangetic Delta." These are heard in the delta and the hills to the north of it. He states that five suggested explanations have been given of the phenomenon, viz.:—(1) The breaking of surf rollers, (2) the falling in of high banks, (3) the firing of bombs, (4) atmospheric electricity, (5) subterranean or subaqueous volcanic seismic agencies. None of these he considered entirely satisfactory, except, perhaps, the last. He further suggests that the noises may be due to slight movements of layers of silt.

As the result of Sir George Darwin's note, the next volume (Vol. 53, 1895-6) of *Nature* contains contributions to the subject from a number of writers. H. G. Olcott refers to the *Theosophist Magazine* (Vol. 9, p. 705 and Vol. 11, p. 409) for his personal experiences of the Gangetic phenomenon. This periodical I have not been able to consult. He considers that the sound resembles an evening gun and that all the theories so far proposed were inadequate.

G. B. Scott had heard them frequently in parts of India, near river-banks, sometimes as a single report, sometimes two, three or more in succession; sometimes near, sometimes far off. One, which was like the crack of a horse-pistol or a musket, was quite close and seemed to be in the air near by. The natives said that the sounds were in the air and came from the gods who thus celebrated the continuous marriage of the Ganges (Goddess Ganges) with the Brahmaputra (Son of Putra). They said the sounds had been heard in their father's time and long before that.

W. Smith had heard these sounds frequently on Lough Neagh (Ireland). W. Stoney mentions that Charles Darwin had heard earth sounds in North Chili and refers to similar sounds said to have been noticed near Mount Sinai.

H. H. Godwin-Austen suggested that there are two different kinds of these noises, one heard near the sea and due to the swell, the other consisting of booming reports like cannon heard at the base of the East Himalayas. These he had heard several times and the natives had then said 'the earth speaks.' He appears to think that the noise is due to the falling in of river-banks.

T. D. La Touche called attention to an article on the subject by Van der Broeck in *Ciel et Terre*, which I have been unable to consult. The words 'mist pouffers' mean really, he says, fog belchings or hiccups. C. Tomlinson suggested globular lightning as the cause. Henry Harris mentioned the hearing of six reports like those of guns, supposed to be due to electricity, recorded by the s.s. *Resolute* at a high north latitude.

R. Lloyd Praeger stated that in August 1886, he heard a rumbling sound on Lough Neagh, followed by a whirlwind, connected as he thought with it. He quoted Patterson's 'Glossary of Words of Antrim and Down,' as follows:—"Water Guns—Sounds as of gunshots, said to be heard around the shores of Lough Neagh by persons sailing on the lake. The cause of the sounds, which are generally heard in fine weather, has not been explained."

C. H. Robinson referred to sounds like those caused by pieces of ordnance heard by expeditions in the Rockies (1808) and Black Hills (1810) in America. The description at the latter place is as follows:—"In the most calm and serene weather and at all times of the day or night, successive reports are now and then heard among the mountains, resembling the discharge of several pieces of artillery." The sounds are also said to have been heard in Brazil.

In the next volume of *Nature*, Sir Edward Fry mentions sounds heard in the Peninsula of Sinai, some of which are explained as due to the rushing of sand down the mountain side. In one place, however, where the noise is more like that of artillery, no satisfactory explanation has been given. 'B.W.S.,' in a later issue, refers to these sounds and quotes Palmer's 'Desert of the Exodus,' wherein the writer suggests that the reports may be due to masses of rock being detached by frost and rolling over precipices.

The following note, from a recent copy of *Nature* (Feb. 2, 1911, p. 451), refers to the occurrence of the phenomenon in the Phillipine Islands:—"The Rev. M. Saderra Masó, who has for many years studied the earthquakes of the Phillipine Islands, is now turning his attention to the subterranean noises known in other countries under various names, such as mist-pœffeurs, marinas, brontidi, retumbos, etc. In the Phillipines many terms are used, generally signifying merely rumbling or noise, while a few indicate that the noises are supposed to proceed from the sea or from mountains or clouds. Most of the places where they are observed lie along the coasts of inter-island seas or on enclosed bays; very few are situated on the open coast.

The noises are heard most frequently at nightfall, during the night, and in the early morning, especially in the hot months of March, April, and May, though in the towns of the Pangasinan province they are confined almost entirely to the rainy season. They are compared in 70 per cent. of the records to thunder. With rare exceptions, they seem to come from the mountains inland. The instances in which the noises show any connection with earthquakes are few, and observers usually distinguish between them and the low rumblings which occasionally precede earthquakes. It is a common opinion among the Filipinos, that the noises are the effect of waves breaking on the beach or into caverns, and that they are intimately connected with changes in the weather, generally with impending typhoons. Father Saderra Masó is inclined to agree with this view in certain cases. The typhoons in the Phillipines sometimes cause very heavy swells, which are propagated more than a thousand kilometres, and hence arrive days before the wind acquires any appreciable force. He suggests that special atmospheric conditions may be responsible for the great distances to which the sounds are heard, and that their apparent inland origin may be due to reflection, possibly from the cumulus clouds which crown the neighbouring mountains, while the direct sound-waves are shut off by walls of vegetation or inequalities in the ground."

The frequency with which various observers have heard these sounds in Australia will, I think, exclude the likelihood of their being due to meteors. Sturt hearing them about the same hour on two successive mornings is likewise against such a cause. The report from a meteor that Major Mitchell heard can, therefore, be excluded from the category we are considering. Of the eleven individual Australian records I have given, eight occured between 6·30 and 11 p.m.: Sturt's three are the exceptions, two being heard at 9 a.m. and one at 3 p.m. As regards the season of the year, they were heard as follows:—Feb. (2), April (1), July (3), August (1), Sept. (2), Oct. (1), Nov. (1). These facts agree with Masó's opinion as to their frequency at night, but do not seem to support the view as to their greater prevalence in hot weather, though even in the winter the weather in the interior of Australia may be warm. As the Australian noises have been heard sometimes hundreds of miles inland, there can be no connection with the sea; further, no mountains, only low hills, exist in the neighbourhood of their occurrence. These facts do not fit in with Saderra Masó's suggestions. Earthquakes, as in the Phillipines, can be excluded. What, then, remains as a likely cause for them? It is almost certain they originate in some way in the earth. I have been told they are not uncommon in the Kimberley Districts of Western Australia and that a native, being questioned by a white man concerning them, said 'hill tumble down,' by which he meant that huge masses of rock fell down or cracked apart amongst the ranges. I suppose this explanation is a possible one and perhaps the most likely, especially when it is borne in mind that in the dry interior of Australia, the days are often intensely hot and the nights exceedingly cold. This might easily lead to considerable changes in size of the rocks with perhaps the above results.

It is quite possible, however, that here in Australia, as well as in other parts of the world, as has been suggested, two different phenomena are to be recognised. The sounds heard on Lake Alexandrina by Taplin, on Lough Neagh, on the Delta of the Ganges, and off the coast of Belgium, have, as a common factor, extensive sheets of water. The sounds in these places can hardly be explained by any rock-splitting hypothesis, and some other explanation is therefore necessary. On the other hand, several of the occurrences in

Australia and some of those noticed in hot climates elsewhere, may be explained by rock-splitting, though perhaps here, in some instances at least, an extensive flat desert-like expanse may take the place, in the production of the phenomenon, of a sheet of water.

Addendum.—I have received, since writing the above notes, a description of one of these mysterious sounds from Dr. H. J. Farnsworth, of Sydney, He heard it one morning, between 6 and 8 a.m., in a dry and clear atmosphere, about fourteen and a half years ago not very far from the place where I myself also heard it. Dr. Farnsworth says: "I heard a very loud explosion and a rumbling after for some seconds. We, my companions and I, first thought that it was caused by the exploding of one of the mine magazines either at Marble Bar or Bamboo Creek, but decided that neither place stored sufficient powder, etc., to cause such a big noise, and concluded that an earthquake had taken place somewhere not very far off. At the time of the explosion we were travelling between the Ngullagine and Roebourne (a distance of about 400 miles) and were about 100 miles from Ngullagine and 150 miles from the sea. The report seemed to be in a north-easterly direction."

Mr. E. C. Andrews has also kindly directed my attention to the following reference to the 'desert sound' in 'The Dead Heart of Australia,' (p. 243), by Professor J. W. Gregory, F.R.S. He says:—"The country around Beltana is repeatedly shaken by small earthquake shocks, which, from their nature and distribution, are doubtless caused by slight earth-movements along the fractures that formed Lake Torrens. Farther north, there are fewer earthquake records, but indirect evidence, that earth-movements are still taking place, is afforded by the well known 'desert sound,' when the stillness of the night is often broken by a deep booming, which appears to rise from below the surface of the ground. This desert sound has been recorded by many observers, from Sturt to Winnecke. It appears to be most frequently observed along the line of the Peak Ranges, and is probably due to earth-movements along the northern continuation of the Lake Torrens faults."

Professor Gregory gives a reference to an article entitled 'The Desert Sound,' under the *nom-de-plume* of 'Baldag,' which appeared in the *Australian Mining Standard*, Vol. XI, 1895, p. 312). This paper I have consulted. It is most interestingly written, and evidently by a scientist. After referring to Sturt having heard this sound, the writer says: "Since that date many explorers and pioneers have heard 'the desert sound' in South Australian territory. Mr. Charles Winnecke told me that he had heard it often in the middle of the day while exploring the north-west country. A few years ago my duties compelled me to camp for many months in the northernmost parts of the Flinders Range, and I grew familiar with variations of this mysterious sound from a low growling rumble as of a mass of rocks falling at a distance, to hollow reverberations lasting rarely more than 30 seconds, and seemingly aerial or else very close to the earth, and there was the deep, solemn, double knelling report which I only heard when near the Gammon Range or Mount Serle. . . . The region from whence these weird sounds seemed to issue forth is strictly tabooed by the blacks." One black, in answer to a query, said 'that one growl alonga ground.' The writer mentions that von Humboldt referred to certain granite rocks on the banks of tne Orinoco which gave out musical sounds at sunrise, which he suggests may perhaps be attributed to the difference in temperature between the external air and air in the crevices of the rock. He also states that J. E. Tenison-Woods has suggested that such sounds may be caused by air replacing an intermittent stream of water in its passage downward through crevices in the earth's crust.

Burke and Wills also heard an explosive report on May 24th, 1861, near Cooper's Creek.

Discussion.

Mr. L. Hargrave pointed out that most of the speakers had attributed the booming sounds to the cracking of rocks. Now, stone is not the only substance that makes a report when broken, iron does too, the breaking of a stick and tearing of paper also. Therefore, he thought that when the noises were heard in the deadly silence of a plain where no mountains or rocks were visible, the sounds were due to the cracking of the *alluvial soil.*

Mr. R. H. Cambage considered these sounds arise from different causes, and are probably not confined to the desert country. The reason they are not noticed more in the inhabited parts is partly because they become blended with other sounds, and partly owing to the fact that when it is known that a locality is peopled with miners and others, any sounds are likely to be considered the result of human agency. He was disposed to consider two of the likely causes to be, meteors and earth movements along lines of faulting. He instanced a case where he once heard an explosive sound which was evidently due to the bursting of a meteor. The occurrence dates back to August 1879, at about 3 or 4 o'clock in the afternoon, when a loud explosive sound was heard at Milton, coming from a point in the south-west, at an angle of from 20° to 30° above the horizon. The noise somewhat resembled thunder, but was really more like an explosion. On looking toward the spot whence the sound came, nothing could be seen to suggest the cause, and except for a very few small clouds, the sky was clear. It was noticed that a friend standing about 30 yards away turned right round and looked toward the same spot, thus showing that the position from which the sound emanated could be definitely located. It was ascertained next day that at about the same moment, two or three people saw a bright light flash across the sky towards the point where the explosive sound originated. In considering the general question of these booming noises, he thought the matter was made more difficult and unsatisfactory, because to a large extent the investigation had to be made without the full facts of a particular case being known.

Mr. R. H. Mathews said; It is quite gratifying to me that Dr. Cleland has taken the trouble to bring this matter before the Society for publication, because several years ago I thought of writing an article upon it myself. The best of any previous descriptions which I have seen is that given by Rev. G. Taplin, to which I drew attention when the present paper was introduced. On a few occasions I have heard the noises myself, and have not infrequently been told of similar experiences by squatters and others living out in the quiet bush in the north-western districts of New South Wales and Southern Queensland. My theory has always been that the 'desert sound' was connected with the cracking of the surface of the ground in dry weather. Everyone who has been out in the interior of this country knows of the huge 'sun-cracks' in the ground in many places. Some of these cracks would extend down to larger fissures already in existence under the ground. Such subterranean fissures would be more or less damp and would lose some of their moisture on the admission of dry air from above. This might cause fracture of the material bounding the cavities and give rise to the explosive sounds. This would account for the rumbling or muffled character of the noises. I am of opinion that the origin of the sounds has not been very far from the places where they were heard. Capt. Sturt thought one of the explosions described by him was only half a mile distant.

As regards the cases mentioned by Rev. G. Taplin, the sound would be carried a long way on the surface of the lake. Some of the speakers in this discussion have mentioned the theory of the sounds being caused by the splitting of exposed rocks, but I feel doubtful of this. Over most of the region in New South Wales and Queensland to which my own knowledge and that of my informants extends regarding these sounds, there are no great masses of rock visible. Besides, such an explosion would require to be extremely loud to be heard 10 or 20 miles away. A force to cause a report that would travel such a distance might make a perceptible earth tremor, or leave traces which would be observed at the place of occurrence.

It may be mentioned that gypsum is very plentiful on Yantara Station, near Lake Cobham, where tons of it could easily be obtained. There is also a kind of slacked or rotted gypsum, resembling slacked lime. Gypsum is likewise plentiful on Kallara Station, near Louth, on the Darling River. Sir Thos. Mitchell found aboriginal articles 'made of lime' at Fort Bourke, on the Darling. In 1838, Joseph Hawdon noticed a great quantity of crystalized lime or gypsum at Lake Bonney on the Murray River; it was in masses some tons weight. When I was surveying at Silverton, near Broken Hill, in 1884-5, I saw several outcrops of Limestone, and at one place a small lime-kiln had been formed by the miners. I have merely mentioned the above facts because limestone country is generally iable to have subterranean cavities. Mud-springs—heaps of damp earth or mud, forced up from below, with water oozing out of the sides—are found in the north-western portion of New South Wales. Some that I know of commence about Yantabulla and extend to Eulo and Thargomindah in Queensland. They follow a general course, winding about much the same as a range of hills, with intervals of several miles between them. In some places there are groups of more than a dozen springs within sight and in others only one or two. The upward flow of water in the mud-springs would naturally be along fissures which would continually enlarge and weaken the enclosing walls, which might break with a crushing noise which would reach the surface. The 'desert sound' is familiar to residents of that district.

When one of my sons, Mr. G. M. Mathews, was in Queensland some twelve or fifteen years ago, he told me that subterranean noises are frequently heard in the vicinity of Mount Gregory, between the Belyando River and Mistake Creek, approximately in latitude 22° and longitude $146\frac{3}{4}$°. It is curious that this corresponds closely to the locality where Sir Thomas Mitchell heard the sound described by him in his 'Tropical Australia,' pages 280-81. Most of the rumbling sounds referred to by me took place in the evening, but I attribute that fact to the quietness prevailing at that time. I am of opinion that they occur at any hour of the day or night in the districts mentioned, and probably at other places from which no reports have yet been published.

After the reading of Dr. Cleland's paper, I wrote to my son Mr. H. B. Mathews, Surveyor, Moree, knowing that he had heard similar sounds, and have only just received his reply, as he was away on field duty. He says, "When camped on Doyle's Creek, County of Hunter, on 7th May, 1906, one evening about 7 o'clock, I heard a distant booming noise coming from the west. The evening was perfectly clear and there was no wind to speak of. The country to the westward of my camp was hilly for a long distance."

THE ORIGIN OF THE SMALL BUBBLES OF FROTH.

By J. A. Pollock, D. Sc.,
Professor of Physics in the University of Sydney.

With Plates VIII, IX, X.

[*Read before the Royal Society of N. S. Wales, August 2, 1911.*]

I. Introductory.—When a glass jar containing air and uncontaminated water is vigorously shaken, it will be found, immediately after the agitation, that air-bubbles have been formed in the liquid of comparatively large dimensions; these bubbles rise rapidly to the surface, but burst so quickly that there is only a momentary appearance of froth. With slightly concentrated solutions of many organic substances, or with water contaminated with a drop or two of insoluble oil, the result is strikingly different. In these cases small bubbles of various sizes, which are entirely absent when an uncontaminated liquid is used, are produced in great numbers. Some of the bubbles are so minute that they remain temporarily suspended in the liquid, while the larger ones, which appear almost immediately on the surface, constitute the most lasting part of the froth which is here such a characteristic outcome of the agitation. So numerous are the minute bubbles in many cases that they give a milky appearance to the liquid, thus forming with it a mixture which may conveniently be called an air, or gas, emulsion.

In referring to the question of the durability of liquid films, Lord Rayleigh[1] mentions Marangoni[2] as the first, in 1871, to state in this connection the necessary condition

[1] Lord Rayleigh, Proc. Roy. Soc., Vol. XLVII, 1890; Scientific Papers, Vol. III, p. 341.

[2] Marangoni, Nuovo Cimento, Vols. V, VI, 1871–2.

for stability. Subsequently, in 1878, the matter was independently discussed by Willard Gibbs,[1] who devotes, to the consideration of the general problem, a section of his famous Essay on the Equilibrium of Heterogeneous Substances.

To Lord Rayleigh we are not only indebted for an account of the frothing of liquids, contained in a lecture on "Foam,"[2] given at the Royal Institution in 1890, but we also owe to him, as a result of his experimental researches in connection with surface forces, the knowledge which affords a basis of fact to explanations advanced from theoretical considerations.

So far as I am aware, no explanation has yet been given why, with vigorous agitation, the bubbles are so much smaller and more numerous with a slightly concentrated solution than when a pure solvent is used, and it was to the discovery of the origin of these small bubbles that my own observations have been directed. The phenomenon is a striking one, and I feel that an explanation may have occurred to others, but no reference to its publication can be found.

The question of the origin is closely connected with that of the durability of the bubbles, and in order to present the facts on which depends the description of the way these bubbles are produced, I propose, in the first instance, briefly to recapitulate the explanation which has been given of the durability of froth.

II. Durability of Froth.—The surface tension of a pure liquid has a value which varies only with the temperature. The association of such a characteristic, with the tension of

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[1] Gibbs, Trans. Conn. Acad., Vol. III, p. 467, 1878; Scientific Papers, Vol. I, p. 300.

[2] Lord Rayleigh, Proc. Roy. Inst., Vol. XIII, 1890; Scientific Papers Vol. III, p. 351.

a liquid film, would be incompatible with durability, if the film were not everywhere strictly horizontal. For consider a small element, between two level planes, of a vertical film; the forces due to surface tension at the upper level, acting upwards, must, for the equilibrium of the element, be greater than the similar forces at the lower level, acting downwards, by the weight of the element of liquid considered. Hence, for equilibrium, the surface tension must continuously diminish from higher to lower levels of the film; this condition could not be satisfied in the case of a film of a pure liquid, and, as a matter of fact, pure liquids do not yield a lasting froth.

From the consideration of such an argument Marangoni[1] was led to suggest that, for the durability of a liquid film to be ensured, there must exist, on its surfaces, a layer, of what might now be called contamination, having the property of diminishing the surface tension of the liquid to an extent which becomes greater as the thickness of the layer increases.

With such a surface layer the existence of a film would be automatically maintained; for any motion of the liquid, involving, if unchecked, the breaking of the film, would introduce forces opposing the movement. In the first instance, the initial movement of the liquid, from higher to lower levels under the action of gravity, would reduce the thickness of the layer at the top of the film while increasing it below, thus introducing a diminishing gradation of values of the surface tension, from above downwards, which would continue to vary, with the motion of the liquid, until the tension, at every point, acquired the magnitude sufficient to prevent further movement. Any subsequent disturbance of the film would, in the same way, introduce forces opposed to its development.

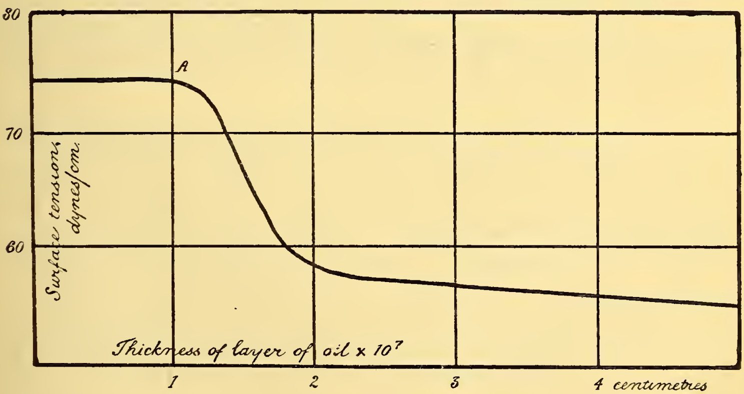
[1] Marangoni, *loc. cit.*

It has been previously mentioned that water contaminated with a trace of insoluble oil gives a froth which is strikingly persistent compared to that of pure water. The durability here can only be due to the presence, on the surfaces of the bubbles, of a layer of oil, which must be excessively thin, judging from the immense number of bubbles which a single drop of oil can render stable.

That such a surface layer possesses the property necessary for it to ensure durability has been fully demonstrated by Miss Pockels and by Lord Rayleigh, both of whom measured the variations in the tension of a water surface caused by changes in the thickness of a contaminating pellicle of oil.

To illustrate the nature of the results which were obtained, figure 1 has been copied from a publication by Lord Rayleigh,[1] the scales to which the abscissæ and the ordinates are drawn being supplied from numbers given in the paper.

Fig. 1.



Relation between the surface tension and thickness of the layer of oil in the case of a water surface contaminated with a pellicle of castor oil. From a paper by Lord Rayleigh.[1]

[1] Lord Rayleigh, Phil. Mag., Vol. XLVII, p. 321, 1899; Scientific Papers, Vol. III, p. 415.

The relation between the surface tension and the thickness of the layer of castor oil, as shown in figure 1, exhibits characteristics which are typical of oil-contaminated surfaces, the work of Lord Rayleigh, in this connection, extending that of Miss Pockels, which is described in "Nature," Vol. XLIII. 1891.

As may be seen from the diagram, Lord Rayleigh found that the tension of a water surface is not affected by the presence of oil until the quantity is more than sufficient to cover the surface with a uniform layer about one ten millionth of a centimetre thick. When the oil is present in less than this critical quantity, it may be assumed to exist on the surface in patches, with lanes of pure water between them. It is considered by Lord Rayleigh that the surface tension *begins* to fall, as represented at *A* in the figure, when, with increasing quantities of oil, the patches, as a result of their growth, join to form a continuous layer over the whole surface. Lord Rayleigh suggests that the layer at this stage is probably not more than one molecule deep, and he has, by the determination of its thickness, made a most important contribution to the estimates of molecular magnitudes.

Once the continuity of the layer of oil is established, the surface tension decreases as the thickness of the layer increases; the oil thus forms just such a pellicle as was considered by Marangoni to be essential for the stability of films. This result of the investigations is of considerable importance, for, with the knowledge of the persistency of oil-contaminated bubbles, it at once changes Marangoni's explanation of durability from a matter of inference to one of fact. A further, most interesting, result appears from Lord Rayleigh's work; as may be seen from the relation shown in figure 1, the layer of castor oil which gives durability to a bubble may have in many cases a maximum thickness less than two ten millionths of a centimetre.

As has been mentioned, the surface tension, in the case of a vertical film, must, for stability, continuously diminish from above downwards, the rate of variation depending on the weight of liquid to be supported. The difference, therefore, between the surface tension at the top and at the base of the film, necessary to be established for its equilibrium, will depend, other things being equal, on the height of the film. Taking the relation shown in figure 1 as an illustration, it is possible, in the case of a large bubble, that the layer of oil might not be sufficient to allow the necessary difference in the extreme values of the surface tension to be attained, while quite enough to ensure the stability of smaller bubbles. Such a consideration may explain why the larger bubbles of froth are often evanescent while the smaller ones are quite persistent.

Frothing, however, is not confined to oil-contaminated liquids, but, on the other hand, is strikingly shown in the case of dilute aqueous solutions, for instance, of a great many organic substances. This is well known, the effect being apparent with some solutes even when present in the minute proportion to the water of only one part in a million.[1]

Recently the matter of the frothing of solutions has become of importance in the mining industry in connection with a floatation process for the concentration of ores, and I am indebted to Mr. H. Howard Greenway for a long list of organic substances which have been found to give a suitable froth, for the purpose of this method of concentration, when added in small quantity to water.

The list, which is, however, not put forward as exhaustive, includes organic acids, alcohols, ethereal salts,

[1] *See* Lord Rayleigh, Lecture on Foam, Proc. Roy. Inst., Vol. XIII, 1890; Scientific Papers, Vol. III, p. 351;
and Ramsden, Proc. Roy. Soc., Vol. LXXII, p. 156, 1903.

ketones, aldehydes, aromatic hydroxy compounds and essential oils, the substances being used, in the practical application, up to an amount which, in proportion to the water, is generally but a very small fraction of one per cent.

A number of solutions on the other hand notably lack the frothing property, and it will now be shown that only those dilute solutions can yield a lasting froth which have a surface tension which diminishes with increasing concentration.

Molecules near the surfaces of matter, from the fact that they are not equally surrounded by molecules of their kind, are subject to an attraction towards the body of the material not experienced by those not thus uniquely placed. The extra restraint, under which molecules exist in this situation, changes in degree from the surface inwards until it vanishes at a depth equal to the radius of molecular influence, the molecules at this depth being as similarly acted on by forces in all directions as those well within the mass. The surface stratum, equal in thickness to the range of molecular action, is thus the seat of special molecular conditions, and really wants a name indicative of some one of its characteristics, preferably its depth; it will be referred to here merely as the surface layer or stratum. So rapidly does molecular attraction diminish with increasing distance that, adopting Quincke's estimate of the range of molecular influence, the thickness of the stratum may be considered of the order of five millionths of a centimetre.

As the molecules within the surface layer are subject to additional restraint, there exists in the stratum a greater molecular potential energy, bulk for bulk, than in the mass of the substance. The excess of the molecular potential energy which exists within the surface stratum over that which would be associated with the layer if the additional restraint were removed is called the surface energy; where a more distinctive designation is desirable, the quantity may be referred to as the surface excess of mechanical potential energy. In connection with solids the magnitude of the quantity cannot be directly ascertained, but for liquids an expression for the value of the surface energy at any temperature was found by Lord Kelvin in 1858.[1] Suppose the area of a surface increased by dS; by the change additional restraint is created for the molecules which constitute the new part of the surface layer; they thus acquire increased potential energy, but at the same moment lose kinetic energy, on the whole, owing to the variation of the restraint within the stratum. The work done in increasing the surface is $\mathfrak{s}dS$, where $\mathfrak{s}$ is the surface tension, here its mean value, so we may write,

$$\textit{gain of potential energy} - \textit{loss of kinetic energy} = \mathfrak{s}dS.$$

Lord Kelvin shows, in the paper to which the reference has been given, that the energy which must be added during the extension of the surface to keep the temperature constant, that is to maintain the kinetic energy, of the molecules under consideration, at its original value, is $-(\theta d\mathfrak{s}/d\theta)dS$, where θ represents the absolute temperature. This term, then, measures the loss of kinetic energy that would have occurred in the adiabatic case had the surface tension remained constant, so that for extension at the tempereture θ we may put,

$$\textit{gain of potential energy} + (\theta d\mathfrak{s}/d\theta)dS = \mathfrak{s}dS.$$

Therefore the additional molecular potential energy associated with the surface layer, per unit area of surface, due to the extra restraint which molecules experience in the stratum, is, for the temperature θ,

$$\mathfrak{s} - \theta d\mathfrak{s}/d\theta.$$

This is the expression for what is known as the surface energy, per unit area of surface, at the temperature θ.

[1] W. Thomson, Proc. Roy. Soc., Vol. IX, p. 255, 1857-9.

For dilute solutions it is known that the value of the foregoing expression for the surface energy becomes smaller if the surface tension diminishes, so that for these solutions it may be said that, provided the surface area is constant, the surface energy decreases with any change which lowers the value of the surface tension. In accordance with a well known mechanical principle, such a change, if possible, will spontaneously occur until the rate of variation of the total energy of the liquid, with reference to the variable involved, becomes zero.

This application of the equilibrium principle of minimum energy to dilute solutions discloses an important fact to which attention was first directed by Willard Gibbs in the essay already mentioned. For if the surface tension of a dilute solution diminishes with increasing concentration, the greater the concentration in the surface stratum the less the surface energy; therefore, associated with the creation of any new surface in such a solution, there will be a movement of the molecules of the solute from the mass of the liquid into the newly formed surface layer. Such a movement, however, increases the chemical energy in the surface stratum, and, under isothermal conditions, equilibrium will be attained when the rate of decrease of the surface excess of mechanical potential energy, with respect to the increased amount of the solute in the surface layer, is equal to the rate of increase of the surface excess of chemical energy with reference to the same variable.

If Γ is the surface excess of solute, per unit area of surface, that is the amount of solute brought into the surface stratum, per unit area, to establish equilibrium, σ the surface excess of mechanical potential energy, per unit area of surface, and μ the chemical potential of the solute, then the condition for equilibrium, under isothermal circumstances, is in symbols, Correction to a paper on "The Origin of the Small Bubbles of Froth," added March 25th, 1912.

In considering, from an elementary point of view, the question of the surface excess of concentration in a paper on "The Origin of the Small Bubbles of Froth," this volume, part II, the change in the kinetic energy of the molecules in the surface layer, which accompanies, under adiabatic conditions, any alteration of the potential energy, was neglected. When this change is taken into account the second term on the right hand side of the expression for the surface excess of concentration on pages 213 and 224 disappears and the formula becomes the same as that previously given by the other writers mentioned. I am indebted to Professor Donnan, M.A., F.R.S., for kindly pointing out the mistake, which involves indeed a misquotation of Willard Gibbs' result.—J.A.P.

[Instruction to binder—To face page 212.]

$$d(\mu\Gamma)/d\Gamma = - d\sigma/d\Gamma;$$

changing the variable this becomes,

$$\Gamma = - d\sigma/d\mu$$

which is the expression given by Willard Gibbs. For dilute solutions $d\mu = R\theta dc/c$, where R is the gas constant, θ the absolute temperature, and c the concentration in the bulk of the solution, so at the absolute temperature θ.

$$\Gamma = - \frac{c}{R\theta} \frac{d}{dc} \left(s - \theta \frac{ds}{d\theta} \right)$$

similar units being used throughout.

This expression contains an additional term to those which appear in the formula given by other writers.[1] The value of the extra term, though quite capable of experimental determination, has not yet in any case been found, its importance, therefore, in connection with the calculation of the surface excess of solute, remains to be seen.

For dilute solutions the heat change associated with adsorption, under isothermal conditions at the absolute temperature θ is, per unit area of surface,

$$\theta\ (ds/d\theta - ds_c/d\theta),$$

where s is the surface tension of the solvent and s_c that of the solution.

Owing to the variation of the value of the additional molecular restraint within the surface stratum, what is here established, by the movement of the molecules of the solute just considered, is a concentration gradient; travelling from the interior of the solution, the concentration will be constant up to a point at a depth beneath the surface equal to the range of molecular influence; it will here begin to increase, attaining a maximum value at the surface. On the other hand, with a solution in which, with increasing concentration, the surface tension becomes greater, the

[1] *See* Milner, Phil. Mag., Vol. XIII, p. 100, 1907; and Lewis, Phil. Mag., Vol. XV, p. 499, 1908, and Vol. XVII, p. 466, 1909.

concentration, up to the same point, will be constant, but will then, until the surface is reached, continuously decrease.

The term concentration gradient will here be used only in connection with variations of concentration within the surface stratum in the direction of the outward drawn normal. For descriptive purposes it is more convenient, in many cases, to consider the average concentration in the surface layer; this will be referred to as the surface concentration in order to distinguish it from the bulk concentration, which is that of the general mass of the liquid.

It may be said, then, that solutions which show a decreasing surface tension with increasing concentration will be more concentrated in the surface stratum than in the interior part of the liquid, whereas the concentration in the surface layer will be less than in the body of the liquid in those solutions which exhibit, with increasing concentration, an increased surface tension.

From the experimental side Lord Rayleigh[1] has made an important addition to the discussion; in an ingenious way he has shown that newly formed surfaces, in the case of dilute aqueous solutions of oleate of soda and of saponine, have, within one hundredth of a second of their formation, surface tensions not very different from that of the solvent, although under ordinary conditions the values are notably less than that of water. With a 10 per cent. aqueous solution of alcohol, a considerable diminution of the surface tension, if not the whole change, was found to have occurred in the same interval.

The important fact is here established that time is required for the full development of the concentration gradient; the value of this time factor is shown to depend

[1] Lord Rayleigh, Proc. Roy. Soc., Vol. XLVII, p. 281, 1890; Scientific Papers, Vol. III, p. 341.

on the nature of the solute, and it may, perhaps, vary with the concentration.[1]

Where the concentration in the surface stratum is greater than in the body of the solution, variations in the value of the surface concentration serve, in connection with solution films, the same purpose as is effected, in the case of bubbles of oil-contaminated liquids, by changes in the thickness of the layer of insoluble oil. Referring again to the question of durability, there is in a newly formed vertical film an initial movement of the solution from above downwards, under the action of gravity, which makes the film wedge-shaped, a fact readily deduced from the arrangement of colours in a soap film; by this movement the surface concentration becomes, at least temporarily, less at the upper levels than below, and there is thus established that diminishing gradation of values of the surface tension, from above downwards, which is required for equilibrium.

On the other hand, with films of those solutions, in which the concentration in the surface layer is less than in the interior part of the liquid, the initial movement would cause similar temporary differences in the actual surface concentration, but with the introduction of an *increasing* gradation of values of the surface tension; films of such solutions must, therefore, be considered as even more unrealizable than those of pure liquids.

A durable froth can, thus, only occur with those solutions in which the concentration in the surface stratum is greater than that in the body of the liquid, which, in turn, only happens, at least with dilute solutions, if increased concentration means a diminished surface tension.

III. Origin of the small bubbles.—The facts which have been stated, in connection with the foregoing presentation

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[1] *See* Milner, *loc. cit.*

of the explanation of the durability of liquid films, further serve to explain the mode of formation of the small bubbles which are created when a solution, capable of frothing, is vigorously agitated.

The froth is readily produced when gas under pressure is forced into the solution from the orifice of a pipe fixed vertically in the liquid, and for purposes of investigation this method of production is perhaps the most convenient one. With this arrangement, using a glass vessel to contain the solution, it is seen that the small bubbles are produced at the base of the main bubbles which are continuously being formed on the mouth of the pipe by the incoming gas. The inference is that the smaller bubbles are created from the newly formed surface separating the liquid from the mass of gas entering the solution, and instantaneous shadow photographs[1] of the bubbles, some of which are reproduced, in natural size, in *Plates VIII*, *IX*, *X*, confirm this view.

Two classes of bubbles have, however, to be clearly distinguished, the one comprises those formed even when pure water is used, while the other class refers to the much smaller bubbles which are only created with a contaminated liquid, and constitute the characteristic feature of the lasting froth which is produced, in this case, by vigorous agitation. The necessity for the distinction may be recognised by comparing the companion photographs in *Plates VIII* and *IX*. Figure 2 of *Plate VIII* shows the breaking up of a large bubble of carbonic acid forced into uncontaminated water, while figure 3 exhibits the effect when a 0·1 per cent. aqueous solution of acetic acid is used, the conditions being, otherwise, the same in the two

[1] The photographs have been taken by the method described by Lord Rayleigh, Proc. Roy. Inst., Vol. XIII, p. 261, Feb. 1891; Scientific Papers, Vol. III, p. 442.

cases. Figures 4 and 5, *Plate IX*, are a similar pair of photographs with the pressure of the gas rather greater than in the former instance.

The photographs show that the small bubbles of the froth of the acetic acid solution are the results of the disruption of the lower surface of the main bubble formed by the inrushing gas, the disintegration of the surface being extraordinarily great compared to the slight breaking up of the bubble, under similar conditions, in water.

It is interesting to find, from Whatmough's[1] measures of the surface tension of acetic acid solutions, that such a profound change, in the effect of the agitation of the water, is brought about by an alteration which only diminishes the surface tension, under isothermal conditions, by about 1·5 per cent. This effect is so small that, in any attempt to frame an explanation of the phenomenon, other factors, besides the mere change in the surface tension, must be taken into consideration.

It has just been shown that if a solution is to give a lasting froth the surface concentration must be greater than that of the mass of the liquid. From Lord Rayleigh's work, previously mentioned, it is known that on the production of a new surface in a solution capable of frothing, such as the surface of the main bubble in the present instance, the excess of concentration in the surface stratum is not instantly established, but requires time for its development. The extra concentration is produced as the result of molecular movement, and it is not to be expected that, while in the stage of growth, it will have, at any moment, the same value at all points of the newly formed surface. It must actually appear in the surface layer, in the first instance, in spots or patches, and wherever such a patch of extra concentration is formed the surface tension

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[1] Whatmough, Zeit. für Phys. Chem., Vol. xxxix, p. 166, 1902.

becomes, as a necessary consequence, less than that of the surrounding parts. The conditions here are not isothermal ones, and the lowering of the tension may be greater than that mentioned above. The newly formed bubble is thus, with reference to its surface tension, for a time at least, essentially uneven in texture, and to this fact, no doubt, the disruption of the surface is mainly due.

The characteristic small bubbles of the froth are only formed when the mass of incoming gas possesses considerable downward momentum. In this case the pressure on the base of the main bubble is high, and as the conditions are anything but those of equilibrium, the liquid underneath is being strongly accelerated. The consequent disruption of the surface, as shown in the photographs, is so complete, that its development cannot be followed in detail, but a not improbable idea of the production of the small bubbles may be formed by considering that the patches of extra concentration on the base of the main bubble, as they offer, at the moment of their appearance, slightly less resistance than the rest of the surface, yield more to the impact of the gas; in the general violent movement the patches may thus get blown out from the bubble before other adjustment of the surface takes place, and appearing first as cylindrical protuberances, finally become completely detached, owing to the well known instability of cylinders, in this connection, when their length exceeds the circumference.

In the case of oil-contaminated water, the first result of agitation will be the dissemination of minute drops of oil throughout the liquid. On coming into contact with large bubbles, these drops will spread out on the surfaces into patches, thus establishing that weakening of the surface tension in spots, which, according to the description just given, is, under highly kinetic conditions, but the preliminary to the disruption of the surfaces. Such an origin would ensure to the small bubbles that layer of contamination essential for their stability, and the explanation of their production, here suggested would thus account for their uniform durability.

Owing to the circumstances of the development, the exact manner of the creation of these small bubbles must remain a matter of some conjecture, and the foregoing description is put forward in no other sense. The surprising feature, which requires explanation, is the fact that the addition to a solvent, which alters the effect of its agitation from a few evanescent bubbles to a dense lasting froth, may involve, in the value of the surface tension, a diminution, under isothermal conditions, of only about one per cent., an amount altogether too small, if taken by itself, to be considered as changing the conditions.

The small bubbles, here under review, are characteristic of the froth which is produced by violent agitation, and are not dependent on the method which is used for introducing the gas into the liquid. It is considered that, in all cases, they are the results of the disintegration of the surfaces of larger bubbles, the essential condition for their creation being the development, on these surfaces, of spots of diminished surface tension, associated with a gas pressure within the bubbles considerably in excess of that required for equilibrium in the circumstances existing at the moment of disruption.

It yet remains to consider the production of the bubbles formed by processes which are independent of the nature of the liquid used, such as those which result from the breaking up of a jet of gas when forced into uncontaminated water, or into a solution which does not yield a lasting froth. In these cases, as may be seen by a comparison of the photographs, the bubbles belong, as a whole, to a much larger class than those in the acetic acid solution whose origin has just been considered.

The larger of the bubbles of the class now under discussion are created by the partition of the volume of gas entering the liquid, considerable portions of the gas being 'pinched off,' as it were, by the action of currents in the liquid, or, having lost their downward momentum, becoming separated from the mass of inrushing gas owing to their buoyancy. Bubbles made in some such way are always created when a liquid of any kind is agitated, and the class includes the largest of the bubbles which are produced by any method of disturbance.

But there are other bubbles of the same general class, though much smaller, whose development follows a more orderly course. These are shown in various stages of their growth in the photographs of *Plate X*, the reference being to bubbles from about a tenth to a few millimetres in diameter in many cases still attached to the parent surfaces.

Figure 6, *Plate X*, shows clearly two of the bubbles in an early stage of development, still part of the lower surface of the bubble caused by a jet of carbonic acid entering an 0·1 per cent. aqueous solution of acetic acid, the pressure of the gas being too low to cause the disintegration of the surface of the main bubble. Figure 7 is a photograph of a bubble of carbonic acid being formed in water, and figure 8 one of a bubble of the same gas in a 0·1 per cent. aqueous solution of sulphuric acid.

Whatmough[1] shows that dilute aqueous solutions of sulphuric acid have a surface tension which *increases* as the concentration becomes greater, they may be said, then, to lack the frothing property even more than water. The

[1] Whatmough, *loc. cit.*

acetic acid solution has a surface tension which *decreases* as the concentration increases, so the photographs of *Plate X* may be taken as exhibiting the bubbles in three typical liquids, and, by showing the similarity of the detail in the three cases, proving a common method of production.

Here the development, previously suggested as that of the small bubbles of froth, is clearly apparent; cylindrical protuberances are formed on the larger surfaces which lengthen until the state of instability is reached, they then become detached as separate bubbles.

In seeking for an explanation to account for these protrusions into the liquid of the surfaces of the gas bubbles, any consideration of a local weakening of the surface tension seems here out of the question. Firstly, a cause is not apparent for an accidental diminution of the surface tension in somewhat large patches, confined within narrow limits as to size; secondly, the effect is shown both with tap and distilled water, used with every precaution to avoid contamination, and no difference occurs when the gas is carefully filtered; moreover, bubbles of the class under consideration, produced in water and in non-frothing solutions, show no special durability. That the phenomenon is not directly dependent on any directed momentum of the gas is proved by the fact that in the photographs the projections are shown on the surface of closed bubbles, in which the gas can have little, if any, general momentum relative to any part of the surface.

The outline in the photographs is fairly sharp as the exposure was of the order of a millionth of a second, but in each case the liquid was in a state of considerable turbulence. With this fact in view, it is suggested that the bubbles, whose development is shown, owe their origin to variations in the external pressure on the parent surfaces due to the motion of the liquid relative to these parts of the larger bubbles. In this case the size and number of the bubbles will depend on circumstances which determine the nature of the liquid movement.

This suggestion as to the origin of these small bubbles is prompted by the result of the process of exclusion previously outlined, and though impossible to prove, as the turbulence of the liquid cannot be directly seen, is not improbable from the appearance of the detail shown.

IV. Summary.—The object of the investigation was to find the origin of the small bubbles which constitute the characteristic feature of the froth which is produced by violent agitation. The froth is readily created when gas under pressure is forced into a liquid through the orifice of a vertical pipe, and in order to study the conditions of its formation, instantaneous shadow photographs have been taken of the jet of gas in various solutions. It is seen from an inspection of the photographs, that the bubbles which result from the breaking up of the jet may be separated, with respect to the exact manner of their production, into three classes.

1. Large bubbles are created by the partition of the main bubble which is being continuously formed on the end of the pipe, considerable portions of the gas being 'pinched off,' as it were, by the action of currents in the liquid, or, having lost their downward momentum, becoming separated from the mass of incoming gas owing to their buoyancy.

2. The photographs accompanying the paper show small bubbles which are clearly the result of the detachment of cylindrical protuberances formed on the surfaces of the larger bubbles, the protuberances having lengthened until the state of instability has been reached. These bubbles are seen in various stages of their attachment to the parent surfaces, and are shown to occur in water, and in a non-frothing as well as in a frothing solution. It is considered

that the typical protuberances, from which the bubbles develop, owe their origin to variations in the external pressure on the parent surfaces, due to the motion of the liquid relative to those parts of the larger bubbles.

3. Finally, there are bubbles, on the whole smaller still, which occur only in cases of the violent agitation of oil-contaminated liquids, or of solutions capable of frothing. These are, indeed, the characteristic bubbles of the froth which is produced in these circumstances. With the special method of agitation which was used in this investigation, these bubbles are shown to be due to the disruption of the lower surface of the main bubble formed by the gas entering the liquid, the disintegration of the surface, in a 0·1 per cent. aqueous solution of acetic acid, being seen to be extraordinarily great compared to the slight breaking up of the bubble, under similar conditions, in water. The surprising feature in connection with the occurrence of these bubbles is the fact that the addition to a solvent, which changes the effect of its agitation from a few evanescent bubbles to a dense lasting froth, may involve, in the value of the surface tension, a diminution, under isothermal conditions, of only about one per cent. The suggestion is made that the disruption of the surface, which results in the small bubbles, is due to a high gas pressure associated with a weakening of the surface tension in small patches, which may occur in a newly formed surface while the surface concentration is acquiring its full value, or in the case of an oil-contaminated liquid, may be caused by the appearance of small oil spots on the surfaces of large bubbles, resulting from the contact of the bubbles with minute drops of oil disseminated, by the agitation, throughout the liquid.

In the earlier part of the paper attention is again directed to the fact that the surface energy of a liquid, per unit area of surface, at the absolute temperature θ, is not measured by the value of the surface tension at that temperature, but by the value of the expression, $s - \theta ds/d\theta$, s being the surface tension. This matter has been emphasized, indeed, by some previous writers, but judging from recent literature the fact is not yet fully appreciated.

For dilute solutions the expression for the surface excess of solute, per unit area of surface, at the absolute temperature θ, is thus,

$$\Gamma = -\frac{c}{R\theta}\frac{d}{dc}\left(s - \theta\frac{ds}{d\theta}\right),$$

the symbols being used with usual significations.

The heat change associated with such adsorption is, under isothermal conditions at the absolute temperature θ,

$$\theta\,(ds/d\theta - ds_c/d\theta),$$

per unit area of surface, where s is the surface tension of the solvent, and s_c that of the solution.

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ISSUED JUNE 26th, 1912.

Vol. XLV. Part III.

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1911.

PART III., (pp. 225-444).

CONTAINING PAPERS READ IN

SEPTEMBER to DECEMBER.

WITH TWENTY-FOUR PLATES.

(Plates iva, xi, xii, xiii, xiv, xv, xvi, xvii, xviii, xix, xx, xxi, xxii, xxiii, xxiv, xxv, xxvi, xxvii, xxviii, xxix, xxx, xxxi, xxxii, xxxiii.)

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1912.

F. WHITE Typ., 344 Kent Street Sydney.

SUICIDE IN AUSTRALIA. A STATISTICAL ANALYSIS OF THE FACTS.

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[*Read before the Royal Society of N. S. Wales, September 6, 1911.*]

SYNOPSIS.

1. Introduction.
2. Secular frequency.
3. Sex-ratio.
4. Variation of frequency with age for each sex.
5. Seasonal fluctuation of suicide.
6. Correlation of seasonal fluctuation with temperature.
7. Mode of suicide.
8. Conclusions.

1. Introduction.—The course of suicide in Australia presents certain features which seem worthy of study by sociologists. To these attention is drawn in the following article, and comparisons are made with like phenomena in Europe. Three things appear to call for special comment, viz.:—

(i) the constancy of the measure of the suicidal tendency;
(ii) its constancy in respect of the relative numbers of each sex; and
(iii) its periodicity, according to seasons or months.

Each of these will be treated in its proper place in this article.

It may be added that the detailed information for a complete analysis is not available for earlier years, and the main deductions of a detailed character must perforce depend on the occurrences in the last two decades.

Regarded quantitatively, suicide does not figure prominently among causes of death, thus for Australia in 1910 it was only 0·1166 per 1,000 of the population, and was only 1·13% of deaths from all causes. But, as the expression of determination to voluntarily part with life, it stands in quite a special position as compared with death arising from diseases, or from violence not self-initiated.

When its remarkable constancy and no less remarkable annual periodicity is realised, the ethical interest of the frequency and characteristics of self-determined death is seen to be unique. While a given set of conditions is maintained it would seem that its frequency is approximately constant, and variations from average conditions are marked by increases or decreases about this average. Though based on small numbers, this frequency therefore may nevertheless have high sociological value as a measure of reactions to economic or other stresses to which the human race is subject under the conditions of modern civilisation.

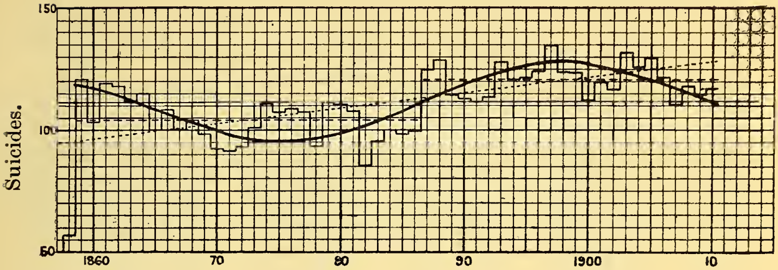
2. Secular frequency.—The secular variation in the frequency of suicide in the Commonwealth, presents no very remarkable features. The total number in a growing population is of no particular moment, but the number per thousand, per million, etc., of the population measures the trend of the suicidal tendency, and gives the necessary grounds for comparisons. The following table gives the results per 10 million inhabitants:—

Annual Rate of Suicides per 10,000,000 persons in Australia, 1858 – 1910.

Year.	No. per 10 million.	Year.	No. per 10 million.	Year.	No. per 10 million.	Year.	No. per 10 million.	Year.	No. per 10 million.
1858	575	1870	926	1880	1107	1890	1133	1900	1125
1859	1207	1871	917	1881	1076	1891	1117	1901	1192
1860	1037	1872	933	1882	859	1892	1140	1902	1170
1861	1188	1873	1010	1883	952	1893	1275	1903	1315
1862	1179	1874	1108	1884	995	1894	1202	1904	1260
1863	1117	1875	1077	1885	983	1895	1217	1905	1292
1864	1148	1876	1084	1886	995	1896	1241	1906	1214
1865	1003	1877	1078	1887	1245	1897	1350	1907	1109
1866	1082	1878	934	1888	1283	1898	1239	1908	1174
1867	1002	1879	1110	1889	1148	1899	1233	1909	1145
1868	1041	1880	1107	1890	1133	1900	1125	1910	1166
1869	981								
				Mean	1117·6				

Notes:—1858-9—State of Victoria only. 1860 to 1866—States of New South Wales and Victoria. 1867 to 1872—States of New South Wales, Victoria, and South Australia. 1873 – 1886—Queensland and Tasmania also included. 1887 – 1910—All the States of the Commonwealth.

Secular Frequency of Suicide in Australia.



EXPLANATION OF GRAPH—*Each vertical division represents five suicides per annum per million of the general population, and each horizontal division denotes one year. The rectangular lines shew the actually observed group-rate of suicide for the years* 1858 *to* 1910. *The general mean is shewn by a firm horizontal line, and the two horizontal broken lines shew the averages for the period* 1859 *to* 1886 *and for the period* 1887 *to* 1910. *The fine inclined dotted line shews the general trend of the frequency for the period* 1889 *to* 1910, *if that trend be regarded as linear in character. The heavy curved line shews the general trend on the assumption that it tends to be periodic, which assumption agrees more closely with the observed frequency than the assumption of a linear trend.*

The result for 1858 is abnormal and is rejected from all consideration of the question of means, or of development.

The aggregate number of suicides in the whole period 1859 to 1910 inclusive was 15,242, and since the sum of the annual populations was 133,136 millions, the actual mean rate of suicide *for the whole period* was 1144·8 per 10 millions per annum. The average of the annual numbers per 10 million is only 1117·6, hence this is the mean tendency to commit suicide about which fluctuation takes place from year to year. The yearly differences from this mean value are given in the table hereunder.

Annual Excess (+) *or Deficiency* (−) *per 10,000,000 persons on the average annual frequency of suicide in Australia, 1859–1910.*

Year.	Differ. per 10 million.	Year.	Differ. per 10 million.	Year.	Differ. per 10 million.	Year.	Differ. per 10 million.	Year.	Differ. per 10 million.
1859	+ 89	1870	−192	1880	− 10	1890	+ 15	1900	+ 8
1860	− 80	1871	201	1881	41	1891	− 1	1901	74
1861	+ 71	1872	185	1882	259	1892	+ 22	1902	52
1862	62	1873	108	1883	165	1893	157*b*	1903	197*e*
1863	− 1	1874	9	1884	123	1894	84	1904	142*e*
1864	+ 31	1875	40	1885	135	1895	99	1905	174*e*
1865	−115	1876	34	1886	122	1896	123	1906	96
1866	35	1877	40	1887	+128*a*	1897	232*c*	1907	− 8
1867	116	1878	183	1888	165*a*	1898	121	1908	+ 56
1868	77	1879	7	1889	31	1899	115	1909	28
1869	136	1880	10	1890	15	1900	8*d*	1910	49

Any sign (+ *or* −) *continues downward to the change of sign.*

In respect of these differences it may be noted that the relatively large increase above the average which characterised 1887 and 1888 (see differences marked *a*) nearly synchronises with a speculating period, viz., the days of the silver and land booms. The large value for 1893 (see *b*) corresponds to the bank failures and collapse of the land boom. The high value for 1897 (see *c*) slightly follows the incidence of drought conditions, viz., in 1895 and subsequent years.

The low value for 1900 synchronises with the South African war, when many men were drawn from Australia for military service in South Africa (see *d* in table). The high values for 1903, 4, 5 (see *e*), correspond to the period of the most serious drought in Australia.

Practically the frequency of suicide for the whole of the period 1859 to 1886 was under the general average frequency, and for the whole of the period 1887 to 1910 it was above the average for Australia. The mean frequency for 10,000,000 population for 1859 to 1886 inclusive was 1040·4 and from 1887 to 1910 inclusive was 1207·8. But a reference to Fig. 1 will shew that the assumption of a slow linear progression does *not* very satisfactorily accord with the facts. Such a progression would be represented by the formula

$$(1)\ldots\ldots S = 1118 + 6{\cdot}5\,(T - 1884),$$

and is shewn in the figure by the dotted straight line. The general trend is however much better exhibited by the curve shewn by the heavy firm line. This has a 46-year period and gives for the average annual rate of suicide

$$(2)\ldots\ldots S = 1118 + 167 \sin 2\pi \frac{(T-1886)}{46}$$

a fluctuation reaching a maximum of only 15%.

In these formulæ S is the number of persons annually committing suicide for an Australian population of 10,000,000, and T is the year in question. The results have been calculated graphically only, the material hardly warranting the application of more rigorous methods.

Owing to the fact that the masculinity (number of males to one female) of the Australian population has changed from about 1·40 for 1860 to about 1·11 for 1910, the ratios in the table for the earlier years are somewhat higher than they would be with a population constituted as it now is, since with a masculinity of about 1·10, 83% of suicides are males (see next section). The application of the correction would however yield nothing material so far as the present data are concerned, and has been neglected.

This average rate of suicide for the period 1858 to 1910 of 111·8 per million does not exceed very greatly the rate for England and Wales. For comparison the results are given for various countries for successive quinquennia from 1871 onwards, and are as follows:—

Rates of all Suicides per Million Inhabitants for Various Countries.[1]

COUNTRY.	PERIOD.							
	1871 to 1875	1876 to 1880	1881 to 1885	1886 to 1890	1891 to 1895	1896 to 1900	1901 to 1905	1906 to 1910
Bosnia and Herzegovina	...	...	...	6	19	37	40	...
Ireland	18	18	22	24	29	29	33	34*e*
Italy	35	41	49	50	57	63	63	...
Scotland... ...	33	47	53	58	60	60	60	57*e*
Finland	29	33	39	40	48	47	55	...
Servia	...	...	38	37	36	40	51	...
Netherlands ...	36	44	53	56	61	55	64	...
Norway	75	72	67	67	65	55	64	...
Roumania ...	...	...	...	42	55	70	...	...
England and Wales ...	66	74	75	79	89	89	103	102*f*
Australia ...	100·9	106·3	97·3	116·1	119·0	123·7	124·5	116·2*g*
Belgium... ...	70	94	107	119	129	119	124	...
Sweden	81	92	97	118	144	119*a*	124	...
Austria	106	162	162	160	159	158	173	...
Hungary, Kingdom	...	...	84	102*b*	123*c*	163	176	179*e*
Hungary, proper	...	76*d*	89	108*b*	132*c*	177	191	192*e*
Japan	...	110*d*	146	159	179	185	201	189*e*
German Empire	...	...	211	205	211	202	212	...
Denmark ...	243	267	248	261	250	221	227	194*f*
France	144	168	194	216	241	232	228	...
Switzerland ...	...	227	233	221	222	222	232	227*f*
General result ...	112	122	133	139	151	152	160	158?

a This sudden decrease is due to the fact that cases of death by poisons self-administered for purposes of abortion have been excluded.

b For 1886-7. *c* For 1892-5. *d* For 1878-80. *e* For 1906-08. *f* For 1906-09. *g* For 1906-10.

It is perhaps remarkable that the rate for Australia should exceed that for England and Wales, and greatly exceed that for the United Kingdom taken as a whole; and, seeing that the race element is identical, since Australia is almost wholly British, the fact would seem to be worthy of investigation.

From 1881 to the present time (1910), the countries whose suicide rates most closely approximate to that for Australia, are Sweden and Belgium.

[1] See Statistik und Gesellschaftslehre. Prof G. v. Mayr, Bd. III, p. 279.

The great range of frequency, viz., from Ireland with only 34 per million, to Switzerland with say 230—nearly seven times the frequency for Ireland—is worthy of note, also that Australia occupies approximately the mean position between these extremes.

It is obvious from the table that mere locality on the earth's surface, (latitude), or average annual temperature, etc., has no marked influence on the suicidal frequency, and it would also appear that the influence of race is negligible. Probably social and economic conditions are the most potent factors governing the phenomenon of suicide.

Respecting the question whether the suicidal tendency is or is not growing, it may be pointed out that it is clear from the above table that there is a fairly steady increase in the frequency of suicide in the civilised world. If we multiply the numbers in the preceding table by the populations and divide by the sum of the populations the quotients will furnish a general result, shewn in the last line of the table, and this result will roughly exhibit the general tendency. From this it would appear that suicide is decidedly on the increase, but also that the rate of increase is steadily diminishing.

Thus the number of suicides per million per annum (S) for the civilised world generally would appear to be roughly given for any year by the formula

$$(3)\ldots S = 112 + 2{\cdot}2\,(T - 1873) - 0{\cdot}022\,(T - 1873)^2$$

in which T is the year in question. This would imply that the rate per million per annum (dS/dT) is increasing as expressed by the following formula, viz.:—

$$(4)\ldots dS/dT = 2{\cdot}2 - 0{\cdot}044\,(T - 1873);$$

which gives for the rate of increase per million per annum for 1873, 2·20 and for 1910 only 0·57, a very considerable reduction of the rate of increase, and one which indicates that there is some likelihood of its ceasing.

3. Sex-ratio.—It is a remarkable fact that in the western world the frequency of suicide among men ranges from double to quintuple the frequency among women, while in India and Burmah the relation is reversed, that is, suicide is more frequent there among women than men.

For Australia, for the four decennia between 1871 and 1909 inclusive, we have (omitting West Australian suicides, for which figures are not available till 1896) the following results, viz:—

Years.	Males.	Females.	Total.	Males (per 1000 of total suicides.)	Females (per 1000 of total suicides.)
1871–1909	11,051	2,250	13,301	831	169
1900–1909	3,992	811	4,803	831	169

This constancy of relation of 83·1% males and 16·9% females is remarkable, and is approximately true for each decennium. It shews that in the Commonwealth of Australia 4·92 males commit suicide for each female who commits that act, a ratio that is exceeded only by one country,—Switzerland. This apparently exact constancy of ratio is, however, fortuitous, since its significance depends upon the constancy of the ratio of the numbers at each age in the two sexes. If we assume that there is no change in the distribution according to age, we can correct the ratio for any change in the relative number of males and females. The mean masculinity (or number of males to one female) was 1·1440 for the whole period 1871 to 1909 inclusive and for the period 1900 to 1909 inclusive it was only 1·1091. The results therefore require correction before comparisons are made. This may be roughly given by assuming a result on an identical relative number of males to females, say 110 males to 100 females in each case, and will then give for the periods in question not quite identical results, the relative frequency of suicide being:—

Year 1871–1909, 825 males, 175 females per 1,000.
1900–1909, 830 males, 170 females per 1,000.

In order to compare the significance of this ratio with the ratio in other parts of the civilised world, the following results, compiled from the statistics of other countries, are furnished. These give the crude ratios, viz., the number of male suicides divided by the number of female suicides.

Table shewing Crude Ratio of Male to Female Suicides in various Countries.

Country.	Period.	Ratio.	Country.	Period.	Ratio.
Japan	1881 – 1905	1·65	Prussia ...	1881 – 1905	3·80
Servia	1881 – 1905	2·06	German Empire ...	1881 – 1905	3·85
Scotland ...	1881 – 1905	2·52	Norway ...	1881 – 1905	3·85
Roumania ...	1891 – 1900	2·68	Sweden ...	1881 – 1905	3·91
Bulgaria ...	1896 – 1905	2·96	Netherlands...	1881 – 1905	4·05
England and Wales ...	1881 – 1905	2 98	Italy	1881 – 1905	4·05
Scotland ...	1896 – 1905	3·00	Spain... ...	1881 – 1905	4·22
Ireland ...	1881 – 1905	3·00	Finland ...	1881 – 1905	4·31
Russia	1881 – 1890	3·38	Sweden ...	1901 – 1905	4·59
France... ..	1881 – 1905	3·55	Belgium ...	1881 – 1905	4·93
Austria ...	1881 – 1905	3·58	*Australia* ...	1881 – 1905	4·95
Denmark ...	1881 – 1905	3·62	Switzerland ..	1881 – 1905	5·22

India etc., 1907.

Countty.	Ratio.	Country.	Ratio.
Burmah	1·16	East Bengal and Assam ...	0·67
Central Provinces	1·00	Eastern Territory	0·59
Bombay	0·92	Bengal	0·57
Punjab	0·79	North West Provinces ...	0·55
Madras...	0·74	Agra and Oudh	0·34

The lower figures in the above table are for India and Burmah, where generally there are more female than male suicides. This fact punctuates the great difference between the social condition in the two civilisations.

Since the relative number of males and females differs in each country, the crude rates are not quite satisfactory. Results are comparable only when these relative numbers are identical. The most satisfactory method is to deduce separately the rate for males and that for females (say the number per million in each case). Then the one rate (for males) divided by the other (for females) gives a relation independent of the masculinity. This has been called the *corrected* frequency relation.

This corrected frequency relation, obtained by thus deducing the rate for each sex separately, has been computed for the period 1861 to 1910, for Australia, and the annual average number of males and females per 10,000,000 of each sex committing suicide for each quinquennium was found to be as shewn in the following table, in which the ratio of frequency of suicides of males to suicides of females is also shewn. These average annual rates per quinquennium are deduced for each sex by dividing the sum of the suicides in a quinquennium by the sum of the mean annual populations of the respective sex.[1] The ratio m/f denotes the true relative frequency of suicide in the two sexes.

Average Annual Number of Male and Female Suicides per 10,000,000 of each sex in Australia to 1910.

Period.	Frequency Male Suicides.	Frequency Female Suicides.	Ratio. m/f	Period.	Frequency Male Suicides.	Frequency Female Suicides.	Ratio. m/f
1861 – 1865	1677	391	4·29	1886 – 1890	1783	433	4·12
1866 – 1870	1547	341	4·54	1891 – 1895	1843	444	4·14
1871 – 1875	1545	392	3·94	1896 – 1900	1911	479	3·99
1876 – 1880	1631	360	4·53	1901 – 1905	2094	410	4·89
1881 – 1885	1517	333	4·55	1906 – 1910	1813	435	4·71
			Mean	4·317			

The difference between the values for individual 5-year periods and the mean give no indication of any systematic trend, and may be regarded as accidental. The relative frequency 4·317 may, therefore, be regarded as constant, and as the proper (corrected) frequency of male suicides as compared with female in Australia.

4. Variation of frequency with age for each sex.—Since the constitution of a population, in respect of the numbers of each sex for corresponding age-groups, differs with each country and even in the same country at different periods, comparisons of the suicides within the various age-groups

[1] The numbers for individual years are somewhat irregular, so that it was deemed desirable to group them in quinquennial periods.

inter se, and between country and country, can be satisfactorily made only by deducing for each group the proportion or relative number committing suicide (say the number per million in the group). These numbers disclose the frequency of suicide at different ages, and thus the age at which the tendency is most strongly expressed. Since the total number of persons in any age-group ordinarily diminishes with increase of age and differs both from period to period as well as from country to country, the absolute numbers of suicides at various ages are of little interest: it is the relative numbers which are significant. The absolute numbers have therefore not been given.

In the following table, the results as given by Prof. von Mayr[1] where not already in the required groups, have been computed, and multiple results have been combined so as to furnish a single series of values.[2]

In column (12) the simple average is given, including Australia, for purpose of comparison. It is not weighted in any way.[3] The results in column (11) for Australia shew that, as in most other lands, the growth of the suicidal tendency with age is retarded with woman during the child-bearing period of married life.

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[1] Statistik und Gesellschaftslehre, Moralstatistik, Bd. III, pp. 313 – 316.

[2] This has been done by regarding the frequency given as the ordinate corresponding to the middle of the period as abscissa. A continuous curve then passed through all the points enables the frequency for any other middle value to be determined. Any theoretical defect of this method is far less than the range of uncertainty in the data. The combination of results has been effected by weighting according to the number of years of observation, but without regard to increasing population. The result will suffice for the present purpose.

[3] The unweighted average does not express the tendency of the groups of nations included (considered as an integral group) but rather the mean of the habits of different races in different localities and under different conditions.

Number of persons per 1,000,000 of each age-group and each sex, committing suicide—Various countries.

MALES.

Age-group.	Austria 1896 – 1901.	Baden 1891 – 1905.	*Buenos Ayres 1899 – 1904.	Denmark 1886 – 1905.	France 1893 – 1906.	Italy 1901 – 1905.	Massachusetts 1876 – 1885.	Prussia 1891 – 1905, 1908	Saxony 1903 – 1907.	Sweden 1891 – 1907.	Australia 1891 – 1910.	Simple Mean including Australia.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
10 – 14	2	20	4	36	28	5	2	31	53		5	18
15 – 19	165	161	175	144	161	71	35	186	341	42	32	134
20 – 24	330	317	233	291	277	166	103	331	442	170	119	255
24 – 29	384	376	264	313	374	138	136	315	482	238	190	295
30 – 39	313	380	212	431	364	126	159	396	505	313	272	326
40 – 49	423	594	276	700	537	165	230	654	929	442	403	508
50 – 59	566	870	193	1112	726	208	365	880	1297	574	563	716
60 – 69	585	987	187	1183	869	223	445	951	1589	588	602	802
70 – 79	621	1086	187	1284	909	210	551	942	1664	554	556	838
80	621	1408	187	1210	954	202	264	1105	2780	468	443	946

FEMALES.

Age-group.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
10 – 14	1	11	4	6	21	1	2	8	26		4	8
15 – 19	92	57	235	82	131	34	16	98	192	20	40	76
20 – 24	130	74	206	127	170	48	31	115	177	52	68	99
24 – 29	122	80	120	94	244	40	43	90	160	54	53	98
30 – 39	82	120	78	89	338	37	53	97	149	56	76	100
40 – 49	86	149	56	178	342	37	56	134	243	84	86	140
50 – 59	99	139	25	226	444	43	64	175	338	114	88	173
60 – 69	99	184	25	279	515	42	82	193	302	115	87	190
70 – 79	147	171	25	270	528	46	55	215	437	91	91	205
80	147	171	25	386	526	38	24	259	557	89	57	225

* Buenos Ayres not included in mean.

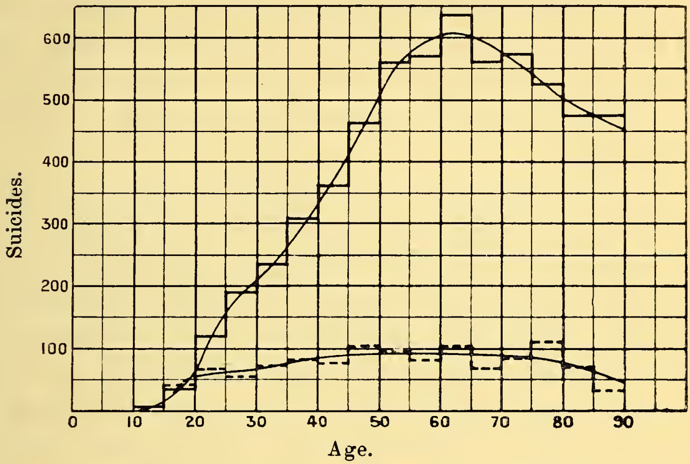
The suicidal frequency per million for each 5-year group in Australia based on the records of the last two decades,[1] is as follows:—

Suicides per million in each age-group and sex; Australia 1891 – 1910.

Age-group.	Males.	Females.	Age-group.	Males.	Females.
10 – 14	5	4	50 – 54	559	94
15 – 19	32	40	55 – 59	569	81
20 – 24	119	67	60 – 64	637	102
25 – 29	190	53	65 – 69	560	69
30 – 34	235	71	70 – 74	573	82
35 – 39	309	81	75 – 79	524	109
40 – 44	361	76	80 – 85	474	70
45 – 49	461	102	85	475	32

[1] These are computed on the basis of the constitution at the 1901 Census, which is sufficiently accurate for the purpose in view.

Frequency of Suicide according to Age. Upper Curve, Males. Lower Curve, Females.



EXPLANATION OF GRAPH.—*Each horizontal division denotes* 5 *years of age, and each vertical division denotes* 50 *suicides per annum per million of the population of the corresponding sex and age. The upper rectangles denote the observed frequency per annum per million males of each quinquennial age-group, and the lower rectangles denote the observed frequency per annum per million females of each quinquennial group. The two curves denote the probable instantaneous values for any age between the limits* 0 *to* 90, *the upper being for the male sex, the lower for the female sex, the ordinates thereto being per million per annum of the corresponding sex.*

These tabulated results are better grasped when graphically exhibited. The curves in the preceding figure, based upon the group-results in the table, shew the probable instantaneous value at each age, the upper curve denoting the frequency of male, and the lower the frequency of female suicides. For males the frequency is seen to increase almost linearly from 15 to 55 years of age. The maximum frequency is about 62, after which the frequency decreases decidedly, but not as quickly as it increases for earlier ages. Italy and Sweden shew a similar decrease of frequency, the maximum being between the ages 60 and 70, so also do Massachusetts and Buenos Ayres. With females the maximum frequency is by no means well-defined, and the aggregate numbers for Australia are too small to justify any conclusion as to the age at which the tendency occurs with females.

It would appear from the preceding tables that the measure of the stress of life is special to each country, and that, measured against the capacity to endure this stress it falls off in Australia at the age of about 60 to 65 for men, becoming even at 90 as small as it was at 47 for that sex. It also distinctly decreases for the later years of life, for women. It is further worthy of note that the average frequency among Australian women never reaches, at any period of life, the average frequency at the age of 23 among men.

5. Seasonal fluctuation of suicide.—The actual numbers committing suicide are of practically little importance for the purpose of disclosing the seasonal fluctuation. This fluctuation is perhaps best shewn where, as in Australia, the numbers are small, by computing for a period of years how many persons commit suicide per month. Two corrections are necessary, one for the equalisation of the months (so that equal periods of time are represented), the other to reduce the numbers to what they would be for a constant population. The scheme of applying these corrections is fully indicated in my paper on "Statistical applications of the Fourier Series," this Journal, Vol. XLV, pp. 76 – 110. Briefly it may be said that it is preferable to reduce the monthly numbers to that value which would correspond to the population at the middle of the period under consideration, that is to say, all results from January to June inclusive have to be *increased* (in decreasing amounts), and all results from July to December inclusive, have to be *decreased* in increasing amounts, the correction depending on the rate of growth of the population. In this way we obtain the following absolute and relative results, viz.:—

Monthly Frequency of Suicide, Australia.

Month.	Numbers per 10,000,000 of Population.				Numbers per 10,000 Suicides.			
	N.S.W. and Queensl'd. 1890—1899.	All States of Australia 1900—1910.			N.S.W. and Queensl'd. 1890—1899.	All States of Australia 1900—1910.		
	Persons.	Males	Females	Persons	Persons.	Males	Females	Persons*
January	116·3	179·7	35·7	110·8	859	935	842	920
Feb.	105·3	163·6	42·1	105·7	777	853	994	878
March	101·9	166·1	36·6	104·1	752	866	864	865
April	95·6	154·0	41·3	100·2	706	803	975	832
May	107·2	152·0	35·2	96·2	792	792	831	799
June	100·2	139·8	26·5	85·7	740	729	625	712
July	95·4	147·6	32·1	92·2	704	769	758	766
August	122·1	154·8	38·0	99·0	902	807	897	822
Sept.	108·0	150·2	31·8	93·6	798	783	751	778
October	128·4	169·8	39·3	107·4	948	885	928	892
Nov.	122·7	162·2	30·7	99·2	906	845	725	824
Dec.	151·2	179·0	34·3	109·8	1116	903	810	912
	1354·3	1918·8	423·6	1203·9	10000	10000	10000	10000

* For result for 1890 to 1910 see Table hereinafter.

It will be seen from the above that while there is a distinct seasonal fluctuation, it is apparently not identical from decade to decade, and from the last three columns that the curve is by no means identical for the sexes. For the purpose of comparison the results for a long series of observations in various European countries are given hereunder, and the corresponding results for Australia for 1890 to 1910 are also given. These shew in a general way that the seasonal relationship of the maximum frequency is identical in Australia with that of the Northern Hemisphere, the absolute difference between approximately 6 months.

For Europe generally the simple mean may be taken to roughly represent the fluctuation of suicide during the year. The Australian figures for the last 21 years are based on

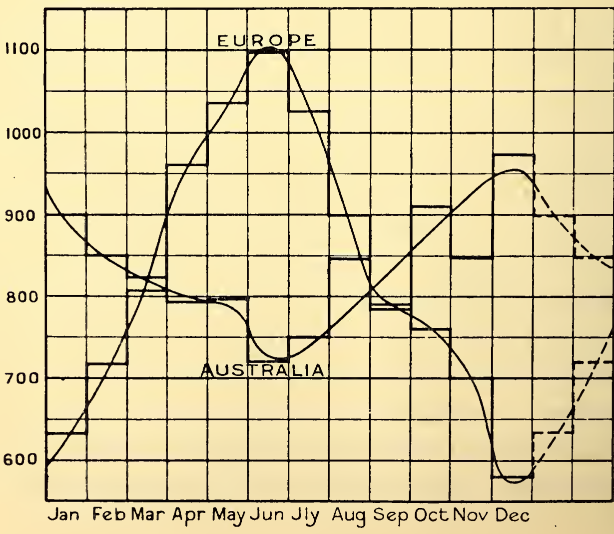
Number of Suicides occurring in each equalised month in 10,000 Suicides.

	France*	Prussia	Saxony	Württemberg	Württemberg	Baden	Switzerland	Italy	Denmark	Simple Mean	Australia†	Australia†
	1827 to 1876	1885 to 1900	1875 to 1889	1846 to 1879	1889 to 1893	1881 to 1900	1884 to 1893	1864 to 1876	1896 to 1905			1890 to 1910
Jan.	690	625	629	547	658	676	637	610	618	632	July	749
Feb.	719	688	696	805	742	664	744	771	629	718	Aug.	846
March	851	803	817	848	800	864	749	827	713	808	Sept.	784
April	955	982	987	896	983	903	973	995	964	960	Oct.	910
May	1018	1018	1040	998	1009	972	1025	1121	1135	1037	Nov.	848
June	1092	1053	1088	1134	950	1059	1078	1216	1207	1097	Dec.	973
July	1053	997	1010	1063	983	991	1039	1023	1072	1026	Jan.	900
August	871	907	927	961	892	896	871	868	893	898	Feb.	849
Sept	757	836	813	769	833	805	832	714	740	789	March	832
Oct.	744	787	758	742	775	803	810	641	762	758	April	793
Nov.	643	692	664	717	867	730	659	610	688	697	May	796
Dec.	607	612	571	520	508	637	583	604	579	580	June	720
	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000		10000

* Computed approximately from results given in Prof. v Mayr's work (*Op. cit.* p. 262).
† New South Wales and Queensland only for 1890 to 1899, and all States of Australia from 1900 to 1910 inclusive.

two States for the first ten years, and on all for the last eleven years, the complete information not being available. The results for Australia are so corrected as to apply to a population constant throughout the year.

Annual Fluctuation in the Frequency of Suicide.



EXPLANATION OF GRAPH.—*The horizontal divisions denote not calendar but equalised months and the vertical divisions denote* 50 *suicides per month out of an assumed total of* 10,000 *per annum* (833⅓ *per month*). *The rectangular lines denote the group results for the equalised months on the basis assumed. The upper curve denotes the probable instantaneous values for the whole of Europe, the lower the probable instantaneous values for the whole of Australia. The results are so corrected as to correspond to a population constant throughout the year.*

In the diagram the rectangular lines shew the rates for the various months for Australia and Europe generally, and the curves give the most probable form of the fluctuation.

6. Correlation of seasonal fluctuation with temperature. If the monthly mean temperatures of the capital cities of Australia be weighted in proportion of the populations, the resultant mean is as follows:—

Month	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Temp. Fah.	71·1	70·7	68·4	63·5	57·7	53·6	51·8	54·1	57·7	61·8	65·6	69·0

and these results may be regarded as approximately representing the temperature conditions influencing the rate of suicides owing to the fact that the populations of the cities have a preponderating place.

It was shewn in a paper by the author, "On the application of the Fourier Series to Statistics," see this Journal, Vol. XLV, p. 109, that the frequency (q) of suicide per million per diem in Australia could be put in the form

$$(5)\ldots q = 0·329 + 0·00304\,(t - 62°)$$

where t is the temperature Fahrenheit given by the curve indicated in the above table: or say

$$(5a)\ldots q = 0·33 + 0·003\,t$$

where t is the temperature above 62° Fahr.

Owing to the irregularity of the results in Australia from month to month the remarkable correlation between temperature and suicide frequency is best seen by combining the results for pairs of months. In this way we obtain the two upper lines in the following table :—

	Dec. Jan.	Feb. Mar.	April May	June July	Aug. Sept.	Oct. Nov.
Temp. Fahr.	70·0	69·5	60·6	52·7	55·9	63·7
Suicides per 10,000	1832	1743	1631	1478	1600	1716
Calculated	1805	1796	1645	1511	1565	1698

This correlation is very approximately expressed by $615 + 17t$ (where t is the temperature Fahrenheit), a formula which gives the results in the last line. Here it may be pointed out that Australia differs very remarkably from Europe in this respect, viz., that the range of temperature throughout the year is decidedly smaller in Australia. Thus a mean for the various countries of Europe gives the range between the averaged hottest and coldest months of the year about 33° Fahr., while for Australia the range is only about 19° *i.e.*, but little more than one half. We thus have:

Ranges in	Temperature.	Suicide Frequency.
Europe	33° Fahr.	517
Australia	19° ,,	253

That is to say, the variation in the suicide frequency on the whole corresponds very closely to the range in temperature, being strongly marked where the temperature differences are strongly marked. It is evident from this that large temperature fluctuations tend to bring about large changes in the frequency of suicide.

7. Mode of suicide.—In a relatively small population the number of suicides for individual years by any particular mode of self-destruction is naturally variable, nevertheless there is greater uniformity than might have been anticipated *a priori*. The statistics have been computed for the years 1907 to 1910 inclusive.

These results shew that the mode of suicide is very regular. The relative frequency of any particular mode is

Number of Male and Female Suicides, Australia, 1907 to 1910.

	MALES.				FEMALES.				TOTAL.			
Year	1907	1908	1909	1910	1907	1908	1909	1910	1907	1908	1909	1910
Population in millions	2·15	2·18	2·22	2·27	1·97	2·01	2·05	2·10	4·12	4·19	4·27	4·37
Mode of Death.												
Poison	57	88	70	79	32	35	54	34	89	123	124	113
Asphyxia	2	1	2	...	...	...	...	...	2	1	2	...
Hanging or strangulation	71	68	67	72	12	15	9	10	83	83	76	82
Drowning	37	31	24	42	19	14	19	19	56	45	43	61
Firearms	129	143	138	134	3	7	6	6	132	153	144	140
Cutting instruments	61	54	74	79	5	6	5	13	66	60	79	92
Precipitation from a height	6	4	7	3	1	2	...	...	7	6	7	3
Crushing	3	6	5	8	2	2	1	...	5	8	6	8
Other modes	19	15	11	15	2	3	3	2	21	18	14	17
Total	385	413	398	432	76	84	97	84	461	497	495	516

therefore best seen by the number represented by each class in a given aggregate, say 100, 1,000, or 10,000.

Relative number per 10,000 Suicides of each sex, and of both sexes, dying by particular modes, in Australia during the period 1907 to 1910.

Mode.	Males.	Females	Total.	Mode.	Males.	Females	Total.
Poison... ...	1806	4545	2280	Cutting etc....	1646	850	1508
Asphyxia ...	31	...	25	Precipitation from height	123	89	117
Hanging ...	1707	1349	1646	Crushing ...	135	147	137
Drowning ...	823	2082	1041	Other modes...	369	293	356
Firearms .	3360	645	2890	(Total) ...	10,000	10,000	10,000

Thus in Australia poison and drowning are resorted to two and a half times more frequently by women than by men; suicide by cutting is resorted to twice as often, and shooting five times as often, by men as by women.

The preceding results may be compared with those of a few other countries. For example:—

Relative Number of Persons in 1,000 of each Sex resorting to particular Modes of Suicide.

Country.	Period.	Hanging.		Drowning.		Shooting.		Poison.		Cutting.	
		M	F	M	F	M	F	M	F	M	F
Russia ...	1904–1908	573	396	122	312	194	32	52	166	?	?
Japan ...	1902–1907	623	444	184	430	24	3	27	25	39	27
Servia ...	1902–1906	341	619	98	71	415	239	73	9	49	53
Australia	1907–1910	171	135	82	208	336	64	181	455	165	85

This comparison discloses the great diversity of frequency in the several countries indicated by each sex in resorting to particular modes of self-destruction. The results are equally diversified when the total number of suicides is considered (irrespective of sex). These total results may be compared with those of a number of other countries for several forms of suicide, viz. by hanging, drowning, shooting, and cutting. The following table furnishes the relative numbers :—

Relative number out of a total of 1,000 Suicides dying by hanging, drowning, shooting, or cutting; various countries.

Country.	Period.	Mode of Suicide.			
		Hanging.	Drowning.	Shooting.	Cutting.
Australia ...	1907 - 1910	165	104	289	151
Austria ...	1887 – 1891	444	259	173	?
Bavaria ...	1887 – 1890	536	203	208	?
Belgium ...	1889 - 1893	492	249	155	19
Denmark ...	1896 – 1900	749	130	54	13
England ...	1889 – 1893	277	227	93	182
France ..	1887 – 1891	435	260	125	24
Italy... ...	1889 – 1893	167	232	254	41
Norway ...	1888 – 1890	656	172	78	47
Prussia ...	1891 – 1900	586	184	129	23
Saxony ...	1891 – 1900	598	196	117	20
Sweden ..	1889 – 1893	495	154	140	56
Württemberg	1890 – 1899	589	158	152	27

It is remarkable in cases of suicide that what would *a priori* seem to be negligible factors should really have weight. If for example, we take the cases of suicide by drowning in the years 1907 to 1910 inclusive, we find that in the warmer months November to April inclusive, the suicides were 4·61 per month per annum, while from May to September, they were only 3·75 per month per annum, *i.e.*, 18·7% less frequent. The total suicides for the colder months are only 10·7% less frequent, hence the cold acts as a deterrent in respect to this particular mode of suicide to the extent of about 8%.

8. Conclusions.--The following conclusions are drawn from an examination of the whole of the results:—

(i.) The relative frequency of suicide in Australia is very constant.

(ii.) It apparently exhibits a secular oscillation of 46 years period and of relatively small amplitude, viz., 15%. The existence of this cannot be decisively determined till another half century has elapsed.

(iii.) While economic conditions express themselves in the frequency of suicide, their effects are relatively small, and are comparable in magnitude only with the regular annual fluctuation. In a half century's experience the greatest deviations from the mean are −15% to +21%, and from the oscillation of 46 years period less than 14% either way.

(iv.) Australia occupies a mean place in a list of frequency of suicide for all countries.

(v.) The annual fluctuation in Australia (fluctuation from month to month) is well marked, but is only about half of what it is in Europe. It ranges between −14% to +10%.

(vi.) In Europe the mean temperature range, between the hottest and coldest months is about 33° Fahr. and in Australia it is only 19° Fahr., say 57% of that of Europe; the range of suicide frequency during the year is similarly only about 50% of that of Europe.

(vii.) The annual fluctuation stands in the same relation to the seasons, *i.e.*, the maximum and minimum frequencies in Europe are in the months June and December respectively, and in Australia in the months December and June.

(viii.) It would appear from this that the annual temperature fluctuation or some unknown phenomenon associated therewith has a profound influence on the frequency of suicide.

(ix.) Suicide is on the increase for the world generally, but in decreasing ratio. It is decreasing in Australia.

(x.) It may be stated that there is a fairly well marked increase in the frequency of suicide in Prussia for the ages 15 to 25, viz., the intensive educational period of life. The data have however, not been given in the paper.

(xi.) In Australia frequency of suicide at first increases with age, attaining with men a maximum at about age 62, after which it declines. With women it never attains in the western civilised world or in Australia a comparable magnitude to the frequency with men, but exhibits in a less marked way the tendency to increase with age to a limit and then to decline.

(xii.) The western civilised world stands in startling contrast with the east, and especially with India in this respect, where female suicide preponderates. Even in Japan the frequency of female suicides is large compared with any European country.

(xiii.) The mode of suicide shews considerable constancy, and is apparently influenced by physical conditions.

NOTE ON A NEW TYPE OF APERTURE IN *CONULARIA*.

By CHAS. F. LASERON.

With Plate XI.

[*Read before the Royal Society of N. S. Wales, October 4, 1911.*]

So little is known of the structure and systematic position of the genus *Conularia* that any information concerning it should be of some scientific value. In spite of the great abundance of specimens found in some geological horizons, examples showing the complete aperture are so rare that in only two or three species is the aperture known. As the specimen forming the subject of these notes has the aperture exceptionally well preserved, it is, therefore, worthy of notice.[1]

CONULARIA *cf.* LÆVIGATA, Morris.

(Strzleckis, Phys. Desc. N.S.W., p. 290, pl. 18, f. 9, 1845.)

The specimen consists of a portion of the test about three inches in length. The section is slightly rhomboidal at the aperture, but this is evidently due to compression for at the lower end it is practically square. All four sides are equal, tapering from ·75 to ·5 of an inch in width at the extremity. Thus the apical angle is very low, not more than 7°. The sides are slightly convex, and are separated by four deep longitudinal furrows. These furrows are divided medially by ridges, upon which the continuations of the transverse ridges alternately terminate. The ridges are thin, angular and numerous, 32 being counted within the space of one inch. They slope from the lateral furrows upwards towards the aperture, and are intersected in the centre of each face by a fine longitudinal mesial ridge, upon which they alternate.

[1] The specimen was exhibited at a meeting of the Linnean Society of N.S.W., *see* Vol. XXXIV, p. 590, 1909.

The aperture, however, is the most interesting feature in connection with the specimen. Here the four walls are bent regularly over, and diverge downwards for at least half an inch into the centre of the shell. How far they continue is uncertain, the central cavity being partially filled with matrix. The ornamentation is also continuous upon the infolded portion of the walls, the ridges, however, sloping in an opposite direction, or towards the apex.

Locality and Horizon:—This specimen was forwarded from the Maitland District, and, from its resemblance to other specimens, probably comes from the Lower Marine Series in the vicinity of Cessnock. It is now placed in the collection of the Technological Museum, Sydney.

Observations:—Concerning the identification of the various species of *Conularia* some difficulty arises. The tests of our several Permo-Carboniferous species are on the whole very similar to each other, depending for their separation chiefly on such characters as the apical angle, relative proportions of the four walls, variation in the ornamentation etc. The following are the species occurring in the Permo-Carboniferous formation of Eastern Australia:—*Conulara inornata*, Dana, *C. lœvigata*, Morris, *C. quadrisulcata*, Miller, *C. tasmanica*, Johnston, *C. tenuistriata*, McCoy, and *C. torta*, McCoy.

Of these, our specimen most nearly approaches *C. lœvigata*, particularly in the low apical angle, and the nature of the ornamentation, but it differs chiefly in the relative proportions of the four walls. In *C. lœvigata* the section is oblong, one pair of sides being larger than the other, whereas in this case the four sides are practically equal.

The aperture also differs from that of all known specimens. In the few species of which this character is figured, the four walls are prolonged upwards, and, diverging towards the centre, partially close the orifice.

The best specimen so far found, from the Carboniferous of Scotland, was figured by R. Etheridge, junr.,[1] who has also described a specimen of *C. inornata* from the Upper Marine Series at Farley.[2] But no specimen yet recorded shows the remarkable infolding of the four walls here figured. It seems probable that in the future as the apertures of other species become known, they will show other marked differences, and prove to be characters of specific value.

THE RIVER GRAVELS BETWEEN PENRITH AND WINDSOR.

By H. I. Jensen, D. Sc.,

[*Read before the Royal Society of N. S. Wales, October 4, 1911.*]

For many years past Sydney geologists have been well acquainted with the river gravels in the railway cutting near Glenbrook. These gravels have been described by Professor David in his Anniversary Address in 1896 before this Society, and they were also referred to in his paper on the Kurrajong Fault.[3] In the above mentioned address reference is also made to Pleistocene and recent alluvials consisting of river gravels and red sandy soil extending along a length of 20 miles from Mulgoa to Richmond. Professor David clearly included in this series only the alluvials up to 20 feet above present high flood mark. The Glenbrook gravels he regards as older Tertiary or

[1] Geological Magazine. 1873, p, 295.
[2] Proc. Linn. Soc. of N.S.W., Vol. xx, p. 751, f. 1, 1889.
[3] Proc. Roy. Soc. N.S.W., December, 1902.

Cretaceous. Subsequently Mr. R. Cambage, F.L.S., discovered another area of gravels and boulders, similar to and correlative with those of Glenbrook, on the heights to the west of Mulgoa overlooking 'The Basin' where the Nepean and Warragamba rivers unite. These gravels as well as those of Glenbrook have been recorded on the 'Geological Map of the Country in the Vicinity of Sydney' under the direction of Mr. E. F. Pittman. As far as the writer is aware no reference has ever been made to the series of river gravels which are the subject of this note.

On a visit to the Penrith and Windsor districts last year Mr. C. Wilson, Engineer of the Public Works Department, drew the writer's attention to the existence of gravels and boulder beds following a direct line between Richmond and Windsor and having their maximum development near Rickaby's Creek. The gravel areas were carefully mapped by Mr. O. K. Hutchison, Surveyor of the Works Department, in the course of the preparation of a soil map of the district. The accompanying map, figure 1, copied from the official soil map by permission of the Works Department, shows the position of these outcrops, which the writer personally inspected and examined on several visits to the district.

The boulders range from a few inches to over a foot in diameter, and are composed of the same kinds of rock as the Glenbrook gravels, namely granite, quartz-porphyry, quartzite and slate. The sandy matrix is in many places compacted into a fairly coherent rock, and in one place, about three miles south of Penrith, it had been silicified by spring action, so that the cement was harder than the included boulders.

The boulder beds usually form ridges, and the outcrop generally has a width of from 200 to 400 yards, while the depth of the gravel must in many places exceed 30 or 40

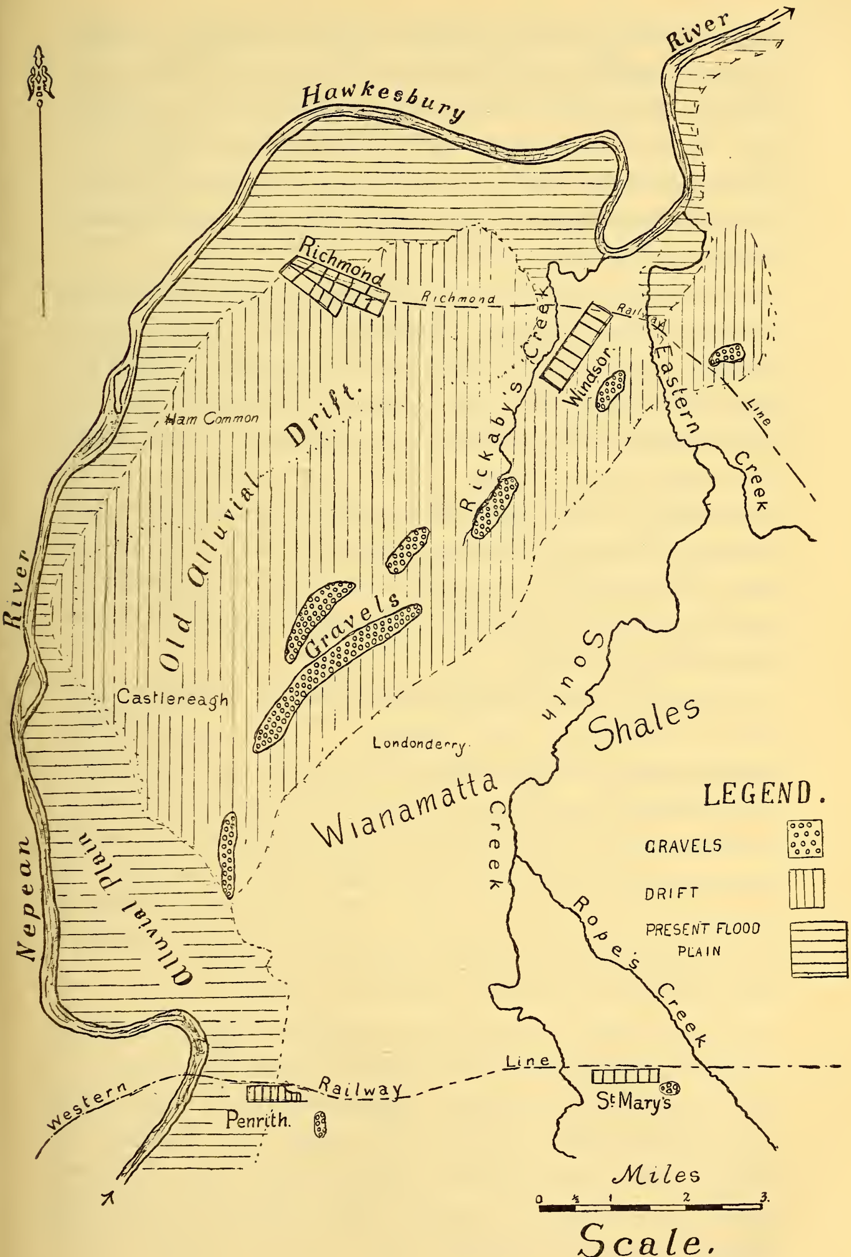


Fig. 1—*The Trend of the Old River Gravels between Penrith and Windsor.*

feet. The height of the boulder ridges is variable, ranging from 40 to perhaps 150 feet above the present water level of the Nepean River. The boulder formations run slightly north of north-east from the Penrith alluvial plain, at a point three miles from Penrith where the present Nepean River turns abruptly to the west. They are approximately parallel to Rickaby's Creek.

To the north and west of the line of gravels the soils are mainly of alluvial origin, consisting of light sandy loams, which are partly the product of river deposition during the period when the river was changing its course from the line of gravels to the present bed, and partly redistributed silt washed down from the old bed now represented by the gravel hills. A few isolated patches have soils indicating derivation from Hawkesbury sandstone and Wianamatta shale. To the south and east of the line of gravels the soils invariably indicate their derivation from the Wianamatta shale formation.

The gravels along this line are far more extensive than those of Glenbrook and Mulgoa. They unquestionably belong to the same age and are of the same derivation. The vast stretch of poor sandy soil between the old gravels and the alluvials of recent age is of drift origin as above stated, and may indicate a rapid shifting of the river from its ancient to its present course. The Glenbrook, Mulgoa and Rickaby's Creek gravels are in the writer's opinion of late Tertiary, Pliocene or Pleistocene Age.

From a study of the country around Penrith, Mulgoa, Windsor and Richmond, the writer has arrived at the conclusion that in late Tertiary times (probably Pliocene) the Warragamba river flowed in the course now occupied by Mulgoa Creek, the gravels on the elevations east of Penrith indicating that the old Nepean often meandered east of the course marked by Mulgoa Creek and the present river.

The old Warragamba and Nepean rivers joined at a spot not far from the westerly bend of the Nepean north of Penrith. The boulder belt thence to Windsor was the product of the combined stream.

In his anniversary address in 1896, Professor David suggested that the Glenbrook gravels might be correlated with the gravels at St. Mary's. The writer is, however, quite satisfied that the St. Mary's gravels were deposited by the Nepean River, and not by the combined Nepean and Warragamba, and also that the gravels found at St. Mary's and in various places to the north-east, belong to an older period in which the Nepean occupied a still more easterly course.

The cause of the shifting of the course of the Warragamba River from the old Glenbrook channel to its present position on the plains has been well explained by Professor David in his anniversary address of 1896 (*op. cit.*) and in his paper on the Kurrajong Fault (this Journal 1902). The formation of the monoclinal fold slowly tilted the river out of its old course.

The diversion of the Nepean River into the Warragamba River at the Basin has, however, not been explained, and while the solution of the problem which is here proffered has not been fully established, it nevertheless has strong arguments in support of it.

First it should be stated that the production of the Lapstone monocline was very slow and probably commenced as far back as the Pliocene. Secondly, we must take into consideration that we have to deal with an area in which there have been two causes of movement, tectonic movement and igneous uplift. The tectonic movement followed the north and south line of the monoclinal fold. Intersecting it at right angles we have a line of igneous intrusions extending from the Basin in an east-north-east

Fig. 2—*Map showing the suggested old courses of the Nepean and Warragamba Rivers, and axes of earth movements.*

direction through Luddenham and Minchinbury to Prospect; and many areas, such as the heights east of Mulgoa, Frogmore Farms south-west of St. Mary's and others, were elevated by the intrusion of laccolites at a depth. The numerous basalt dykes on the surface in these places hint of masses like that of Prospect below. We have reason to believe that the basaltic eruptions of the County Cumberland belong to the late Pliocene or early Pleistocene period of volcanicity—the period of the newer leads (Andrews, 'Geographical Unity,' this Journal, Nov. 1910.)

The Warragamba River had prior to the commencement of the monoclinal folding a small tributary which rose not far from the old course of the Nepean and flowed westerly into the main river at the Basin. The Warragamba River was carried towards the west by the monoclinal fold in the region of Mulgoa and the Basin, the line of maximum uplift or axis of folding being east of the old river course. At Glenbrook the old bed of the river lay east of the axis of folding, so that the river was thrown to the east.

After the fold movement had set in the intrusion of basaltic laccolites commenced along an axis almost at right angles to the axis of folding. The uplift caused by igneous intrusions has been very considerable at Mulgoa and between Mulgoa and St. Mary's, so much so that the magnitude of the monoclinal fold has been considerably obscured in this region by the intrusive uplift.

The radical difference between the mode of action of an igneous uplift and that of a tectonic uplift lies in the fact that the former kind is rapid and sudden, whereas the latter is very slow. The rapid elevation of a portion of the bed of the old Nepean by the igneous uplift running nearly east and west from the Basin towards Prospect enabled a small tributary of the Warragamba to capture the Nepean before the monoclinal uplift had neared its present magnitude. The hookshaped bend of the Nepean before it joins the Warragamba points to origin by river capture. The nature of the Glenbrook gravels and Mulgoa Heights gravels at the Basin point to derivation from the granite areas at the head of Cox's River. The gravels along Mulgoa Creek and on the heights east of Penrith point to derivation from the Hawkesbury and Permo-Carboniferous sandstones to the south in the drainage area of the present Nepean. The gravels of the St. Mary's district are also typical of the Nepean drainage area.

It therefore follows that in late Tertiary times the Nepean and Warragamba Rivers effected a junction somewhere to the north of the present town of Penrith, and the capture of the Nepean by the Warragamba was in all probability brought about by the igneous uplift occasioned between Penrith and Mulgoa by intrusions of basalt and diabase which manifest themselves on the surface in the form of dykes.

The shifting of the river to the north of Penrith from its old course between Penrith and Windsor to its present course is due to a distinct movement of depression in the area around Richmond. In the absence of igneous intrusions in this area, the depression of the eastern limits of the Lapstone monocline was very much accentuated here, a fact which is also established by the north-westerly dip of the Wianamatta shales in those parts of the parishes of Londonderry, Castlereagh, Ham Common and Windsor which adjoin the old river channel. Whatever may be the case with the Sydney district as a whole, and the writer is in agreement with Andrews in regarding it as akin to a senkungsfeld, there can be no doubt that the Richmond district is a subsidence area.

The extrusion of alkaline basalt in the Sydney district may be here as elsewhere a phase, function or effect of senkungsfeld formation.[1]

Conclusions.

1. It has been shown in this note that an old river channel representing the combined course of the Nepean and Warragamba extended from the Penrith Plain to Windsor along Rickaby's Creek.

2. That the gravels at Mulgoa overlooking the Basin and at Glenbrook belong to the Warragamba stream.

3. That the old Nepean flowed along the Mulgoa Creek valley due north and south.

4. That this river was probably captured by the Warragamba because of the igneous uplift at right angles to the monocline forcing it back.

5. That the St. Mary's gravels belong to an older period in the history of the Nepean.

6. That depression of the Richmond area caused a tilting of the combined river to the west from its old course along Rickaby's Creek.

7. That the Warragamba was tilted to the west at the Basin because it was slightly west of the monoclinal axis and was perhaps partly coincident with the line of depression which is expressed in the Kurrajong fault and the fold at Glenbrook railway station described by Prof. David, this Journal, 1902.

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[1] *See* The Age, Origin and Relationship of Alkaline Rocks, Proc. Linn. Soc. N.S.W., 1908.

AN AUTOGRAPHIC AIR-FLOW RECORDER.

By W. R. HEBBLEWHITE, B.E.

(Communicated by Prof. S. H. Barraclough, B.E., M.M.E.)

[With Plate XII.]

[*Read before the Royal Society of N. S. Wales, November 1, 1911.*]

1. Introductory.—The following paper describes the construction and method of working of an instrument devised for autographically recording the quantities of gas passing through any system, before discharging to atmosphere. Its construction was primarily the outcome of a difficulty experienced in connection with research work on the steam condenser plant in the Mechanical Engineering Laboratory at the University of Sydney, in which it was found that an accurate measurement of the air-vapour mixture passing through the condenser was essential.[1] In the present design the author has endeavoured to produce an apparatus which combines the essential characteristics of simplicity, accuracy, moderate cost, and suitability for every day use in condensing plant tests.

2. Principle of Action.—The principle on which the recorder works is as follows:—

The air (or other gas) to be measured is conducted by a pipe into an inverted cylinder floating on water, and free to move vertically. Escape from this cylinder is by way of holes in its side, the number of the holes above the water level being dependent on the height of the float in the water.

[1] The author is indebted to Mr. H. W. Fry, who had previously been making investigations on the condenser, for the suggestion that it might be possible to modify the Weighton Air Gauge so as to accomplish this purpose, and also for his assistance with the design: see "Steam Condensing Plant for Cargo Steamers," (Morison) in Cassier's Magazine, Vol. xxxv.

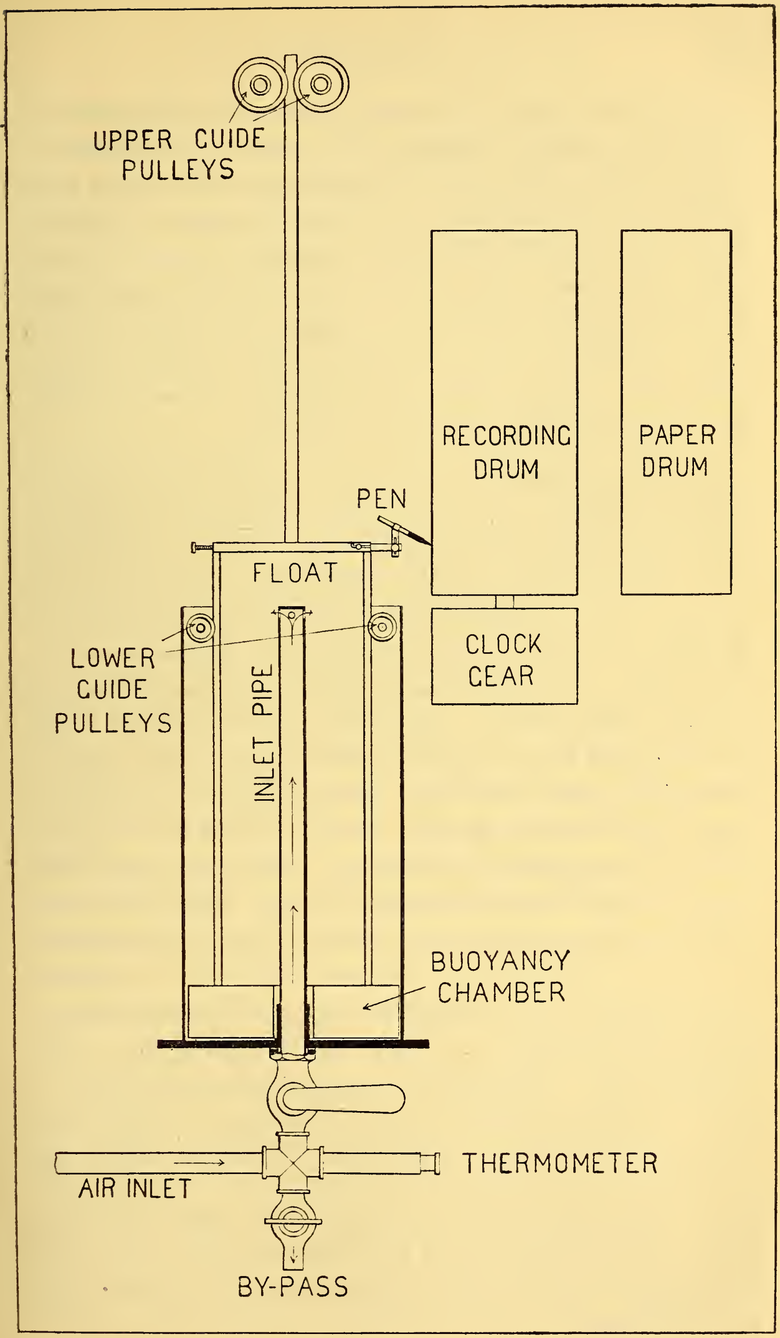

Fig. 1—*Diagram of the Autographic Air-flow Recorder.*

A given rate of flow of air will require a certain number of holes by which to escape. The air will, therefore, lift the float until sufficient holes appear above the water level to allow of its discharge. An increase in rate of flow will cause a further rise of the float, and a decrease will cause a fall of the float, since the pressure of the air is governed by the height of the float in the water. Any height of float, when equilibrium is maintained, will correspond to a definite rate of flow of air, and to a definite pressure difference between inside and outside the float.

3. Construction.—The instrument constructed for the laboratory (Fig. 1 and Plate XII), consists of a brass containing vessel 6″ diameter, 12″ high, mounted by brackets on a vertical wooden stand. The float is 4″ diameter, and is made of No. 36 gauge sheet brass soldered to shape. At its base it carries a buoyancy chamber $5\frac{7}{8}$″ diameter outside, with a central opening 1″ diameter through which the air inlet pipe passes. The depth of this chamber is $1\frac{1}{2}$″. The effect of this air-tight chamber is to nearly balance the weight of the float in the water, reducing the pressure under which the air escapes. The air enters the float by a $\frac{5}{8}$″ inlet pipe passing through the base of the containing vessel, to which it is permanently fixed. This pipe passes to level with the top of the vessel. The end is plugged, and the air passes from it through holes in the circumference at the top, thus preventing gusts of air impinging on the top of the float and disturbing its equilibrium. The float's motion is constrained to a vertical direction by two pairs of pulleys carried on pivot bearings, the lower pair being mounted at the top of the containing vessel, and running on light brass guides attached to the sides of the float. The upper pair are mounted on the main base-board about 14″ above the top of the vessel, and between them runs a single circular guide standing from the centre of the top of the float.

The discharge holes (see Plate XII) are in a vertical row, $\frac{1}{8}''$ spacing, and about $\frac{1}{32}''$ diameter. They are countersunk to reduce the tendency for a film to remain over them as they rise from the liquid. To further reduce this trouble arising from the surface tension of the liquid, it has been found desirable to use a mixture of alcohol and water. Alcohol would be satisfactory but for its rapid evaporation. A half and half mixture is found satisfactory, and does not evaporate to any appreciable extent during a test. Its density is kept constant by the aid of a hydrometer. The height of the liquid is adjusted to a mark on a gauge glass (see Plate XII) in front of the containing vessel, when the instrument is out of action, and the air space at atmospheric pressure. The instrument is emptied after each test through a drain cock in the base.

The recording glass tube pen (Fig. 1 and Plate XII) is attached to the end of a plunger working in a horizontal barrel across the top of the float. It is kept in contact with the recording drum by a spring in the barrel, whose compression is regulated by means of a screw. A catch enables the pen to be held out of action, and it is also adjustable as to height. A fixed pen gives a base line from which the height of the diagram is taken. The two pens are set to the same line before the instrument is put into action.

The recording drum is 4″ in diameter and is clock-driven, making one revolution per hour. It unwinds a roll of paper 9″ wide from another drum 3″ in diameter. The temperature of the air is read at entrance to the instrument where, also, a valve enables the air to be by-passed to atmosphere.

The instrument at 7″ height of diagram is passing 1·41 cubic feet of air at the barometric pressure at the time of use. The measuring capacity of the instrument is increased without affecting its sensitiveness by fitting diaphragm plates with varying apertures on the top of the float. For quantities above 1·4 cubic feet per minute, this plate is replaced by one having a hole sufficiently large to pass a large proportion of this amount of air. The float now falls considerably, but further increase in the rate of flow will again cause it to rise and begin a new range. There are three such "ranges" of readings, giving a total capacity of 3 cubic feet per minute. The capacity might be increased by enlarging the discharge holes, but this would decrease the sensitiveness. For a larger plant, however, it would be advisable to do so.

4. Calibration.—Each range was calibrated separately, and the curves are shown in Fig. 3. Calibration was effected by the use of standard meter calibrating tanks. The varying pressures of the air were read from a manometer, and the necessary allowance made.

5. Diagrams.—Sample diagrams taken by the instrument are shown in Fig. 4, superimposed, with a common zero line. The amount of air passing was varied by the air cock on the exhaust main. It will be observed that in the second and third ranges, the vibrations diminish very considerably as compared with the first range diagram.

6. Impulse Absorber.—The absorber apparatus, as at first arranged, was an attempt to provide a reservoir in the air passage, which, while free to take up, by change of volume, the irregularities in the air flow, maintained at the same time the constant pressure corresponding to that in the instrument for the given rate of flow. This was easily arranged by the use of a small gasometer in the air path, the float of which was balanced by a counter-weight sufficiently large to give the required air pressure. The gasometer rose and fell under the varying irregularities, but the air passed on at a constant pressure to the recorder and gave a good diagram. The gear was not automatic

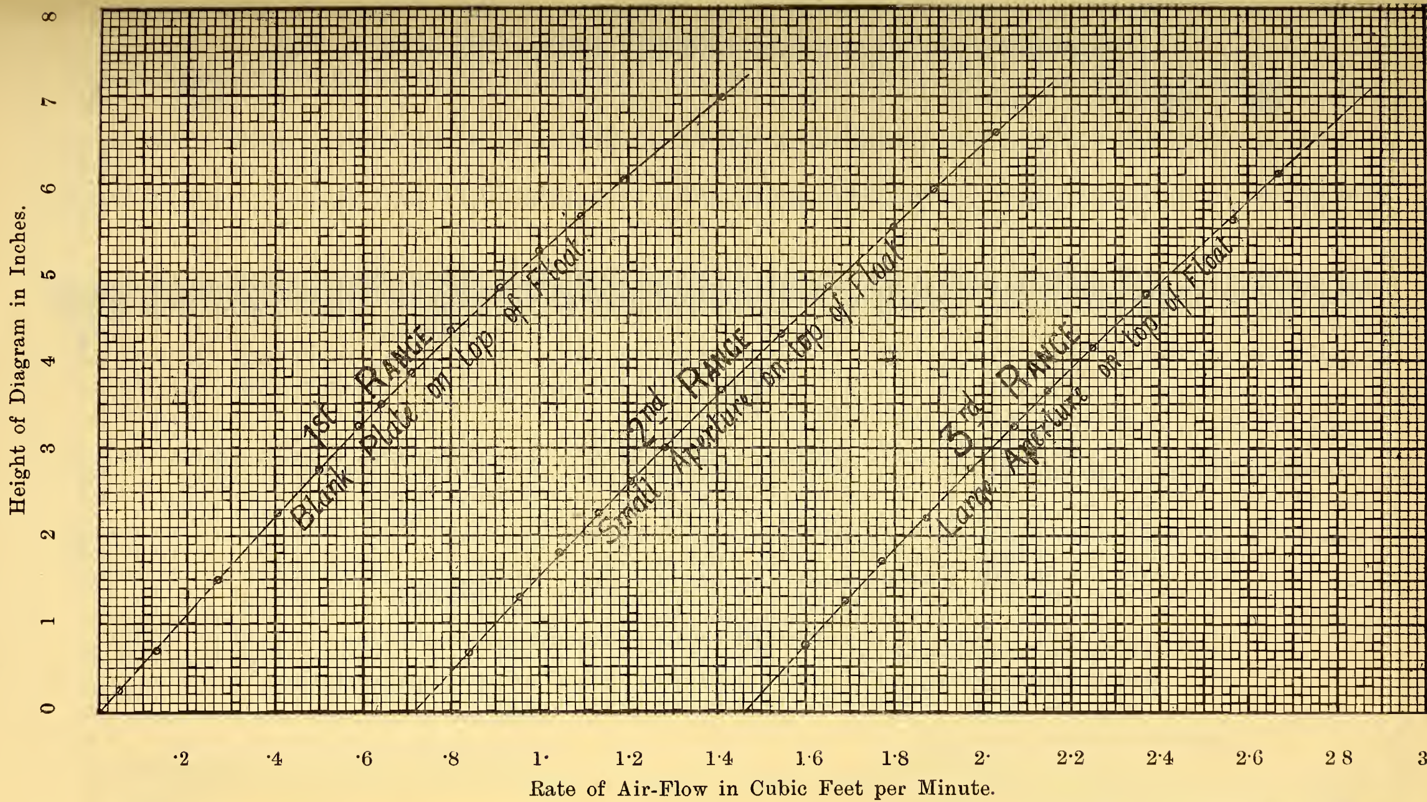

Fig. 3—*Calibrating Curves for the three ranges representing the blank, small aperture, and large aperture plates, respectively, fitted to the top of the float.*

A. Zero line.
B. First Range, with absorber suspended over water by long spring, as finally adopted.
C. First Range, with absorber fixed over water.
D. First Range, with no absorber in use.
E. Second Range.
F. Third Range.

G. First Range, instrument thrown into action.
H. Air leakage increased.
J. Air leakage decreased slightly.
K. Air leakage cock shut.
L. Normal leakage of plant.
M. Instrument thrown out of action.

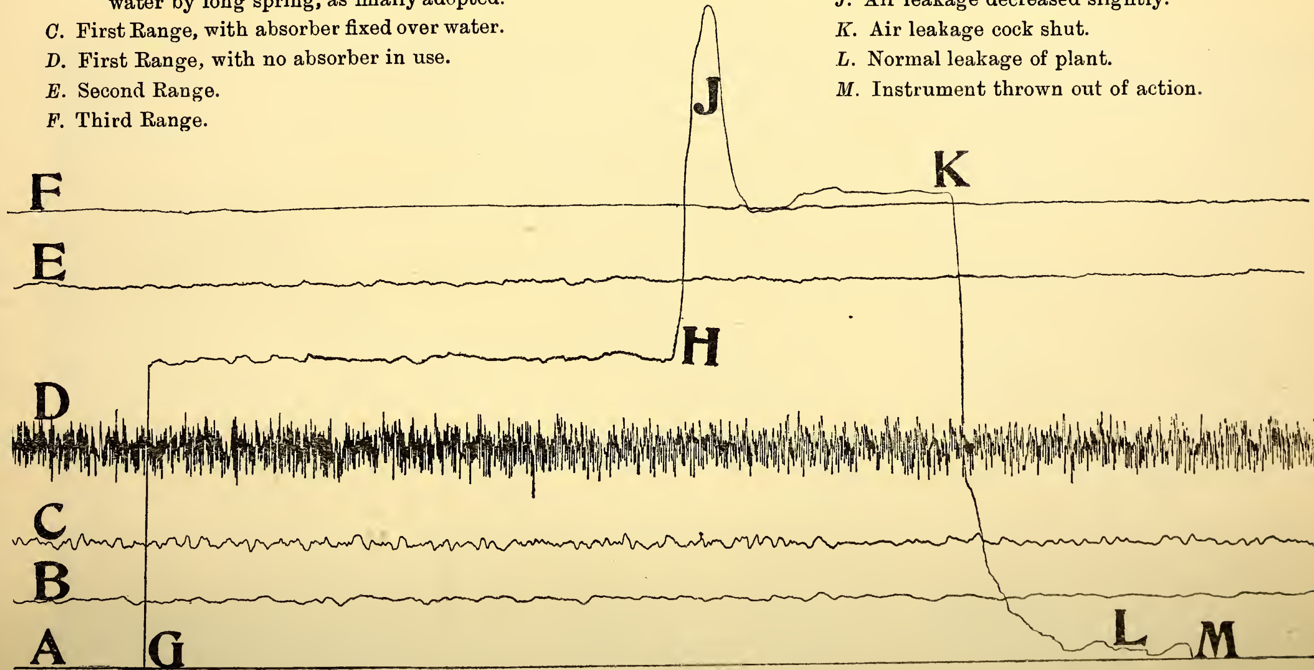

Fig. 4—*Superimposed Sample Diagrams taken with no steam load on Condenser.*

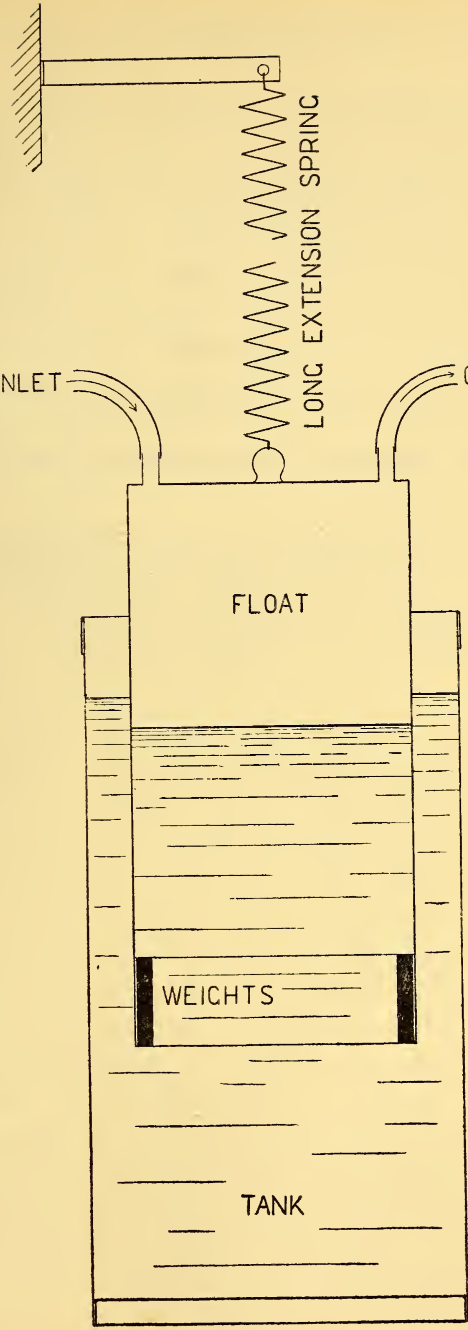

Fig. 5—*Impulse Absorber, for damping the impulses due to the action of the pump.*

and required adjustment of the counter-weight for variations of the mean rate of flow, *i.e.*, of the mean pressure. The apparatus finally adopted (Fig. 5) is a modification of the above and is automatic in its action. A spring replaces the cord and counter-weight. Hence, the gasometer rises under the air pressure until the tension of the spring has relaxed sufficiently to give equilibrium. By choosing a spring of very long range, a considerable variation in volume may occur by rise or fall of the gasometer without any appreciable change in the mean pressure of the air. The efficiency of the apparatus is demonstrated by the sample cards.

The author desires to acknowledge his indebtedness to Prof. S. H. Barraclough for his help in the construction of the apparatus, and to Messrs. Parkinson and W. and B. Cowan for the use of their calibrating plant.

On some NEW ENGLAND EUCALYPTS and their ECONOMICS.

By Richard T. Baker and Henry G. Smith,

Technological Museum, Sydney.

With Plate XIII.

[*Read before the Royal Society of N. S. Wales, November 1, 1911.*]

Introduction.—The ground covered by this paper includes botanical remarks, descriptions, chemistry of the oils and general economics of the following species of Eucalyptus:

E. acaciaeformis, Deane and Maiden.
E. Andrewsi, J. H. Maiden.
E. Bridgesiana, R. T. Baker.
E. laevopinea, R. T. Baker.
E. nova-anglica, Deane and Maiden.
E. campanulata, sp. nov.

New England might be called the land of the "Peppermints," for in no other part of New South Wales is the term "peppermint" applied to so many Eucalypts in such an indiscriminate manner, and one might add without sufficient reason, for many of the trees so called do not contain the peppermint constituent, piperitone, in their oil. What has been the ruling feature in such naming is, however, not far to seek. The designation has most probably been applied originally, and since passed on, to the nature of the bark, for it resembles in its general features the characteristics of the Sydney Peppermint, *E. piperita*, to which species of Eucalyptus the name peppermint, owing to the presence of the peppermint constituent, was applied by the medical officers of the First Fleet in 1788, and consequently this is regarded as the type of all peppermint barks.

It would have been better from a commercial standpoint if the early northern settlers had acquired more than a superficial knowledge of the trees from a general appearance of their barks, before applying a common name.

Out of the four so called "peppermints" only one,—*E. Andrewsi*, is really entitled to be called a "peppermint," as neither of the three others contains piperitone in their oil, whilst the new species here described yields that constituent, and yet has not received the name of peppermint so far as we are aware. This is a good illustration of how chary one must be in dealing with Eucalypts from their common names.

The following will give some idea of the vagaries of vernacular nomenclature in this district of four of the species mentioned in this paper:—

E. acaciaeformis.

Red Peppermint at Tenterfield.
Peppermint (generally).
Narrow-leaved Peppermint (Deane and Maiden).

E. Andrewsi.

Peppermint at Bundarra.
New England Peppermint.

E. Bridgesiana.

White Peppermint at Uralla.
White Peppermint at Tenterfield.
White Peppermint at Woolbrook.

E. nova-anglica

Black Peppermint at Black Mountain.
Red Peppermint at Armidale.
Red Peppermint at Woolbrook.
Broad-suckered Peppermint (J. H. Maiden).

Timber.—The timber tests here given have been made by Mr. Nangle, Lecturer in Architecture at the Technical College, and are the first recorded.

Oils.—The portion devoted to the determination of the volatile oils of the species of Eucalyptus included in this paper, embraces two sections: (1) The investigation of new oils obtainable from the leaves of *E. Andrewsi*, *E. acaciaeformis* and *E. campanulata;* and (2) results of investigations into oils of species not examined previously from this locality. The results obtained by this additional chemical evidence go to support the fact that there exists a remarkable constancy in the chemical products of identical species of Eucalypts, which has enabled an auxiliary method of discrimination between species to be evolved, one which in conjunction with botanical and physiological features assists in determining the relations between members of the several groups and allied sections of this large class of Australian vegetation. The study, in this instance, has been devoted largely to the characters of the oils derived from species yielding products which may perhaps be considered of an anomalous nature, so far as ordinary Eucalyptus oils are concerned. The economic side of this question, too, cannot be ignored, especially in view of the prominence Eucalyptus oil has lately reached. The species dealt with in this section are *E. laevopinea*, *E. nova-anglica* and *E. Bridgesiana.* Prior to the discovery of the prominence of the terpene pinene in certain Eucalyptus oils, it had been generally recognised that the terpene phellandrene was the most abundant product of their terpene oils. While this is true, so far as the species of one large group is concerned, yet, it has been possible to show that not only does the terpene pinene occur in abundance in the oils of some Eucalyptus species, but that both active modifications are obtainable from different trees. *Eucalyptus laevopinea* may, probably, often have been considered by botanists as *E. macrorhyncha*, the "Red Stringybark" of Southern New South Wales, or perhaps *E. pilularis*, but from a commercial point of view alone this supposition cannot be entertained, and it was with the endeavour to determine how far the constant botanical and chemical characters hold that the present investigation has been undertaken. The localities, Armidale and Uralla, are far away from Rylstone from which locality the first described material was obtained. The original data derived from that material were published in our work "Research on the Eucalypts," pp. 41 and 242. Eucalyptus species appear always to give chemical products practically identical in composition and general characters, no matter where found growing, of course allowing for slight differences always found in natural products of this nature. While one could readily distil laevo-rotatory turpentine from the leaves of *Eucalyptus laevopinea*, it would not be possible to do so from those of either *E. macrorhyncha* or *E. pilularis*. Unfortunately the yield of oil from naturally growing trees of *E. laevopinea* is somewhat small (0·6 per cent.), and thus the commercial production of turpentine from this source is not possible at its present price, (although the yield of oil from *E. dextropinea* is somewhat larger) but it perhaps might be feasible, by a proper system of treatment and cultivation, to induce this and similar species to secrete a greater abundance of pinene, and so render its production profitable. If the quantity of oil from the chief pinene bearing species was as great as that from the most prolific phellandrene bearing species, the maufacture of turpentine from the Eucalypts could be made a profitable undertaking. From all the evidence we have obtained there seems no doubt but that *E. laevopinea* is a distinct species of Eucalyptus, and differs in characters from any other. It may, perhaps, be considered as the "Stringybark" of the Northern Highlands of New South Wales, while *E. macrorhyncha* is the "Red Stringybark" of Southern New South Wales, and as the one species goes north and the other comes south, they both meet in the neighbourhood of Rylstone, and are thus found growing together in that locality.

The other species of special interest is *E. nova-anglica.* As its name implies, its principal location is in the New England district. The previous determination of its essential oil was published in the "Research on the Eucalypts," p. 34, and it was there shown to consist principally of the sesquiterpene peculiar to Eucalyptus oils. Nearly three-fourths of the oil of this species consists of that constituent. The chief terpene in this oil was also shown to be dextro-rotatory pinene. It might reasonably be supposed that the presence of such a large amount of a high boiling constituent as the sesquiterpene would cause the oil to alter considerably at various times of the year, or when the trees were grown under variations of climate, or influenced by soil or local conditions, and to decide this point further investigations have been made with the oil of this species. Here again, however, was found a remarkable constancy of constituents and physical properties in the oils from varying localities.

Species.

EUCALYPTUS ACACIAEFORMIS, Deane and Maiden.

"Red" or "Narrow-leaved Peppermint."

Historical.—It was first brought before the scientific world by J. H. Maiden in a paper on "Some Eucalypts of the New England Tableland," read before the A.A.A.S. in 1898, being Eucalypt No. 3, of that article.

Messrs. Deane and Maiden described and figured it in the Proc. Linn. Soc. N.S. Wales, 1899, under its present specific name.

Remarks.—This is one of the most widely distributed of the "Peppermints" of New England, and so far has not been recorded outside that area. Its oil is now described for the first time.

Essential Oil.—Leaves were obtained from Tenterfield and distilled 15/1/10. The material was collected as for commercial distillation, so that the yield is an average one. The crude oil was red in colour, very mobile, and had a rank, turpentine like odour. It consisted principally of dextro-rotatory pinene and the sesquiterpene of Eucalyptus oils. Phellandrene could not be detected, and eucalyptol was only present in very small quantity. The amount of ester was somewhat large for an oil of this class, and consisted almost entirely of geranyl-acetate. In its general characters the oil of this species has some resemblance to that of *E. nova-anglica*, although the abundance of dextro-rotatory pinene (with a very high rotation), the less yield of oil, the higher ester content, the lower specific gravity, and the small quantity of the sesquiterpene, all show it to differ from the oil of that species. The following results were obtained with the crude oil :—

Yield of oil per cent.	= 0·197
Specific gravity at 15° C.	= 0·8864
Rotation a_D	= + 35·7°
Refractive index at 20° C.	= 1·4713

Insoluble in 10 volumes 80 per cent. alcohol.

Ester by boiling, 3·216 gram oil required 0·056 gram KOH ∴ S.N. = 17·41.

Ester in the cold, two hours contact, 2·59 gram required 0·042 gram KOH ∴ S.N. = 16·21.

From this determination the ester is principally geranyl acetate and the cold saponification of the oil shows 5·7 per cent. of that ester to be present.

Only 50 cc. of the oil could be spared for rectification, and only one or two drops came over below 154° C. (cor.) Between 154 – 157° 70 per cent. distilled; between 157 – 183 16 per cent. came over, leaving 14 per cent. of high boiling constituents in the still. The specific gravity of the first fraction at 15° C. = 0·8644; of the second = 0·8772 and of the residue = 0·9833. The rotation of the first fraction

a = + 40·4 or specific rotation $[a]_D$ = + 46·74°; of the second fraction a_D = + 35·5°. The refractive index at 21° C. of the first portion = 1·4661; of the second = 1·4686.

The residue gave S.N. 80·6 or 28·2 per cent. of ester, calculated as geranyl acetate. The acid of the ester was isolated and determined to be acetic. The saponified oil had a marked odour of geraniol, but it was too small in amount to enable the alcohol to be separated. All the evidence, however, goes to show that the ester of this oil is almost entirely geranyl acetate.

EUCALYPTUS ANDREWSI, J. H. Maiden.
"New England Peppermint."

Historical.—According to Mr. Maiden the specimens collected by Mr. W. Christie in 1877 in connection with his paper on "The Forest Vegetation of Central and Northern New England in connection with Geological Influences," Proc. Roy. Soc. N.S.W., 1887, belong to this species.

Messrs. Deane and Maiden describe it in the Proc. Linn. Soc. N.S.W., 1898, p. 794, under the name of *E. Sieberiana* var. *Oxleyensis.*

It was however raised to specific rank in 1904 by Mr. J. H. Maiden, Proc. Linn. Soc. N.S.W., and is more fully dealt with by this author in his "Critical Revision of the Genus Eucalyptus," Part VII. (Vide note under remarks in this paper as to systematic position of this Eucalypt).

Remarks.—Like most other Eucalypts this tree unfortunately has several vernacular names, being known as "Blackbutt," "Peppermint," and "Messmate," but these are not mentioned here to be perpetuated, but the reverse, and the hope is expressed that the name of New England "Peppermint" will in future be associated with it.

This common name now carries an important commercial significance from its association with phellandrene in the oil. The chemical results here given will probably lead to an exploitation of the tree almost immediately, as similar oils are now in great demand in connection with the treatment of ores by the flotation process.

The botanical and chemical evidence available in the Technological Museum goes to show that this tree is the northern form of *E. dives*, Schau., and the fruits depicted in the "Critical Revision of the Eucalypts," Part VII, pl. 36, and "Forest Flora of N.S.W.," J. H. Maiden, Part XXI, under *E. Andrewsi*, J.H.M., faithfully delineate those of *E. dives*, Sch., ("Critical Rev. Gen. Euc." Part VII). The normal leaves of these two trees are identical, as also are the timbers and bark. It seems now that the only difference so far is that no sessile, cordate, sucker (abnormal) leaves have been found in connection with *E. Andrewsi* as obtains in *E. dives*. Mr. Cambage informs us that the seedlings of these two trees are different. The oil obtained from the Tenterfield specimens contains practically the same constituents as *E. dives*, although it is less in yield. These slight differences may perhaps be accounted for by its occurrence on granite ranges from which formation our specimens were obtained.

Timber Tests.—

TRANSVERSE TESTS.

	No. 1.	No. 2.	No. 3.	No. 4.
Size of specimen in inches	B. 3; D. 3; L. 36.	B. 3·04; D.3; L. 36.	B. 3; D. 2·99; L. 36.	B. 2·99; D. 3·03; L. 36.
Area of cross section, sq. inches	9	9·12	8·97	9·05
Breaking load in lbs. per sq. in.	4,960	4.990	4,660	5·900
Modulus of rupture in lbs. per sq. in.	9,920	9,849	9·382	11,606
Modulus of elasticity in lbs. per sq. inch	1,440,000	1,578,947	1,322,269	1,428,571
Rate of load in lbs. per minute	708	623·7	665·7	453·8

Essential Oil.—Leaves were obtained from Tenterfield and distilled 21/1/10. The material was collected as would be done for commercial distillation. The crude oil was lemon-yellow in tint, and but slightly coloured, and had a secondary odour of peppermint. It has all the appearances and characters of a "Peppermint Oil," and resembles very closely the oils distilled from the group of which *E. dives* may perhaps be considered the type. The principal constituents in the oil are laevo-rotatory phellandrene, piperitone, and the sesquiterpene, of which the first predominates very greatly, in fact, this species may be considered as yielding one of the most pronounced phellandrene bearing Eucalyptus oils, not even excepting *E. radiata.* Pinene appears to be quite absent, and eucalyptol was only detected with difficulty. The amount of ester was very small, as was to be expected. The crude oil gave the following results:—

Yield of oil per cent.	= 1·27
Specific gravity at 15° C.	= 0·8646
Rotation a_D	= − 41·5°
Refractive index at 15° C.	= 1·4854
S.N. of the ester + free acid	= 4·3
Insoluble in 10 volumes 80 per cent. alcohol.	

On rectification only a few drops of acid water and a small quantity of volatile aldehydes came over below 174° C. Between 174 – 178° 56 per cent. distilled; between 178 – 182° 26 per cent.; between 182 – 194° 6 per cent. The temperature then rose to 245° and between that and 255° 8 per cent. came over. It thus divided roughly into the fractions containing the main constituents, although in the higher ones phellandrene was still present.

The specific gravity at 15° C. of the first fraction = 0·8508; of the second = 0·8563; of the third = 0·8749; and of the fourth = 0·9034. The rotation of the first fraction a_D – 47·2;

of the second −44°; of the third −32·9°; with the fourth light did not pass. The refractive index at 18° C. of the first fraction = 1·4819; of the second = 1·4839; of the third = 1·4862; of the fourth = 1·4968.

The nitrite was prepared with the phellandrene, and was separated into two forms, one melting at 112 – 113° C. and the other melting at 105° C.

In view of the prominence recently acquired by the phellandrene Eucalyptus oils in the separation of metallic sulphides from ores by the flotation process, this species, as stated above, has value as an oil producing tree. The yield, however, is much lower than with such species as *E. dives* or *E. amygdalina*. At present we do not know of any other species growing in the New England District of New South Wales from which a greater yield of phellandrene oil can be obtained.

Eucalyptus Bridgesiana, R. T. B.
"White Peppermint."

Historical.—This was specifically described in the Proceedings of the Linn. Soc., N.S.W., in 1898 by one of us.

Remarks.—Since this species was established further material has been obtained from many parts of New South Wales, and its range even extended to South Australia. All this additional evidence goes to prove the stability of the species and further justifies the contention that it is quite distinct from the "Apple" of Victoria upon which *E. Stuartiana* was founded by Baron von Mueller, as maintained by Dr. Howitt and J. G. Luehmann. Vide also remarks under *E. Bridgesiana*, "Eucalypts and their Essential Oils," p. 86.

The fruits preserve a constancy of shape, but vary in size, the largest fruited form being at Woolbrook (Tamworth).

Essential Oil.—Leaves were kindly sent to the Technological Museum from Walcha by Mr. J. F. Campbell, and distilled 18/9/99. The material was collected as would be done for commercial distillation. The crude oil was of an orange-lemon colour, and had an odour indicating an oil of the pinene-eucalyptol class. It was very rich in eucalyptol, contained some pinene, but phellandrene was quite absent. The higher boiling portion consisted largely of the sesquiterpene common to these oils. The ester was small in amount. The rectified oil was slightly tinged yellow as is common with the rich eucalyptol oils of this class.

Leaves of this species were received later from Woolbrook and distilled 8/4/08. The oil was identical with that from the previous material both in the crude and rectified condition.

The following are the results obtained with the crude oils from these two localities:—

	Walcha, 18/9/99.	Woolbrook, 8/4/08.
Yield of oil per cent.	= 0·729	= 0·744
Specific gravity at 15° C. ...	= 0·9223	= 0·9246
Rotation a_D	+ 1·9°	+ 1·8°
Refractive index at 19° C. ...	= 1·4716	at 20° = 1·4729
S.N. of ester and free acid ...	= 8·7	= 7·6
Eucalyptol in portion distilling below 183° C.	= 73 per cent.	= 78 per cent.

As the eucalyptol in the Walcha sample had been determined by the phosphoric acid method, that in the Woolbrook oil was also so determined.

Rectifying the Walcha sample, between 172–183° 77 per cent. distilled; between 183–245° 11 per cent.; and between 245–265° 5 per cent. These results agree very well with those obtained with the Woolbrook sample.

The first fraction as shown above consisted very largely of eucalyptol with pinene. The oil from the original material described in the "Research on the Eucalypts," p. 87, contained a little more dextro-rotatory pinene, owing to its being collected at the time of the year when pinene is most pronounced in the oils of this class, otherwise the oils are almost identical.

A portion of the crude oil was rectified by steam distillation, as for commercial purposes. The product was yellowish in tint, resembling in this respect oils rich in eucalyptol of this class, as those of *E. globulus*, *E. goniocalyx*, etc. It had a good odour and consisted very largely of eucalyptol. It had specific gravity at 15° C. = 0·9203; rotation $a_D = +3{\cdot}1°$; and refractive index at 21° C. = 1·4602.

EUCALYPTUS LAEVOPINEA, R. T. B.
"Silver Top Stringybark."

Historical.—The first material (imperfect) of this species was obtained from the Gulf Road near Rylstone (R. T. Baker), and was thought then to be a form of *E. obliqua*, L. Her., Proc. Linn. Soc., N.S.W., 1896.

In the same Proceedings and later in the same year, Messrs. Deane and Maiden state, "they are unable to place it either with *E. macrorhyncha*, F.v.M., or *E. capitellata*, Sm.

In "Notes on a trip to Mount Sea View" by J. H. Maiden, Proc. Linn. Soc., N.S.W., 1898, appears the following reference to this tree:—

"*E. macrorhyncha*, F.v.M. Near the summit of Mount Sea View there occurs a Stringybark with large fruits undoubtedly belonging to this species. The fruits are similar to those collected by Mr. R. T. Baker, Gulf Road, Rylstone, except that the rim is a little more domed and the valves a little more exserted, probably because the Sea View specimens are a little riper. In my opinion Mr. Baker's specimens are now undoubtedly to be referred to *E. macrorhyncha*, F.v.M., a point in regard to which Mr. Deane and myself had some doubt."

In 1898 full material was obtained by one of us, when the evidence derived from its investigation proved that it had characters sufficient to warrant its being raised to specific rank under the name of *E. laevopinea*, Proc. Linn. Soc., N.S.W., p. 414.

Messrs. Deane and Maiden in the same year and in the same proceedings refer to the species as follows:—

"We have not had sufficient opportunity of examining these trees although we have been favoured with herbarium specimens by Mr. Baker . . . . we think it is a pity that the chemical products of that species *E. pilularis* had not been enquired into before naming the two new ones." (*E. pilularis* had been chemically investigated at this time although not published.)

"We must, however, offer our protest against naming species after recondite properties which can only be recognised after close analysis in the laboratory."

We are glad to see however, in the "Critical Revision of the Genus Eucalyptus," Part VIII, p. 247, that Mr. Maiden now recognises the value of chemical evidence in determining differences in species.

Reference is again made to this species, Proc. Linn. Soc., N.S.W., 1901 by Deane and Maiden, in these words:—

"We find that *E. laevopinea*, R. T. B., is specifically identical with *E. dextropinea*, R. T. B., and consequently with *E. Mulleriana*, Howitt."

In Part I of the "Critical Revision of the Genus Eucalyptus," Maiden, places it along with *E. dextropinea* and *E. Muelleriana* as a synonym of *E. pilularis*, Sm. A determination to which we cannot agree as our researches show that the two, *E. pilularis* and *E. laevopinea*, differ in timber, bark, fruits, buds. leaves, oil and habitat.

In Part VIII, same work, *E. Muelleriana* is restored to specific rank; and on p. 221, the following reference is made:—

"The fruits of *E. laevopinea*, R. T. Baker, from Gulf Road, Rylstone (R. T. Baker) display such variation in size and shape as to have caused differences of views as to the species. For example, in Proc. Linn. Soc., N.S.W., 1896, Mr. Deane and I referred some of them to an abnormal form of *E. macrorhyncha* between it and *E. capitellata.* That they are identical with *E. Mulleriana*, Howitt, has since been shown"

Under *E. macrorhyncha* in the same work no reference is made to *E. laevopinea.*

Remarks.—From the above it will be seen that on morphological grounds considerable differences of opinion have arisen in regard to this species. Since it was described in 1898, however, further material of this Eucalyptus has been examined from trees growing far north of the original locality of Rylstone, and so far no new facts have been brought to light that would warrant its being described as other than that it is specifically distinct from any of its congeners. To place it under *E. pilularis* or *E. macrorhyncha*, with their chemical characteristics, would be fatal to the commercial exploitation of *E. laevopinea* and *E. dextropinea* for their respective turpentine oils.

With the price of turpentine now ruling, manufacturers will necessarily look to other fields for supplies. The "Oil and Colour Trades Journal," August 26th, says:—'According to Bulletin 40 of the United States Agricultural Department, the supply of turpentine in the United States will be exhausted in 1918. While the sources of supply have been decreasing, statistics show the demand has increased over 90 per cent. in the last 15 years.'

This question is therefore of some importance to Australia, as it would be possible to procure early supplies of turpentine from young plants of pinene yielding Eucalypts grown from seed. The leaves of the young growth of eucalyptus species yield oils identical in composition with that obtained from the mature trees, and often produce it in larger quantity. By scientific treatment, beet has been made to secrete sufficient sugar to enable it satisfactorily to compete with sugar obtained from cane. Similar scientific treatment, with the right species, should also make it possible to produce turpentine from the Eucalypts to satisfactorily replace that now derived from the oleoresin of Pine Trees.

Timber Tests.—

TRANSVERSE TESTS.

	No. 1	No. 2.	No. 3.	No. 4.
Size of specimen in inches	B. 3·00; D. 3·04; L. 36.	B. 3·00, D. 3·03; L. 36.	B. 3·02; D. 3·02; L. 36.	B. 3·02; D. 3·02; L. 36.
Area of cross section, sq. in.	9·10	9·09	9·12	9·12
Breaking load in lbs. per square inch.	5,750	5·750	5,050	5·710
Modulus of rupture in lbs. per square inch.	11,201	9·313	9,901	11,196
Modulus of elasticity in lbs. per square inch.	1,383,640	1,309,090	1,230,379	1,285,714
Rate of load in lbs. per minute.	638	650	505	713

Essential Oil.—Leaves were obtained from Armidale, 1st July, 1907, and from Uralla, 13th July, 1907. The material for distillation was collected as would be done for commercial purposes, so that the yield of oil given here is what would be obtained in practice. The crude oils in both instances were red in colour, but this colour being due to iron derived from the still, was easily removed with a few drops of aqueous alkali, or by agitating with two or three drops of phosphoric acid. The oil thus treated, after well washing and drying was of a very light lemon colour. When rectified, the products were colourless. The crude oil has a turpentine odour which is more pronounced in the large fraction distilling near the temperature required for pinene. Phellandrene does not seem to be present in the oil of this species at any time, thus differing in this respect from the oil of *E. macrorhyncha.* The stearoptene of Eucalyptus oils (Eudesmol) although such a pronounced constituent in the oil of *E. macrorhyncha*, has not been detected in the oil of *E. laevopinea.* A very small quantity of eucalyptol occurs in the oil of *E. laevopinea*, not exceeding 5 per cent.; it is however a very pronounced constituent in the oil of *E. macrorhyncha.* About 3 per cent. of ester, calculated as geranyl-acetate, is present in the oil of *E. laevopinea.* The following table gives the general results obtained with the crude oils of this species, those previously recorded for the Rylstone sample being given for comparison :—

	Rylstone. 1/8/98.	Armidale. 1/7/07.	Uralla. 13/7/07,
Yield of oil, per cent.	= 0·66	= 0·586	= 0·573
Specific gravity, 15°C.	= 0·8755	= 0·8875	= 0·8871
Rotation a_D crude oil	...	– 30·7°	– 33·3°
Rotation a_D portion distilling below 164° C.... ...	– 40·65	– 36·4°	– 38·6°
Refractive index 19°C	1·4709	1·4691	1·4697
Solubility in 80% alcohol, scarcely soluble in ...	10 volumes	ditto	ditto
Phellandrene ...	absent	ditto	ditto
Eudesmol	absent	ditto	ditto
Eualyptol, less than	5 per cent.	ditto	ditto
Amount distilling at low temperature, below	164°C. = 60%	163°C. = 62%	164°C. = 63%
S.N. of ester and free acid	7	11·06	10·27

That the oil of this species consists largely of laevo-rotatory pinene was shown previously, see "Research on the Eucalypts" Sydney 1902, pages 41 and 242 ; and Proc. of this Society, 1898, p. 202.

On rectifying 200 cc. of the Armidale sample using rod and disc still head it commenced to distill at 155° C. (all temperatures corrected); between 155 – 158°, 100 cc. came over, and between 158 – 170°, 50 cc. more, or 75 per cent. below 170° C. These two fractions were again distilled, when 100 cc. distilled below 156·5° and 20 more between that temperature and 159°.

The portion distilling below 156·5° had specific gravity at 15° C. = 0·8682; rotation a_D = – 38·9° or specific rotation $[a]_D$ = – 44·8°; and refractive index at 20° C. = 1·4651. The second fraction had the same specific gravity and refractive index, but the rotation was a little less a_D = – 36·0°. That it is pinene was shown previously.

The distillate had after a few days, acquired a turpentine odour agreeing with that of commercial turpentine. It was water-white, and had properties closely approaching those for pure pinene.

A portion of the crude oil was steam distilled, when 90 per cent. readily came over. The slightest tinge of yellow was perceptible in it. It had a turpentine odour, and of course contained the small amount of eucalyptol present. Its specific gravity at 15° C. = 0·8775; rotation a_D = – 33·4°, and refractive index at 19° C. = 1·4659.

The Uralla sample was partly rectified, only a few drops as usual came over below 155° C. (cor.); between 155 – 164° 63 per cent. distilled. This fraction had specific gravity at 15° C. = 0·8699; rotation a_D = – 38·6°; refractive index at 20° = 1·4641. It had the characteristic odour of turpentine, and was practically identical with similar lower boiling portions of the oil of this species from other localities.

[*Essential Oil (E. dextropinea)*—Although this species does not appear to occur in the New England district yet it was thought advisable that a comparative test should be made to again determine the relation of the oil of this species to that of *E. laevopinea*, and to confirm the results published in the "Research on the Eucalypts," pp. 38 and 241. Material was procured from Tallong in this State, and distilled 25/10/1911. At this time of year the yield of oil exceeded 1 per cent. from terminal branchlets, collected as would be done for commercial purposes. The pinene was just as pronounced as previously, was highly dextrorotatory, and on rectification produced an excellent turpentine. The saponification number of the ester + free acid = 22·1 when boiled, (almost identical with that obtained previously), and S.N. 10·55 in the cold with two hours contact. Thus nearly half the ester appears to be geranyl-acetate, as the presence of acetic acid was determined and geranyl-acetate is readily saponified in the cold with alcoholic potash. The percentage of geranyl-acetate in the crude oil was thus equal to 3·7 per cent. From a commercial standpoint this may be of some importance, as it might eventually be possible to extract the perfumery alcohol geraniol, from this residue, or perhaps the ester itself might be separated, which is even more valuable. The saponification number in the residue of the crude oil by boiling, after steam distilling, was 77·4, and in the cold, with two hours' contact, it was 31·9, or equal to 11·17 per cent. of ester calculated as geranyl-acetate. The following results were obtained with the crude oil:—

Yield of oil per cent. ... ... = 1·02
Specific gravity at 15° C. ... ... = 0·8831
Rotation a_D ... ... = + 24·2°
Refractive index at 21° C. ... ... = 1·4688
Saponification number of ester + free acid = 22·1.
Insoluble in 9 volumes 80 per cent. alcohol, but soluble in 10 volumes.

On rectifying 200 cc., using a rod and disc still head, between 155–158° C., 112 cc. came over, and 48 cc. between 158–168° C. (all temperatures corrected). These two fractions were added together and again distilled, when between 155 – 156° C., 100 cc. came over, and between 156 – 159° C. 30 cc. more, or 65 per cent. of the crude oil.

The specific gravity of the first fraction at 15° C. = 0·8639; rotation a_D = + 25·4°; refractive index at 22° C. = 1·4643. The specific gravity of the second fraction at 15° C. = 08658; rotation a_D = + 24·8°; and the refractive index at 22° C. = 1·4646.

These results confirm those previously obtained with the oil of this species, and the chemical evidence shows the botanical difference between these two trees to be specific. A portion of the crude oil was steam distilled, when over 90 per cent. came over. This was practically colourless, had a turpentine odour, and traces of eucalyptol were detected. The specific gravity at 15° C. = 0·8698; refractive index at 22° C. = 1·4647; and rotation a_D +24·4°.]

EUCALYPTUS NOVA-ANGLICA, Deane and Maiden.

"Broad Suckered Peppermint."

Historical.—It was first referred to in scientific literature by J. H. Maiden, in A.A.A.S., Vol. VII, 1898, p. 541, under Eucalypt No. 2. Specific rank was given it by H. Deane and J. H. Maiden in Proc. Linn. Soc. N.S.W., 1899, p. 616.

Remarks.—It is well distributed over the New England tableland and is one of the many "peppermints" of that area, being known as white, red, and black peppermints of different localities, these probably referring to its "peppermint" bark.

Timber Tests.—Three pieces were taken, standard sizes 3″ × 3″ × 36″, and gave the following results:—

Transverse tests:—1. Broke under a pressure of 4,850 lbs.
2. ,, ,, ,, 4,400 lbs.
3. ,, ,, ,, 3,750 lbs.

Essential Oil.—Leaves of this species were obtained from Black Mountain near Guyra, and distilled 6/8/07; from Uralla and distilled 11/7/07; from Armidale, (where it is known as "Red Peppermint") and distilled 24/6/07; and from Tenterfield, distilled 12/1/10. The material from which the original data were obtained, published in the "Research on the Eucalypts," p. 34, was collected at Walcha, and distilled 15/9/99, at the time of year when the lower boiling terpenes might be expected to be present in quantity. The crude oils of all these samples were red in colour and inclined to be somewhat viscid, owing to the presence of such a large quantity of high boiling constituents. The odour was rank and not at all distinctive. Light did not pass with the crude oil until the colour had been removed, but after agitating with a few drops of phosphoric acid, light passed readily through the yellowish tinted oil thus obtained. The principal constituents of the oil of this species are dextro-rotatory pinene, and the sesquiterpene, of which constituent more than half the oil consists. Traces of phellandrene can occasionally be detected in the portion distilling at about 176° C., but not always, and the species is thus evidently on the border line where phellandrene commences to come in. Eucalyptol is present in minute traces only at any time of the year. The constituent of peppermint odour (piperitone) does not appear to occur in the oil of this species, so that the vernacular name "Peppermint" cannot be due to the odour given by the leaves, but more likely to the appearance of the bark, and of the tree generally.

The following table gives the general results obtained with the crude oils of this species from the four localities given above. The yields of oil were obtained from leaves and terminal branchlets collected as for commercial oil distillation.

	Black Mtn. 6/8/07.	Uralla. 11/7/07.	Armidale. 21/6/07.	Tenterfield. 12/1/10.
Yield of oil per cent. ...	0·45	0·574	0·436	0·576
Specific gravity at 15° C	0·9249	0·9245	0·9221	0·9301
Rotation a_D	= + 4·3°	+ 4·7°	+ 5·8°	+ 0·9°
Refractive index	1·4857 at 18° C.	1·4944 at 15° C.	1·4892 at 15° C.	1·4932 at 20°
Solubility in 10 vols. 80% alcohol	insoluble	ditto	ditto	ditto
Phellandrene	traces	ditto	ditto	none
Eucalyptol	traces	ditto	presence well mrkd.	traces
Distilling above 245° C. ...	...	70%	55%	76%
S.N. of ester + free acid ...	...	6·4	5·7	6·9

The Tenterfield sample gave, on rectification, the following results:—Less than one per cent distilled below 159° C. although a fair quantity of pinene was present, this was due to the large amount of high boiling constituents present. Between 159–170° C., 10 per cent. distilled; between 170 –245° 9 per cent., and between 245 - 273° 76 per cent. The rotations a_D of the several fractions were—first + 30·3°; second + 22·4°; third – 2·1°. The light passed with the third fraction fairly well when diluted with an equal portion of chloroform. The specific gravity of the first fraction at 15° C. = 0·8652; of the second = 0·8713; and of the third = 0·9326. The refractive index of the first fraction at 19° C. = 1·4679; of the second = 1·4724; and of the third = 1·4989. The first and second fractions were mixed and again distilled, when 9 per cent., calculated on the original oil, came over between 156 - 157° C. This fraction had specific gravity at 15° C. = 0·8631; rotation a_D + 31·6, or specific rotation $[a]_D$ = + 36·61°; refractive index at 18°C. = 1·4677, and was almost pure pinene.

With the Uralla oil 10 per cent. distilled between 160–170° C., which had specific gravity at 15° C. = 0·8638; and rotation a_D = + 27·7, and refractive index 1·4678.

With the Armidale sample 10 per cent. distilled between 160 - 170° C., which had specific gravity at 15° C. = 0·8705;

rotation $\alpha_D + 24{\cdot}4°$, and refractive index 1·4667. It consisted almost entirely of pinene, but eucalyptol was more pronounced in this oil, evidently due to the time of year when the material was collected. This is evidently the best species of Eucalyptus from which to obtain the sesquiterpene to enable its chemistry to be determined.

Kino.—The kino or astringent exudations of both the Armidale and Uralla trees were collected from the logs. Both gave identical reactions. It is friable, gives a green coloration with ferric chloride, and contains eudesmin, characters quite distinct from the kinos of the true "Peppermints."

EUCALYPTUS CAMPANULATA, sp. nov.

"Bastard Stringybark."

An average forest tree. Bark decidedly stringy, persistent on the main trunk, branches smooth.

"Sucker" or abnormal leaves broadly lanceolate, oblique not shining, same colour on both sides, often over 9 inches long, venation well marked, lateral veins oblique, distant intramarginal vein well removed from the edge. Petiole over 1 inch long. Normal leaves comparatively small, lanceolate, oblique, subcoriaceous, not shining. Venation not at all well marked on the smaller upper leaves, but distinctly so in the others. Lateral veins very oblique.

Buds, clevate or club shaped, the operculum domed.

Fruits: At the earliest stage of development campanulate on a slender pedicel, a feature not noticed in other species by us. Mature fruits pyriform, rim truncate or slightly countersunk, about 6 mm. diameter at the rim.

Bark "stringy" as implied in its common name.

Timber, light coloured or whitish, fissile, but close grained, easy working, in fact, similar in general characteristics to some of the "Ashes" or "Stringybarks," although perphaps a little more inclined to develop gum veins.

[Arbor (Bastard Stringybark), distincta, nomine altitudinem 60 ft., attinens, ramulis primum compresso-tetragonis mox teretiusculis.

Cortex partim secedens in trunco persistens ramis levibus.

Folia abnorme (suckers) obliqua falcato-lanceolata petiolata, alterna concoloria vena peripherica a margine remota; vena laterale obliqua graviter. Folia vulgare, falcato-lanceolata, obliqua, petiolata concoloria, alterna subcoriacea, vena aut prominentes aut obscura obliqua, pleraque 3 – 6″ longer.

Pedunculi axillare umbellis multifloris; operculo-depresso hemispherica, mucronulatato breviter, calcycis tubus circa 1 cm. longus; fructibus truncato-ovatis, 1 cm longi, 5 mm. lati valvis non exsertis.]

Remarks.—The material of this tree for investigation was collected by Mr. C. F. Laseron, the Museum Collector, at Tenterfield, where it passes as the "Bastard Stringybark." His herbarium material appears to be identical with specimens collected by Mr. A. Rudder in the Upper Williams district.

The fruits somewhat resemble those of *E. virgata*, Sieb. or *E. Sieberiana*, but then the timber, bark and oil differ from these species. The oil of *E. virgata* consists almost entirely of eudesmol, as shown in our work on "The Eucalypts and their Essential Oils." Fruits, timber and oil differentiate it from *E. obliqua*, which species has been collected in almost the same neighbourhood, at Mount McKenzie, Tenterfield.

There is a distinguishing feature of the species in its very early fruits, which are quite bell shaped and remind one of the shape of the mature fruits of *E. Deanei.* As they mature, this shape passes gradually away, the calyx gradually tapering into a pedicel, very rarely is the fruit hemispherical.

On a cortical classification it would be placed with the "Stringybarks," or between them and the "Peppermints," but the timber may be classed as one of the "Ashes," such as *E. regnans*, *E. oreades* or *E. Delegatensis.*

The large oblique suckers are not at all unlike those of *E. obliqua*, or even the above three species.

At Tenterfield it is found growing amongst such "Stringybarks" as *E. obliqua* and *E. laevopinea.*

Essential Oil.—Leaves of this species were obtained from Tenterfield, and distilled 14/1/10. The material was collected as for commercial distillation, so that the yield is an average one. The crude oil was of a light yellowish tint, and had a secondary odour of peppermint, due to a small quantity of piperitone. The presence of this constituent, and the absence of aromadendral, distinguish this oil from that of *E. obliqua.* A small amount of eudesmol was present at the time of distillation. The oil of this species consists principally of phellandrene, and pinene seems to be quite absent. Eucalyptol was detected in the portion distilling at about 176° C., but it was very small in amount. The oil of this species agrees with those of the members of the "Mountain Ash" group of Eucalyptus, but in its general characters more closely approaches, perhaps, that of *E. oreades* than any of the others. The following results were obtained with the crude oil:—

Yield of oil per cent. ... ... = 0·851
Specific gravity at 15° C. ... ... = 0·8804
Rotation a_D ... ... = − 25·8°
Refractive index at 18° C. ... ... = 1·4856
Scarcely soluble in 10 volumes 80 per cent. alcohol.
Saponification number for ester + free acid = 7·6.

On rectifying the oil only the usual few drops of acid water came over below 175° C., together with a very little oil containing some volatile aldehydes. Between 175 – 188° C. 68 per cent. distilled; between 188 – 224°, 11 per cent. came over; between 224 – 265°, 11 per cent. distilled. The specific gravity at 15° C. of the first fraction =0·8589; of the second = 0·8714; of the third = 0·9224. The rotation of the first fraction a_D = – 34·8°; of the second – 32·6°. Light did not pass with the third. The refractive index at 18° of the first fraction = 1·4812; of the second = 1·4835; of the third = 1·4989.

Kino.—The kino of this tree agrees in its appearance and reactions with those of *E. Sieberiana* and allied species. It gives a violet coloration with ferric chloride, slowly changing to a grey precipitate, and does not contain either eudesmin or aromadendrin.

Explanation of Plate.

Fig. 1. Sucker or abnormal leaf.
,, 2. Twig with buds and flowers and normal leaves.
,, 3. Early fruits.
,, 4. Twig with leaf and fruits.
,, 5. Individual fruit.

All natural size.

ON ROCK SPECIMENS FROM CENTRAL AND WESTERN AUSTRALIA.

Collected by the Elder Scientific Exploring Expedition of 1891–2.

By J. Allan Thomson, B.A., D.Sc., F.G.S.

(Communicated by Prof. David, B A., C.M.G., F.R.S., Hon. D.Sc, Oxon.)

[With Plate XIV.]

[*Read before the Royal Society of N. S. Wales, November 1, 1911.*]

The rocks described in the present paper were presented to Professor David by Mr. Richard Helms, the naturalist of the Elder Scientific Exploring Expedition of 1891-2. Through the kindness of the former gentleman the writer was permitted to examine the collection and prepare the following notes on the rocks.

The expedition, well equiped by Sir Thomas Elder, crossed from South Australia to the Murchison Goldfield in the years 1891 and 1892.[1] A large number of rock specimens were collected all along the route, and a brief account of these, and of the chief geological features of the country passed over has been given by Mr. Victor Streich.[2] The rocks here described appear to be in some respects supplementary to those listed by Mr. Streich. One of them comes from Fraser's Range, E.N.E. of Norseman, W.A.,

[1] *Cf.* Lindsay, D., Journal of the Elder Scientific Exploring Expedition. 1891-2. With Maps. Adelaide, 1893.

[2] Trans. Roy. Soc., South Austr., Vol. xvi, Part ii, 1893, pp. 74–110; also Stelzner, A. W., Supplementary Notes on the above named Collection *ibid.*, pp. 110-2. Tate, R., Appendix, List of Rock-specimens collected by Mr. Wells, Second Officer, on a Journey east from Murchison Goldfield, *ibid.*, pp. 113-5. Map of route showing position of camps and geological formations, *ibid.*, facing p. 236.

the other sixteen come from localities between the Barrow Ranges and the Everard Range, *i.e.* between longitudes 127° E. and 132° E., and latitudes 25° S. and 28° S.

Considerable practical interest attaches to the geology of this region. In the first place it lies not far north of the country to be traversed by the proposed Transcontinental Railway from Port Augusta to Kalgoorlie or Esperance; and in the second, it lies to the east of the great belt of gneiss that forms the eastward boundary of the gold-fields of Western Australia, and there is still the possibility that new gold-fields will be found once the gneiss is crossed. The rocks, however, are not of a nature to give us as much information on the solid geology as might have been hoped, since they appear to be in large measure dyke rocks; on the other hand, some of them possess great intrinsic interest.

The gneissose belt referred to has been recently traversed and described by Mr. C. G. Gibson, for the Geological Survey of Western Australia.[1] His map shows a large granitic or gneissic belt lying east of the greenstone belt in which Kanowna, Bulong and Mount Monger lie. The belt trends to the north-east and is succeeded on the east by the Tertiary limestones of the Hampton Tableland. Lindsay's route in this part lay entirely within the gneiss, and this accounts for the paucity of fundamental rocks collected, for the gneiss area is largely covered by sand and spinifex flats. Streich considered this part of the country as "the most westerly part of the Great Australian mesozoic basin." The outcrops which he considered mesozoic, viz., "a system of terraces, having a general N.W. and S.E. trend, their strata dipping at a low angle to the North-

[1] The Geological Features of the Country lying along the Route of the Proposed Transcontinental Railway in Western Australia, Bull. 37, Geol. Surv. W.A., 1909.

East" are probably superficial deposits of desert origin similar to the surface quartzites of the South African arid regions. Dr. J. M. Maclaren has informed me that he has found such terraces northwards from Leonora, and that he considers them of analogous origin to the ferruginous laterites of Western Australia, and proposes to designate them by the name of "siliceous laterites."

The only rock in the collection from the southern end of this gneiss belt is that from Fraser's Range. It is practically identical with a rock collected by Gibson from Simon's Hill, Fraser's Range, and labelled "gneiss" in the Register of the Geological Survey of Western Australia (No. 8696). Besides garnetiferous gneiss, garnetiferous mica schist and pegmatite from Fraser's Range. Streich records a hornblendic schist as forming the main mass of the range, of which rock Stelzner writes:—"671 is according to the microscopic examination of the rock section, an undecomposed diabase, which is distinguished on account of its containing highly pleochroic augite and biotite and apatite as accessory components." This is obviously the rock now to be described.

The hand specimen is a dark, distinctly banded rock, the banding being due to the separation of the felspathic and the femic minerals into poorly defined layers. Microscopic examination shows that the latter minerals consist preponderatingly of hypersthene, with subordinate biotite and rare hornblende. Iron ores and apatite are the only accessories (Fig. 1, Plate XIV). The felspars are sometimes twinned on the albite and pericline laws, but the twinning is fine and not very constant, and is absent in many of the crystals. They all possess refractive indices superior to that of Canada Balsam, so may be all referred to plagioclase. The largest extinctions on symmetrically placed albite lamellae amount to 19°, indicating a species at least as basic as andesine. The felspars never show crystal outlines, but form a polygonal mosaic of uneven grain. No evidence of cataclastic structure is seen, but strain shadows are not rare. The hypersthene is a little schillerised, strongly pleochroic variety with rose-red to green tones, and is optically negative with a fairly high optic axial angle. It occurs in irregular layers which have a rude parallel arrangement, but within the layer the mineral is not definitely oriented. It has sometimes considerable tendency to idiomorphism, but when surrounded by felspars occurs in more rounded forms. Closely associated with, and often penetrating, the hypersthene is a considerable amount of reddish-yellow to black biotite. In Helm's specimen, but not in Gibson's, there is a little common green hornblende intergrown with the hypersthene. Apatite is fairly abundant in stout prisms with a general elongation in the direction of the banding. Fig. 1, Plate XIV, gives an adequate idea of the relative proportions of the different minerals.

While it is not impossible that the rock belongs to the gneissic series, its structure and mineralogical composition suggest, as more probable, that it is of directly igneous origin, as Stelzner supposed, and is a norite with feeble protoclastic structure and well marked fluxion banding. The presence of hypersthenic dyke rocks at Norseman[1] makes the presence of norite dykes in the Fraser Range quite probable.

The northward extension of this gneiss belt has not yet been delimited by the Western Australian Geological Survey. Apparently the western margin turns north towards Burtville, where the gneiss is found a few miles east of the town.[2] The eastern boundary is unknown in the northern part.

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[1] Campbell, W. D., The Geology and Mineral Resources of the Norseman District, Dundas Goldfields, Bull. 21, Geol. Surv. W.A., 1906, p. 24.

[2] Gibson, C. G., The Laverton, Burtville and Erlistown Auriferous Belt, Mount Margaret Goldfield, Bull. 24, Geol. Surv. W.A., 1906, pp. 29, 30.

Two rocks in the Helms' collection are possibly to be referred here. The first is labelled "12 miles N.W. of Camp 23, 17/7/91," *i.e.*, in the northern part of the Blyth Range. It has the appearance and mineralogical composition of a hornblende granite, but some peculiarities in structure, though neither hand specimen or section show any parallel structure. Both orthoclase and quartz are abundant, together comprising the bulk of the rock, and the first peculiarity is the relation of these two minerals. Large pseudoporphyritic plates of orthoclase are found enclosing small rounded grains of quartz in poecilitic fashion (Fig. 2, Plate XIV). Such a structure, if original, as there seems no reason to doubt it is, may be explained by the fact that the magma originally contained quartz in excess of that required for the quartz-felspar eutectic.[1] The structure is, however, further complicated by the presence of a thin zone of quartz-felspar intergrowth between the host and the enclosed mineral. Outside the large plates of orthoclase such intergrowths are very abundant, but are always of fine grain, and have a great tendency to resemble gridirons rather than the script-like forms that have given rise to the term 'graphic.' Their presence between the orthoclase and enclosed quartz suggests that they are not original, but of the nature of 'myrmekite,' a type of structure which in Sweden and Finland is taken to prove great metamorphism and the Archæan age of the granite.[2] Besides orthoclase there is also a smaller amount of microcline and oligoclase, both bounded by similar intergrowths. The oligoclase is sometimes included within the orthoclase. All these minerals occasionally show strain shadows. The

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[1] *Cf.*, quartz in oligoclase. Dwerryhouse, A. R., On some Intrusive Rocks in the Neighbourhood of Eskdale (Cumberland), Q.J.G.S., LXV, 1909, pp. 63 and 70.

[2] Holmquist, J. P., Studien über die Granite von Schweden. Bull. Geol. Inst, Upsala, VII, 1904-5, Nos. 13, 14, p. 116.

dark minerals, iron-ores, hornblende and biotite occur in intricate clusters, along with much apatite and a little zircon. The hornblende is almost opaque from dusty magnetite inclusions, is intimately penetrated by biotite and is embraced by compact iron ores, around which and in the bays of which biotite is freely developed. The rock may therefore be interpreted as a hornblende granite, probably belonging to the gneiss series.

The second rock is labelled "10 miles E. of Camp 33," *i.e.*, from the east of the Barrow Range. Streich states that the Barrow Range consists of eruptive granite, but mentions the occurrence ten miles east of the range of two small "isolated hills of granulite, which is distinctly stratified with a low angle of dip towards south." Stelzner remarks of one of these specimens that "it resembles so closely the granulite of the Saxon granulite-ellipsis that it could have been found there as well." The present specimen is distinctly banded in yellow and dark layers, and presents considerable superficial resemblance to the more yellow varieties of jaspers so abundant in the goldfields of Western Australia. It differs from them, however, in a profusion of small red garnets, which when examined with a lens show no sign of crystal faces. In addition the lens reveals an abundance of an elongated well cleaved colourless mineral with adamantine lustre.

In section the latter mineral shows prismatic forms, with a perfect longitudinal cleavage, has straight extinction, positive elongation, and a birefringence considerably superior to that of quartz (between ·015 and ·020 according to Levy and Lacroix's colour scale). Basal sections are approximately quadrate in shape, and by their study the mineral is shown to be almost uniaxial and optically positive; the opening of the axial brushes is almost imperceptible. An examination of tho crushed mineral in liquids of known refringence prove the maximum refractive index to be in the neighbourhood of 1·658. This combination of properties precludes identification with any well known uniaxial mineral. To test the possibility of the mineral being phenacite, Mr. G. J. Burrows very kindly undertook a qualitative examination of the rock for beryllium, but with negative result. There is no common biaxial mineral of low axial angle which agrees in all the above characters, and as the amount of material was too small to permit of isolation and chemical analysis, the mineral must be left unidentified for the present.

The other minerals present are quartz and orthoclase in large amount, magnetite in smaller quantity and occasional crystals of zircon. The yellow colour of the rock is due to staining by limonite, the orthoclase in particular being striated by plates of this mineral along the cleavage planes. The quartz and orthoclase form an uneven grained mosaic with a limonitic cement, a structure which in many respects suggests a clastic origin. On the other hand the nearly constant orientation of the unnamed mineral, and an alternation of bands of clear mosaic with other bands containing magnetite and limonite points more strongly to a parallel structure developed in situ (Fig. 3, Plate XIV). It is reasonable to suppose that the rock is a member of the gneissose series.

There is only one rock that resembles the rocks of the auriferous areas of Western Australia, and it is from the Cavanagh Range. The hand specimen is a light green aphanatic rock, which shows when wetted a few veinlets of lighter colour. The section shows that it consists predominatingly of fine grained albite and clinozoisite with smaller amounts of a pale actinolite, chlorite, sphene and accessory apatite. The felspars, in bundles of sub-radiating prisms, form a network within which the other minerals lie in characteristic forms, clinozoisite and sphene in granules, actinolite and chlorite in more or less elongate prismatic forms. There are in addition a few nests of secondary quartz and epidote, while the veinlets are seen to consist of clinozoisite with a little sphene. The rock is a fine grained amphibolite, rather more felspathic than usual.

Rocks very similar to this are of frequent occurrence in the goldfields of Western Australia, *e.g.*, Kalgoorlie, Norseman, the Murchison Valley, etc. They seem to form the country into which large dykes of coarse grained basic rocks, now also amphibolites, have been intruded, and may therefore be termed the older amphibolites. As a rule these fine grained amphibolites are not conspicuously auriferous, except near the contact of graphite or quartz-porphyry. The specimen, however, is of considerable importance in showing that the rocks of the known auriferous belts are found as far eastwards as the Cavanagh Range.

The remaining rocks are probably intrusive, though the interpetation of some is not without doubt. A rock from Skirmish Hill (22/7/91) is probably to be identified as a much altered quartz porphyry. The hand specimen is grey-black and aphanatic except for red phenocrysts of felspar. In section these phenocrysts are excessively turbid, but may be identified as orthoclase in many cases, although an acid plagioclase also appears to be present. Apatite occurs in large prisms of such size as to deserve the name of phenocryst, and magnetite also occurs in large grains. Much more abundant than the felspar is quartz, in very perfectly elliptical shapes. Sometimes these are occupied by one large plate of quartz, with a marked rim of dusty inclusions at a short distance from the margin, or a marginal fringe of small grains, at other times by a mosaic of grains of smaller size. Though bearing much resemblance to amygdules, these elliptical plates of quartz may perhaps be more correctly interpreted as corroded phenocrysts round which a secondary deposition of quartz has taken place. The groundmass consists of a fine grained structureless aggregate of quartz, turbid felspar and magnetite with an abundance of chlorite much stained by limonite. The rock is therefore a porphyry, and perhaps a quartz-porphyry. Streich states that Skirmish Hill is composed in the main of a porphyritic syenite.

Another rock, certainly a dyke rock, is labelled Cavanagh Range. It is a dark grey, very finely crystalline rock in hand specimens. In section it is seen to be porphyritic, the phenocrysts being in part small euhedral prisms of red-violet, slightly pleochroic titaniferous augite, and in part much larger pseudomorphs of some earlier mineral. The pseudomorphs now consist mainly of chlorite (pennine) with a less amount of carbonates, sphene and flakes of tremolite. Their forms are distinctly suggestive of olivine, although if they represent this mineral, the alteration is an unusual one. The groundmass of the rock is made up largely of small prisms of brown-green hornblende, often green on the margin. They contain occasional small kernels of augite and are surrounded by short fibrous outgrowths of paler hornblende. Next in importance comes felspar in short multiply twinned lath-shaped or radially built forms. The low birefringence, refractive indices less than that of Canada Balsam, and extinction angles up to 15°, refer the species to albite. Here and there large nests of yellow epidote are found, in whose neighbourhood the hornblende is chloritised and carbonates are abundant. Small iron ores are plentifully scattered throughout the groundmass; their form refers them to the magnetite group, while a partial alteration into sphene shows that they are titaniferous (titanomagnetite).

The rock is certainly an augite-hornblende lamprophyre, probably a camptonite. It is the first rock of this class so far found in Western Australia.[1]

A rock of very peculiar character may be described here, as it has some faint resemblance to the camptonite just described, (Cavanagh Range, 31/7/91). It is probably the rock referred to by Streich as tachylite, of which Stelzner remarks:—"This rock is of such an extremely fine grain that I cannot determine it, even with the aid of the microscope on rock sections." The hand specimen is a dark aphanitic rock with some superficial resemblance to a tachylite, but contains a few clear patches of quartz and small geodes containing pyrites. The section (Fig. 4, Plate XIV) shows a number of small elliptical and larger irregularly shaped areas formed of small rods of almost opaque material grouped together like bundles of faggots; between these bundles and acting as a cement are clearer areas consisting of irregular biotite flakes and an indeterminate green mineral in a fine grained quartz base. The green mineral possesses a higher birefringence and lower refringence than the biotite, but a similar absorption and a pleochroism from opaque to dark green or yellow. It appears to be uniaxial or feebly biaxial, is optically negative with positive elongation. The dispersion is very strong, comparable to that of chloritoid, from which, however, it differs in its direction of maximum absorption and its lack of polysynthetic twinning. Most often it occurs in shapeless plates, but occasionally gives lozenge-shaped sections. These differ from hornblende only in the absence of cleavage planes. The mineral thus appears to be intermediate between biotite and chloritoid in its characters, and may possibly be pseudomorphous after hornblende.

[1] The rocks described as camptonites by Simpson and Glauert from the Philips River Goldfield appear to the writer to be really contact-altered amphibolites, Bull. 35, Geol. Surv. W.A., 1909, pp. 42-3.

The faggot-like areas give an aggregate polarisation colours like those of carbonates, but under high magnification this is seen to be due to the presence of numerous minute flakes of biotite. The small rods appear most often to be opaque, but on the edges of the section they are seen to consist of the green mineral described above. Finally there are a few elliptical areas like amygdules, consisting of coarse grained quartz and large flakes of biotite.

The interpretation of such a rock is impossible without field work to fix its geological nature, and in case it is an alteration product, to enable one to trace stages from some recognisable form. Assuming the small rods to be pseudomorphous after hornblende, the rock might represent a fine grained amphibolite or more likely a camptonite such as that described above. Such an assumption is, however, little removed from guesswork. The rock is certainly not a tachylite.

The remaining ten rocks, though not all from the same locality, form a distinct and related group. They show a graduated mineral composition, and differ chiefly in grain size. They are remarkable for the freshness of their felspars and pyroxene, and although the olivine and iron ores are at times somewhat altered, there is no sign of saussuritic, sericitic, chloritic or epidotic alteration products. They must, therefore, be assumed to be of much later age than the gneissose, and probably also the dyke rocks, just described. They are for the most part holocrystalline, coarse grained and almost black, the felspars being so transparent as to affect the colour of the rock very little. The mineral composition is that of gabbros or norites, but on account of the perfect ophitic structure displayed, the term dolerite is preferable. The more basic rocks contain much olivine, the most acid contain free quartz in micropegmatite, while the whole series is characterised by the small amount of iron ores and a great richness in ferro-magnesian minerals, viz. olivine, hypersthene and enstatite augite. The following table shows the mineral composition, the rocks being arranged approximately in order of their basicity:—

	7	8	9	10	11	12	13	14	15	16
Olivine	†	†	†	†	†	*	*	–	–	–
Hypersthene	†	†	†	†	†	†	†	–	–	–
Enstatite-augite ..	–	†	†	†	†	†	†	†	†	–
Augite	–	–	†	†	–	†	†	–	†	†
Pyroxene-perthite ...	–	†	–	†	†	–	†	–	†	†
Hornblende	–	–	–	–	–	*	*	–	†	†
Biotite	*	*	–	*	*	–	*	*	*	*
Iron ores	†	*	†	†	*	*	*	†	†	†
Apatite	*	–	–	*	–	–	–	–	*	†
Plagioclase	†	†	†	†	†	†	†	†	†	†
Orthoclase	*	*	–	*	*	–	–	–	*	†
Quartz	–	–	–	–	–	–	–	*	†	†

† An important constituent. * A minor constituent. – Absent.

7. *Near Camp* 9, 23/6/91. 8. *Hills near Camp* 5, 20/6/91. 9. *Zig Zag Range*, 15/7/91. 10. *Near Camp* 8, 23/6/91. 11. *Thirteen miles west of Depôt I*, 19/6/91. 12. *Cavanagh Range*. 13. *Cavanagh Range*, 29/7/91. 14. *Near Depôt I, Cap of Range two and a half miles distant*. 15. *Cap of Granite Range, Depôt I, Camp* 4, 9/6/91. 16. *Cavanagh Range*, 21/7/91.

The above table displays the interesting fact that while orthoclase and biotite are present in almost all the rocks, hornblende appears only in the acid rocks concomitantly with the disappearance of olivine.

The iron ores are seldom abundant, and exhibit variable relationships. In No. 7 they are quite idiomorphic to hypersthene and orthoclase, but present a broken outline towards plagioclase, to which they appear to be posterior. In other cases they are distinctly moulded on the plagioclase and also on the pyroxenes. In No. 7 the species is ilmenite, but in the others it appears to be a titaniferous magnetite, to judge from the octohedral sections and the very slight leucoxenic alteration on the borders of some grains. A small amount of secondary magnetite is found in the olivine of some of the specimens.

Olivine occurs plentifully in the more basic rocks. Sometimes it is clear, with only a slight separation of iron ores along the cracks, and is a variety with an axial angle approximating 90° (No. 7), and occasionally shows a slight schiller structure (No. 11). In No. 14 it is of a violet colour and is always surrounded and apparently partially replaced by iron ores. In the other rocks, when present, it shows an incipient or complete alteration into a brown or green biotite-like mineral of high birefringence that may be referred to iddingsite, accompanied in No. 12 by a considerable amount of iron ores and talc. The olivine is sometimes of early crystallisation (Fig. 1), but is sometimes ophitic to the plagioclase (Figure 6, Plate XIV). It never shows perfect crystal outlines, but occurs in more or less embayed forms, which are sometimes cresentic when the mineral is enclosed in a pyroxene. There is in places a considerable amount of hypersthene interposed between the olivine and felspars.

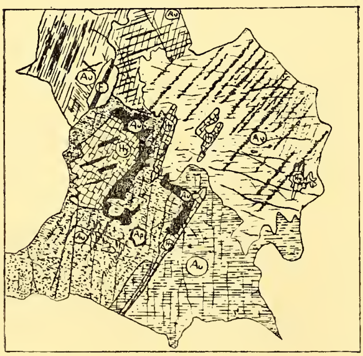

Fig. 1.—*Olivine dolerite with hypersthene and enstatite-augite. No.* 13. *Cavanagh Range. Crossed nicols. Magnification* 15 *diams.*

The pyroxenes are very interesting in their relations. A rhombic pyroxene referable to hypersthene on account of its optically negative character but with somewhat variable intensity of pleochroism, is abundant in the basic rocks. It is usually subordinate in amount to the monoclinic pyroxenes, but in No. 7 it predominates in

Figure 2.—*Polysomatic group of enstatite-augite with intergrowth of hypersthene. Dolerite, Cavanagh Range. Magnification* 23 *diams.*

typically ophitic forms. In some cases it veins the augite in a peculiar manner that suggests coarse intergrowths (Fig. 2) and at times is clearly intergrown with the enstatite-augite on a fine scale (Fig. 5, Plate XIV).

The monoclinic pyroxenes, though all optically positive, vary considerably in optical angle, from practically 90° to 0·4°. It has been shown by Wahl[1] that this variation is dependent on the amount of lime entering into the composition of the mineral. In normal diopside, with high axial angles, the proportion of CaO : MgO + FeO is nearly 1 : 1, but in a series of pyroxenes in which the proportion of lime is gradually less, the axial angle is correspondingly smaller, until it passes through 0° and the optic axes open out in a plane normal to the plane of symmetry, so that in certain cases the mineral is uniaxial for a given colour. For this series, which he supposes to consist of solid solutions of ordinary diopside or augite on the one hand, and clino-enstatite or clino-hypersthene on the other, Wahl has proposed the generic name of enstatite-augite, with specific names for different members of the series. Rosenbusch[2] has preferred to call the group magnesian-diopsides. These peculiar augites have been recognised in Australia so far

[1] Wahl, W., Die Enstatitaugite. Tsch. min. u. petr. Mitth. xxvi, (1907), pp. 1 – 31.

[2] Rosenbusch, H., Mikr. Phys., i, 2.

only by Osann[1] in a Tasmanian dolerite. They are fairly common, according to my observations, in the Mesozoic dolerite sills of Tasmania, specimens of which have been kindly given me for this purpose by Mr. Twelvetrees, Government Geologist, and slides prepared by Mr. R Priestly. They are also not uncommon among the later dykes of dolerite and quartz-dolerite traversing the gold-fields of Western Australia

Wahl[2] has also pointed out the presence of intergrowths of various pyroxenes with one another, and after the analogy of the felspar group has given them the name of pyroxene-perthites. As it has not been possible to obtain a copy of this paper in Sydney, the writer cannot make further comparisons between those observed in these rocks and those described by Wahl.

As the size of the optic axial angle can be observed only on suitably oriented sections, it is impossible by its observation alone to ascertain the relative amounts of common augite and enstatite augite. Moreover it is not uncommon to find that there are great variations of axial angle in the same crystal. Enstatite augite has often a characteristic basal striation and a peculiar alteration along the basal plane, which is sufficient to distinguish it from augite in the absence of such a striation in the latter. In the rocks under consideration, hypersthene curiously enough never shows schiller structures. The monoclinic pyroxenes are also in the finer grained rocks quite free of any such structures, while in the coarser rocks, in which rod-like inclusions both parallel to the A-pinacoid (diallagic schillerisation) and parallel to the basal plane are abundant, no distinction can be made out between the enstatite-augite and common augite in this respect.

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[1] Osann, A., Ueber cinem Enstatitaugit Führenden Diabas von Tasmanien. Centralbl. F. Min. etc., No. 23, pp. 705-11, 1907,

[2] Wahl, W., Analogien Zwischen die Pyroxen und Felspathgruppe. Quoted from memory. ? Ref. a Finnish Journal.

All the pyroxenes are clearly posterior both to the olivine and the felspar, embracing the latter in typically ophitic fashion (Fig. 6, Plate XIV, and Text Fig. 1). In general the hypersthene appears to be posterior to the monoclinic pyroxenes,[1] but in some cases is seen in parallel growth with them, and again is sometimes clearly intergrown with them, forming a pyroxene-perthite (Fig. 5, Plate XIV). The finer pyroxene-perthites are apparently homogeneous augites in ordinary light, but between crossed nicols they closely resemble micropegmatite. In the latter the intergrowth is too fine to permit the determination of both species of pyroxene, although one of them is often hypersthene.

Hornblende, a greenish variety, is confined to the more acid rocks, and in these to the exterior of the pyroxene grains. In Nos. 12 and 13, where it is fibrous and confined to the exteriors of the hypersthene, it may confidently be described as uralite. In Nos. 15 and 16, where it is compact, brownish-green, and occurs as crystallographic outgrowths on the pyroxene, it is more probably original, but in these also there is a subordinate amount of a paler and somewhat fibrous hornblende which is probably uralitic.[2]

Biotite occurs in small quantity in almost all the rocks. It is found only in ragged flakes, and in most cases surrounds or lies alonside the iron ore, from which it appears to have been derived by a partial resorption.

The felspars, which are the most abundant minerals, are for the most part glassy clear, but in some of the rocks the plagioclase has a milky brown appearance due to the

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[1] *Cf.* Elsden, J. V., The St. David's Head 'Rock-Series.' Q.J.G.S., LXIV, (1908) pp. 286-8.

[2] For a more detailed discussion of the writer's views on the distinction between uralite and primary hornblende, and the raison d'etre of the latter's occurrence, *cf.* Thomson, J. A., Petrological Notes to Bulletin 33. Geol. Surv, Western Australia, 1909, pp. 132-5.

presence of extremely minute inclusions, while the orthoclase is practically clear. The latter occurs in but slight amount in the more basic rocks, and is always interstitial to all the other elements, and generally crowded with needles of apatite. In those rocks containing quartz it is more abundant as an element of the micropegmatite. The plagioclase is a thoroughly basic variety with only at most a slight peripheral zoning of acid material. Its refractive indices are always greater than those of balsam and of quartz whenever a comparison is possible. Carlsbad, albite and pericline twinning are abundant, and the extinctions indicate, by Levy's method, basic labradorite and bytownite.

One of the rocks, No. 12, was kindly analysed by Mr. G. J. Burrows, in the geological department of the Sydney University. With it may be compared some similar analyses made on the same class of rock elsewhere.

	I.	II.	III.	IV.	V.
SiO_2	51·55	50·55	50·76	52·49	8592
TiO_2	0·53	0·05	0·46	0·62	66
Al_2O_3	18·85	17·16	16·83	16·44	1848
Fe_2O_3	0·32	1·04	4·16	2·60	20
FeO	6·77	3·40	4·45	5·30	940
MnO	0·13	0·19	0·69	trace	18
MgO	7·09	9·97	10·09	6·18	1772
CaO	14·04	14·77	11·30	11·71	2507
Na_2O	0·63	1·62	0·97	2·06	102
K_2O	0·08	0·11	0·06	1·09	9
H_2O	0·11	0·36	0·14	1·42	
H_2O	0·04	0·12	...	0·15	
P_2O_5	trace	...	none	trace	
CO_2	none	...	...	...	
FeS_2	none	0·17	...	...	
	100·14	99·51	100·06	99·91	
Analysis.	Burrows.	Simpson.	Ditrich.	Harrison.	

I. Cavanagh Range.
II. "Norite," Norseman, W. A., Bull. 21, Geol. Surv. W.A. 1906, p. 119.
III. "Diabase," Barina District, British Guiana, Rep. Geol. N.W. District, II, p. 6, 1898.
IV. Hunnediabase, Launceston, Tasmania, Quoted in Ann. Rep. Dept. Mines, 1908.
V. Molecular proportions of I.

The analysis is interesting in the first place as adding to our information of the chemical composition of the Hunnediabase. Typical quartz-dolerites (Kongadiabas) show in general a lower proportion of alumina than normal rocks of the same silica percentage, whereas this rock possesses, if anything, a higher figure. These peculiarities are due, in the former to the presence of free silica, in the latter to the abundance of a very basic felspar, for anorthite is relatively richer in alumina than albite. It is somewhat surprising to find a pyroxene poor in lime crystallising from a magma so rich in that element, but a calculation shows that after apportioning lime to alumina to form anorthite, there is relatively little non-felspathic lime. The mineral composition may be calculated as follows :—

Quartz					6·23
Orthoclose			0·49	Felspar	54·12
Albite	5·34	Plag.	53·63		
Anorthite	48·29				
$CaSiO_3$			8·93	Pyroxene	38·16
$MgSiO_3$	17·72		29·23		
$MnSiO_3$	0·24				
$FeSiO_3$	11·27				
Magnetite	0·46			Iron ores	1·47
Ilmenite	1·01				
H_2O	0·15				
	100·13				

According to the norm of the American authors there is 17·86 diopside and 20·30 hypersthene. In the mode, however, there is not so much hypersthene, and most of the metasilicate is contained in an augite poor in lime. It is difficult to account for the presence of quartz in the norm in a rock from which olivine has crystallised.

The analysis is fairly closely paralleled by that of the "norite" of Norseman, which is a very similar rock as is pointed out below. It contains, however, a higher proportion of hypersthene. The diabase from British Guiana, of which I have not been able to compare the mineral composition, also agrees sufficiently well to place it in the same class, but with a higher percentage of soda there is a distinct drop in the amount of lime, reflected by a smaller drop in the alumina. The Hunnediabase from Launceston shows the same differences and also lower iron and magnesia percentages, due probably to the absence of olivine. In spite of these minor differences, the four analyses obviously show a close agreement.

The nomenclature of this group of rocks is a matter of difficulty. Overlooking the presence of hypersthene, those rocks with enstatite-augite and without quartz come under Rosenbusch's group of Hunnediabase; those with quartz, under his group of Kongadiabase, while No. 7 may be described as an ophitic norite or a hypersthene diabase. The writer prefers, however, to call them all dolerites, indicating their special characters by the prefixing of the names of those minerals not common to all dolerites, *e.g.* hypersthene enstatite-augite olivine dolerite. This method though admittedly clumsy, gives due weight to each element of composition.

The affixing of correct names to the rocks is, however, only a matter of secondary importance. What is more important is the recognition of this group of rocks in

Central Australia. The nearest allies known to the writer are to be found in the dyke at Norseman already referred to. A study of eight specimens from different parts of the dyke, kindly presented to the writer by Mr. A. Gibb Maitland, Government Geologist of Western Australia, shows a series of rocks ranging from hypersthene through olivine norite to quartz norite, with enstatite-augite and pyroxene-perthite in many of the specimens. The dyke runs east and west through a series of amphibolites and schists that lie in N.E-S.W. belts. It is distinctly the youngest of the solid rocks of the field, later even than the granites and accompanying quartz-porphyries, which run in the plane of the foliation. In these respects, and in its petrological characters (though not its coarseness) it is typical of a large series of dykes traversing the rocks of the different gold-fields. These "later dykes" as the writer proposes to term them, are in many fields distinct from the gold bearing lodes, which they intersect and fault. The areas occupied by them in Central Australia may therefore be presumed to be non-auriferous. It does not necessarily follow, however, that the whole area is non-auriferous. Owing to differential erosion, these later dykes frequently stand up above the softer auriferous rocks, and afford the best opportunities of collecting specimens. So it may be that in central Australia the later dykes are intrusive through auriferous rocks also. The evidence on this point is quite non-conclusive.

The presence of enstatite-augite and quartz-dolerites in Central and Western Australia leads to theoretical considerations of more than local interest. Though those described are fairly deep-seated and approaching gabbros in crystallisation, there are petrologically similar rocks of finer grain among the later dykes of Western Australia known to the writer which clearly show the close connection between the group and the Mesozoic dolerites of Tasmania before alluded to. Further, the dolerites and quartz dolerites of Victoria Land, Antarctica, also possess, according to the writer's observations, the same petrological peculiarities, and in particular the minerals enstatite-augite and pyroxene-perthite. Though the writer's observations on the Karroo dolerites of South Africa have not been sufficiently extensive to allow the same affirmation to be made, Wahl has shown[1] that the 'diabase' of Richmond originally described by Cohen[2] contains enstatite-augite, and it is reasonable to suppose that this mineral has a wide occurrence in South Africa.

The Tasmanian and South African rocks are definitely known to be of late Mesozoic or early Tertiary age. There is no evidence so far produced to show that the others are not of the same age. They all occur in the remaining horsts of the foundered Gondwana Land, and the question arises whether they do not point to the presence of an immense magma or to a series of similar magmas, which in Mesozoic times underlay the old Gondwana Land, parts of which were forced up by the earth movements which led to the breaking up of the continent.

Mr. Benson has kindly drawn my attention to a paper in which Prior[3] has already made a similar suggestion, *i.e.* he suggests that the dolerites of Zululand and Victoria Land are of the same age, and further points out the curious association of these rocks on the mainland in each place with later alkaline rocks in outlying islands. This observation might, with reservation, on the island-occurrence of the alkaline rocks be equally applied to Tasmania. But

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[1] *Loc. cit.*, pp. 29-30.

[2] Geognostisch-petrographische Skizzen aus Sud-Africa, Neues Jahr. f. Min. etc. 1887, B.B., p. 234.

[3] Prior, G. T., Petrographical Notes on the Dolerites and Rhyolites of Zululand, Ann. Natal Mus. II, 1910, p. 152.

it does not hold good for Western Australia, where alkaline rocks are quite unknown, nor to New Zealand, where the same alkaline series as that of Erebus is well displayed, but where quartz-dolerites are so far unknown.

In opposition to the suggestion of a petrographical magma common to the whole of Gondwana Land, it may be urged that the class of rocks relied on, viz. quartz-dolerites with hypersthene or enstatite-augite are not by any means confined to remains of that ancient continent, but are equally common in British Guiana, Great Britain, Canada, etc. That would be to imply, however, that similar petrographical provinces could not exist in different parts of the earth. A stronger objection is furnished by certain theoretical views on the mode of formation of these rocks. It has been suggested by Daly[1] that quartz-gabbros and the commonly associated granophyres are formed by the acidification of gabbros by the assimilation of the surrounding walls. Tyrell[2] has elaborated this view with special regard to quartz-dolerites, and suggests further that they represent a critical stage in assimilation, in that they are almost entirely made up of intergrowths of related minerals, and have reached the limit of saturation of a basic magma with quartz. Both these writers totally fail to explain the excess of magnesia and iron over non-felspathisable lime which is necessary for the formation of hypersthene or enstatite-augite. Whether we admit with them that quartz-dolerites have arisen by the assimilation of acid material by a basic magma, or agree with Vogt that they have arisen by differentiation as an "anchi-eutectic" rock, we must still postulate that the primary magma had funda-

[1] Daly, R. A., The Secondary Origin of Certain Granites, Am. Journ. Sci., xx, 1905, pp. 185 – 216.

[2] Tyrell, G. W., Geology and Petrology of the Intrusions of the Kilsyth-Croy District, Dumbartonshire. Geol. Mag., Dec. 5, Vol. vii, 1909, pp. 299 – 309 and 359 – 366.

mental chemical peculiarities to allow it to give rise to a secondary magma capable of producing these minerals, instead of common augite. It is this chemically peculiar primary magma which is necessary for the establishment of a petrographical province.

A further line of evidence which strengthens the writer's suggestion is the recurrence of quartz-dolerites at different geological ages in some of the above fragments of Gondwana Land. Owing to their degree of alteration, it is not possible to assert that the older groups also contained enstatite-augite, but analyses support the view. This phase of the subject is too extended to discuss at length here, but the following facts may be instanced. Among the Western Australian amphibolites of supposed pre-cambrian age there are rocks which can be shown to be merely uralitised and saussuritised quartz-dolerites.[1] Henderson[2] has described similar rocks from the Transvaal, which may be assumed to be much older than the Karroo dolerites.

In India, the important fragment of Gondwana Land from which Mesozoic quartz-dolerites have not been noted, there is a well known occurrence of the rock in the Cuddepah, and in these Wahl has shown the presence of enstatite-augite. But there is also in the Archæan of India the peculiar group of charnockites which exhibit, not indeed the same structural peculiarities but very similar chemical relations, viz. a high proportion of magnesia and iron compared to non-felspathisable lime combined with an excess of silica.[4]

[1] Thomson, J. A., Petrographical Notes to Bull. 33, Geol. Surv. W.A., 1909, pp. 137, 145, 151, and 156.

[2] Henderson, J. A. L., Petrograpical and Geological Investigations on certain Transvaal Norites, Gabbros and Pyroxenites, London, 1898, pp. 29 – 33.

[3] Holland, T. H., On Augite Diorites with Micropegmatite in S. India. Q.J.G.S., LIII, (1897) p. 405. Wahl, *loc. cit.*

[4] Holland, T. H., The Charnockite Series, a group of Archæan Hypersthene Rocks in Peninsular India. Mem. Geol. Surv. India, XXVIII., Pt. 2, pp. 119 - 249, 1900.

Whether the similar recurrence of these rocks at different periods of geological history will be found so abundantly elsewhere as to invalidate the force of this argument, so far as it applies to the rocks of Gondwana Land, remains for the future to disclose. In so far as it applies to Australia, it opens up a fruitful field of enquiry for Australian petrologists.

NOTE.—Since the above was written, an important paper by Dewey and Flett has made suggestions that to some degree undermine the above views.[1] In effect, they propose to recognise besides the well known Atlantic and Pacific suites of rocks yet a third known as the spilitic, and geographically associated with districts of long continued and gentle subsidence. The rocks characterising the suite are picrite, diabase (often albitised), minverite, quartz-diabase, keratophyre, soda felsite and albite granite. The most striking chemical peculiarities of the group are the richness in soda compared to potash and lime, not indeed always to be seen in the original minerals, but betrayed by the juvenile albitisation that the rocks have undergone.

Quartz-dolerites, then, are claimed by them as belonging, at least in part to the spilites, both on account of the albitisation which they sometimes exhibit and of their geological relationships with other members of the suite, whereas in the ideas put forward above, they are attached to the charnockite suite on account of their relative richness in iron and magnesia. It must be admitted at once that the above authors have a far stronger case for their general view, based as it is on a much greater body of observation. There are even features in Western Australia that give support to the possibility of the spilite suite being

[1] Dewey, H., and Flett, J. S., British Pillow-lavas and the Rocks associated with them. Geol Mag,, Dec. 5, Vol. VIII, 1911, pp. 202-9 and 241-8.

developed there, viz. the occurrence of albite granites and the presence of albitisation amongst the older (amphibolitised) quartz-dolerites. If, on the other hand, the commonly occuring rock types are correctly accounted for as anchieutectic rock, as many authors are now willing to believe, there would be a tendency for the development of similar rocks from widely different primary magmas. That such 'diphiletic'[1] rocks are present in the case of the Atlantic and Pacific suites has been consistently denied by Rosenbusch, but even he is unable to ascribe most basalts to one or the other suite, and other observers believe in the possibility of diphiletic rocks. It would not do to push this possibility too far in connection with the views suggested above, or the primary chemical peculiarity postulated above would not be deducible from such a diphiletic anchieutectic rock.

Summary and Conclusions.

A series of seventeen rocks collected by the Elder Scientific Exploring Expedition from the neighbourhood of the eastern boundary of Western Australia are described in detail, and compared with the rocks of the Western Australian goldfields. Only one resembles the immediate country of the auriferous veins. Two are probably to be referred to the gneiss formation. The remainder are dyke rocks; they include a camptonite, the first undoubted occurrence of this type in Western Australia, and a number of very fresh intrusive dolerites of considerable petrological interest, especially in that they are the first rocks on the Australian mainland in which enstatite-augite and pyroxene-perthite have been recorded. A comparison of these rocks with the later dykes of Western Australia and the dolerite sills of Tasmania, Antarctic and South Africa

[1] I am not aware whether the term diphiletic has been used before in this sense. It was suggested to me in conversation by Dr. J. S. Flett.

is made, and the suggestion is put forward that they are of the same age and magmatically related.

The results obtained from this small collection are sufficient to show that the whole official collection, consisting of some hundreds of rocks is worthy of a fresh examination in the light of the recent knowledge acquired in the Western Australian goldfields. Presumably the collection is in the possession of the Royal Society of South Australia.

Explanation of Plate XIV.

Fig. 1. Banded norite, Fraser's Range, Western Australia. Natural light. Magnified 15 diameters.

" 2. Hornblende granite-gneiss, Blyth Range, Central Australia. Crossed nicols. Magnified 15 diams.

" 3. Granulite, Barrow Range, Central Australia. Natural light. Magnified 15 diams.

" 4. So-called tachylite, Cavanagh Range. Natural light. Magnified 15 diams.

" 5. Pyroxene-perthite in quartz dolerite, No. 14, Near Depôt 1. Crossed nicols. Very highly magnified.

" 6. Hypersthene olivine dolerite. showing ophitic structure of both olivine and hypersthene towards felspar. No. 8, Hills near Camp 5, 20/6/91. Natural light. Magnified 15 diams.

A SUGGESTED EXPLANATION OF ALLOTROPISM BASED ON THE THEORY OF DIRECTIVE VALENCY.

By F. B. GUTHRIE, F.I.C., Department of Agriculture.

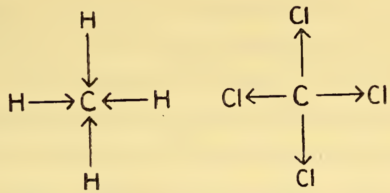
[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

THE suggestion that valency is due to the transference of corpuscles from one atom to the other, and that in consequence the valency bonds familiar to chemists in the graphic representation of molecular structure may be regarded as having definite direction, was first put forward by Sir J. J. Thomson.[1] This hypothesis is enunciated by him in the following terms: "For each valency bond established between two atoms the transference of one (negatively charged) corpuscle from one atom to the other has taken place, the atom receiving the corpuscle acquiring a unit charge of negative electricity, the other by the loss of a corpuscle acquiring a unit charge of positive." Sir J. J. Thomson regards each of these transferences as a "unit tube of electric force between the two atoms, the tube starting from the positive and ending on the negative atom."

The connecting links between the atoms which are usually represented by straight lines would then be replaced by arrows indicating the direction taken by the corpuscles, namely from the more positive to the more negative atom.

Compounds, such as marsh gas and tetrachlormethane would be represented thus:—

[1] The Corpuscular Theory of Matter, pp. 138, 139.



Sir Wm. Ramsay in his Presidential Address to the Chemical Society 1908,[1] has further elaborated this hypothesis and has suggested that electrons are atoms of electricity and serve as the "bond of union" between atom and atom. He explains the constitution and ionization phenomena of complex inorganic salts, such as nitrites of the cobaltammines by this hypothesis.

This extremely interesting suggestion has been pursued further by K. G. Falk and J. M. Nelson,[2] who have shown that many cases of isomerism amongst carbon compounds can be explained by this hypothesis as well as by spacial configuration. They have shown that this method of representing the relation between the atoms can be applied to carbon compounds with triple and double bonds, nitrogen compounds with single and double bonds, and compounds containing double bonds between unlike atoms.

Falk[3] has further applied this hypothesis to the ionization relations of organic acids.

The object of the present communication is to attemp to apply this hypothesis to an explanation of the structure of allotropic forms of the elements.

In the case of the isomers of organic and inorganic compounds, the assumption of valency direction provides a possible second explanation of such isomerism for which a satisfactory explanation is already forthcoming in the

[1] J.C.S., Vol. 93, Trans. p. 774.

[2] K. G. Falk and J. M. Nelson, Journ. Amer. Chem. Soc., 32, 1637.

[3] K. G. Falk, Journ. Amer. Chem. Soc., 33, 1140.

spacial grouping of the atoms. In the case of allotropism, no satisfactory explanation has yet been advanced, and any hypothesis which will explain this phenomenon must have a profound bearing on our conception of molecular structure. The hypothesis most generally accepted to account for allotropism is that it is due to the ability of the element to form molecules of varying numbers of atoms. This is true, for instance, in the case of oxygen at ordinary temperatures, and experimental proof is available of the condensation in the case of the ozone molecule, but attempts to account for other cases of allotropism in the same way have not been successful. Erdmann[1] assumes a molecular structure S_3, for the second dark liquid form of sulphur, on the analogy of oxygen, and proposes for it the name "thiozone." This form is, however, a phase and not an allotropic form, and is dependent on temperature. There is no experimental proof that the sulphur molecule breaks up into any other than S_2 molecules.

In the case of other elements, this variation in the number of atoms composing the molecule is only observed in the state of vapour. Such variations, when observed, depend upon the temperature, (and, in the case of sulphur at its boiling point, on the pressure), and afford no explanation of different physical forms existing at ordinary temperatures and pressures. Iodine, for example, which forms no allotropes, varies like sulphur in respect to the molecular constitution of its vapour at different temperatures; at 600°, the molecule of iodine contains two atoms, whereas above 1,500°, it is monatomic. This variation in the vapour density does not constitute allotropism.

In the case of isomerism amongst organic compounds, the direction taken by the negatively charged corpuscles depends upon the relative electric conditions of the neigh-

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[1] Erdmann, Annalen. 1908, 362, 133.

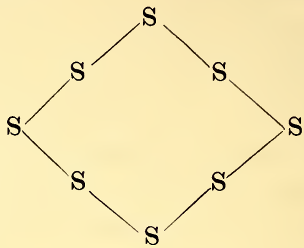
bouring atoms. What, however, happens when, as in the case of an element, the atoms composing the molecules are the same? Is it possible that valency direction is affected by the conditions under which the molecules are formed? The assumption that variation of the conditions attending the formation of the molecule may alter the relative direction of the "tubes of electric force," the directions in which the electrons are discharged, will account for variations in the structure of the resulting molecule which may possibly have a bearing on the different physical forms which the molecule is capable of assuming.

In what follows, the data concerning the molecular weights and allotropic forms of the elements are taken for the most part from Roscoe and Schorlemmer's "Treatise on Chemistry," Vol. I, 1905. All other references quoted have been verified.

Sulphur.

The molecular weight of sulphur as determined by the freezing point depression and boiling point elevation of solutions in carbon-bisulphide and naphthalene, corresponds to a molecule consisting of eight atoms. The vapour density diminishes rapidly with increase of temperature, until at 860° it corresponds with the formula S_2, and remains constant up to 1400°. At temperatures nearer the boiling point of sulphur (400°) the vapour-density is nearly constant at pressures between 540 mm. and 125 mm., and corresponds to a formula between S_7, and S_8, the molecular weight diminishing rapidly with reduced pressure at this temperature. It appears most probable that the sulphur molecule contains eight atoms at lower temperatures, splitting up into S_2 molecules as the temperature rises (or at 440° with diminished pressure).

With regard to its valency, sulphur is divalent in its principal compounds with hydrogen and the metals, occasionally tetravalent (in SCl_4), and hexavalent (SF_6). The molecule of sulphur may therefore be represented by the graphic formula :—



If now we indicate direction in the various bonds and replace the straight lines by arrows showing the direction in which the electrons are projected towards the neighbouring atom, we shall be able to produce a large number of possible figures representing the structure of the different molecules formed by variations in the valency direction.

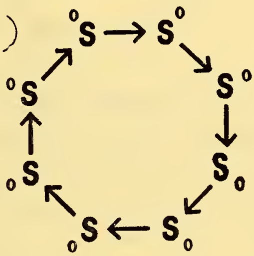
It is fair to assume that the transference of corpuscles takes place only between the atoms within the molecule and that corpuscles are not discharged beyond the molecule, which would result in its disintegration. It is further demonstrable that if a greater number of electrons travel in the one direction than in the other, (except in the case in which they all travel in the same direction) the result is unsymmetrical, and presumably unstable. We thus reduce the number of possible figures to about forty, of which only four are symmetrical, namely :—

1. In which all the corpuscles travel in the same direction, represented by the formula (a a a a a a a a).
2. In which each alternate bond represents a corpuscle travelling in opposite directions, represented by the formula (ab ab ab ab).
3. In which a pair of neighbouring bonds represents corpuscles travelling in one direction (a) alternating with a pair travelling in the opposite direction (b) represented by the formula (aa bb aa bb).

4. In which four neighbouring bonds representing corpuscles travelling in one direction (a) are followed by four travelling in the opposite direction (b), represented by the formula (a a a a b b b b).

Case 1 is represented by the graphic formula :—

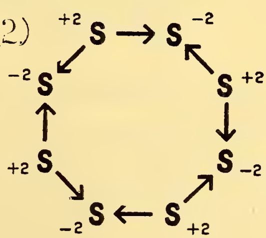
(1)



Each atom has lost a corpuscle (a unit of negative electricity) to one of the neighbouring atoms and has gained one from the other neighbouring atom, the result being a symmetrical stable molecule in which the electrical charge on each atom is neutralized.

Case 2 is represented as follows :—

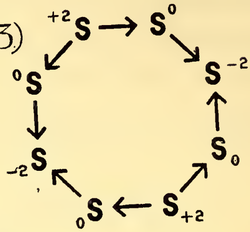
(2)



In this case each alternate atom receives two negative corpuscles, acquiring two unit charges of negative electricity, and loses two negative corpuscles, acquiring two unit charges of positive electricity, the result being a symmetrical stable molecule in which the electrical charge is evenly distributed.

Case 3 is represented as follows :—

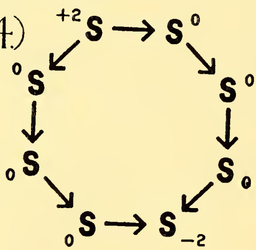
(3)



In this case, one of the upper and lower atoms have each lost two corpuscles becoming in consequence charged with two unit charges of positive electricity, one of the right and left hand atoms have acquired two unit charges of negative electricity, and the intermediate atoms have gained and lost a negative corpuscle and are consequently neutral.

Case 4 is represented as follows :—

(4)



Here again we have a molecule of symmetrical structure in which the positively charged atom in one part of the molecule is balanced by the equally negatively charged atom in the other, but its configuration suggests that it is probably more readily altered than the previously figured molecules in which the electrical charge is more evenly divided. It may represent one of the less stable modifications, probably the plastic variety.

We have here figures that may not unreasonably be regarded as representing the four comparatively stable modifications of the element sulphur. The viscid modification need not be taken into account, as its formation is dependent upon the temperature, and it can hardly be regarded as a true allotrope. Any other graphic representation indicating valency direction will be found to yield either an unsymmetrical molecule or one of the forms already figured.

PHOSPHORUS.

In the case of phosphorus, we have an element whose molecular weight calculated from its vapour density at 444·8° is 126·6, corresponding to the molecular formula P_4.[1] Mitscherlich, and Deville and Troost obtained the molecular weight of 123·84 at the temperature of 515° and 1040° (Roscoe and Schorlemmer).

Determination of the molecular weight from the raising of the boiling point of solutions of phosphorus in carbon bisulphide,[2] and the depression of the freezing point of solutions in benzene,[3] further prove that the molecule consists of four atoms.

If we regard phosphorus as a trivalent element we shall have as the ordinary representation of the phosphorus molecule

If now we assign valency direction to these bonds we get twelve possible cases, assuming as in the case of sulphur that the transference of electrons takes place only between the atoms of the molecules. We obtain :—

Case A. when the double bonds travel in the same direction (aa). This gives rise to three variations according as the single bonds travel—

[1] Chapman, Journ. Chem. Soc. 1899, Trans. Vol. 75, p. 734.
[2] Beckmann, Zeitschr. Physik. Chemie, 1890, 5, p. 76.
[3] Hertz, *ibid.*, 6, p. 358.

1st, both in the same direction as the double bonds (a)
2nd, both in the opposite direction (b)
3rd, one in the same direction with the double bonds (a) and one in the opposite direction (b).

Case B. The double bonds travel, one pair in the direction (aa), the second pair in the direction (bb). There are three combinations possible, as in the previous case.

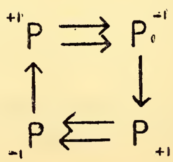
1st, in which both single bonds travel in the same direction (a)
2nd, in which both single bonds travel in the same direction (b)
3rd, where the single bonds travel in opposite directions (a and b).

Case C. One pair of the double bonds travels in the same direction (aa), the second pair travels, one in the direction (a) the other in the direction (b). This also permits of three combinations according to the direction of the single bonds.

Case D. The individual bonds in each pair of double bonds travel in different directions (ab) (ab). Giving rise as before to three modifications depending on the direction of the single bonds.

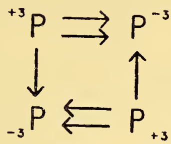
Out of the twelve figures which it is possible to construct we get only the following figures which are symmetrical.

(1)



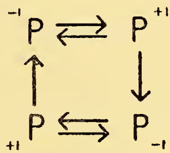
This is Case A1, in which double and single bonds all have the same direction, resulting in a symmetrical stable molecule in which the electric charge is evenly distributed.

(2)



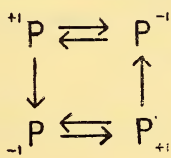
This is Case A2, in which the single bonds travel in the same direction, but in a direction opposite to that in which the double bonds travel. We have also

(3)



A modification of Case D. (*supra*) in which the individual bonds in each pair of double bonds travel in opposite directions, (a and b) and the single bonds travel in the one direction (a). This is identical with figure (1).

(4)



In which the double bonds travel as in (3), and the single bonds travel both in the same direction, (b) opposite to that in which they travel in Figure 3. This is also identical with Figure 1.

Figures 3 and 4 are identical with figure 1, so that there remain only the two possible combinations, figures 1 and 2, which result in symmetrical molecular structures. These may be assumed to represent the yellow and red varieties respectively. All other combinations result in unsymmetrical molecules overloaded in one portion with negative or positive electricity. This agrees with the conclusion of Chapman[1] as to the existence of only two allotropes of phosphorus, and excludes the existence of the so-called "metallic phosphorus," produced by dissolving phosphorus in lead as an independent allotropic form. It is probable that "metallic" phosphorus and red phosphorus are identical, only the former is better crystallised.

Schenck's phosphorus, or scarlet phosphorus[2] is also excluded. This substance is obtained by heating phosphorus in PBr_3, and has not been prepared in a pure state. It appears most likely that it consists of a mixture of a solid hydride of phosphorus and ordinary phosphorus.

Selenium.

According to Saunders,[3] the following well defined modifications of this element exist:—

1. Amorphous, vitreous, and soluble or colloidal. These are all soluble in carbon bisulphide. They differ in appearance, but may be regarded as belonging to the same allotropic form, and are classed by Saunders under the name of "liquid selenium."

2. Red crystalline selenium. This occurs in two closely allied but distinct crytalline forms, soluble in carbon bisulphide.

3. Crystalline grey or "metallic selenium." This is the stable form, and is insoluble in carbon bisulphide.

There thus exist, as in the case of sulphur, four definite forms, for though the red crystalline forms both belong to the monoclinic system, measurements of the crystals made by Mitscherlich and later by Muthmann (both quoted by

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[1] Chapman, Journ. Chem. Soc. Trans. 1899, Vol. 75, p. 734.

[2] Journ. Soc. Chem. Ind., 1903, Vol. 22, p. 1226.

[3] Saunders, Journal Physical Chemistry, 1900, 4, 423.

Saunders) show that they crystallise in different forms of different stability, one of which is isomorphous with monoclinic sulphur.

The third allotrope (metallic selenium) is the stable form into which the red crystalline forms pass over on heating to 170° – 180°. The crystalline forms are produced from the amorphous variety when the latter is dissolved in carbon bisulphide. With certain solvents, such as quinoline, amorphous selenium is converted directly into the metallic modification.

The vapour density of selenium diminishes very rapidly with the temperature and its behaviour resembles very closely that of sulphur. Selenium boils according to Deville and Troost at 665° under 760 mm. The vapour density, as determined by Szarvasy[1] at 774° corresponds to a molecular formula between Se_2 and Se_3.

Between 900° and 1800° the vapour density is constant at 78·6 and corresponds to the formula Se_2.

It is extremely probable that at temperatures closer to the boiling point, the molecule would be very much larger as in the case of sulphur, which selenium so closely resembles.

It is to be noted that in the case of sulphur the vapour density observed at 606° (which is only 160° above its boiling point), corresponds to the molecular formula S_4, whereas at 440° the molecule is S_8. In the case of selenium, the temperature (774°) at which the vapour density corresponds to the molecular formula $Se_{2·5}$ is more than 100° above its boiling point, and we are justified in expecting that at lower temperatures the number of atoms in the molecule would increase as in the case of sulphur.

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[1] Szarvasy, Berichte, 1897, 30, 1244.

[2] Biltz, Zeitsch. Physik. Chemie, 1896, 19, 4, 15.

Beckmann and Pfeiffer[1] have determined the molecular weight by observing the depression of the freezing point of solutions of selenium in phosphorus, and find that this corresponds to the molecular formula Se_8.

We are therefore justified in assuming that the selenium molecule is of similar construction to the sulphur molecule and consists of eight atoms. Like sulphur also, the selenides of hydrogen and the metals have the formula $Se''M_2$. If therefore, we ascribe direction to the uniting bonds representing valency, we obtain as in the case of sulphur four possible combinations, in which the electric charges on the individual atoms are either neutralised or evenly distributed, producing four symmetrical, more or less stable molecules, corresponding to the four definite allotropic forms.

If further speculation is permissible, one would be tempted to suggest that the most stable form (metallic selenium) might be represented by the neutralised molecule (corresponding to Case 1 of sulphur) and that the less stable crystallised modifications are represented by figures similar to Nos. 3 and 4, in the case of the sulphur molecule.

Tellurium.

In the case of tellurium, the information is more meagre and the conclusions less satisfactory. Apparently only two allotropic forms of this element are recognised, namely the crystallised form occurring in hexagonal rhombohedra, with a silvery lustre, and the amorphous variety produced when solutions of the oxide are reduced by sulphurous acid.[2] Gutbier[3] has obtained two colloidal modifications of tellurium, a brown one obtained on reduction of solutions of tellurium dioxide and telluric acid, and a bluish-green one formed only on the reduction of telluric acid. Whether

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1 Beckmann and Pfeiffer, Zeit. Physik. Chemie, 22, 614.

2 Fabre and Berthelot, C.R. 104, 1405.

3 Gutbier, Zeitsch. Anorg. Chemie 1902, 32, 51.

these differences in colour are due to the state of suspension or to variety of allotropic forms he leaves an open question in view of the present state of our knowledge as to the colloidal condition of the elements. On passing an electric current through solutions of telluric acid in the presence of potassium cyanide, Gutbier and Resenscheck[1] obtain a brown violet liquid hydrosol. If ammonium oxalate is used instead of potassium cyanide the solution becomes steel-blue. If the brown solution is hydrolised before metallic tellurium is produced the solution of hydrosol is permanent.

With regard to the molecular weight of tellurium there is an equal difficulty. The only determinations of the vapour density quoted are those of Deville and Troost,[2] who found the vapour density at 1390° to be 9, (Air = 1

Biltz[3] finds this number, (which corresponds to the formula Te_2) to be correct at 1800 degrees. At the same time Biltz considers that Deville and Troosts' conclusions are certainly incorrect, and that at lower temperatures, tellurium vapour has a much higher specific gravity, and like sulphur and selenium, the molecule contains a greater number of atoms, splitting up into smaller molecules at higher temperatures. There are no determinations, as far as I have been able to ascertain, of the molecular weight of tellurium by other methods. The data therefore, in the case of tellurium both in respect to the number of allotropic forms and the molecular weight are not sufficiently reliable to enable us to speculate on the connection between the two.

If we assume that only two allotropic forms exist, and that the formula is correctly represented by the vapour density at 1390° and above, and is Te_2, then we have the very simple explanation that under these circumstances two and only two modifications are possible, namely:—

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[1] Gutbier and Resenscheck, Zeit. Anorg. Chemie, 1904, 40, 264.
[2] C.R., 1863, 56, 891,
[3] Biltz, Zeitschr. Physik. Chemie, 1894, 19, 415.

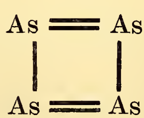
$$\overset{+2}{Te} \rightrightarrows \overset{-2}{Te} \qquad \overset{\circ}{Te} \rightleftarrows \overset{\circ}{Te}$$

If, however as seems more probable, tellurium follows sulphur and selenium, and the molecule at lower temperature more nearly approaches the formula Te_8, then we are confronted with the question whether there are not more than two allotropic forms of the element. If the molecule is octatomic and the atom divalent, then as in the case of sulphur and selenium we would require four allotropic forms if the allotropy is conditioned by the direction of valency. It is possible, of course, that the two recorded colloidal forms are true allotropes, or that there are other allotropic forms not yet isolated. Tellurium is still a somewhat rare element, and its properties have not yet been studied with the thoroughness and care accorded to sulphur.

Arsenic.

The arsenic molecule like that of phosphorus is tetratomic. At 860° the vapour density is 146·88 corresponding to a molecular weight of 293·8 = As_4. At higher temperatures, 1600° – 1700°, the vapour density diminishes by nearly one-half and the molecule only contains two atoms.

Its molecular weight as determined by the elevation of the boiling point of solutions of yellow arsenic in bisulphide of carbon, corresponds also to the formula As_4. We may therefore assign to it a formula similar to that of the phosphorus molecule.



With regard to its allotropes, the number of these has not been definitely established. In addition to the steel-grey crystalline form obtained by reduction of the oxide and sublimation, and the amorphous black variety formed when arseniuretted hydrogen is strongly heated, the following forms have been noticed by different observers.

When arsenic is sublimed in hydrogen it is said to be split up into a crystalline form, an amorphous form, and a yellow vapour depositing grey crystals. These forms are deposited at different distances from the source of heat.

An extremely unstable, but, according to Erdmann and Unruh,[1] a definite yellow crystalline variety is obtained when arsenic vapour is strongly cooled and led immediately into carbon bisulphide in which it is soluble. It is very rapidly converted at ordinary temperatures and by light into the black variety, and it is only possible to keep it permanently in complete absence of light and at a temperature of -65° to -70°.

Erdmann and Unruh (*loc. cit.*) also find that a reddish-brown precipitate separates out very slowly from a solution of the above yellow arsenic in carbon bisulphide. The substance has not been obtained free from sulphur nor has it been obtained in sufficient quantity to enable it to be identified by a specific gravity determination.

Reviewing the information available, there appear to be certainly two well defined and distinct allotropic forms of arsenic, the crystalline and the amorphous.

The molecular structure of these may be regarded as corresponding to those suggested for yellow and red phosphorus. There may be more than one crystalline form, but the information on this point is not definite. The yellow variety of arsenic is exceedingly unstable and might be represented by one of the eight unsymmetrical forms which are producible according to the hypothesis advanced. It appears probable that the red-brown form is not an allotrope at all.

[1] Erdmann and Unruh, Zeitsch. Anorg. Chemie, 1902, 32, 437.

If the two crystalline forms obtained on subliming arsenic are identical or form only one allotrope, then arsenic falls definitely into line with phosphorus, and the two stable allotropic forms (crystalline and amorphous), may be assumed to have the same molecular structures as are assigned above to yellow and red phosphorus.

Carbon, Silicon, Boron.

Speculation on the foregoing lines is not justified in the case of these elements, whose molecular weights have not yet been ascertained with certainty. In the case of carbon it appears probable that the molecule consists of twelve atoms or some multiple of twelve. A representation of a twelve-atom molecule, the atoms of which are tetravalent obliges us to recognize more than three stable symmetrical forms if freedom of direction is assumed for the corpuscles exchanged between the atoms.

Conclusions.

It would appear that the corpuscular theory of valency, involving valency direction, may afford a possible explanation of certain cases of allotropism among the elements. It is suggested that the relative directions of the discharged electron or "valectron" may be due to the condition under which the molecule is produced. Variation in the direction of these corpuscles gives rise to molecular figures which differ from each other in the manner in which the electric charge is distributed amongst the atoms. Those molecules in which the electric charge is neutralized or symmetrically distributed, may be regarded as being more or less stable molecules and as representing the various allotropic forms of the elements. It is not suggested that this is the sole cause of allotropy nor that it supplies an explanation in all cases. The case of oxygen and ozone would appear to be sufficiently explained by molecular condensation.

The only assumption made which is unsupported by experimental proof is that of the valency-values assigned to the several elements under discussion. It is now generally accepted that the valency of any given atom depends upon the nature of the atoms with which it combines and is consequently a variable property.

Sulphur for example is divalent towards hydrogen, tetravalent towards chlorine and hexavalent towards fluorine. Valency is not even a constant quantity towards the same element, thus manganese forms $MnCl_2$, $MnCl_3$, $MnCl_4$ etc.

No experimental evidence is available concerning the valencies of the atoms of an element in combination with atoms of the same element, and the assumption has been made that these are the same as those which the elements exhibit towards hydrogen and in their principal compounds, and which are suggested by their positions in the periodic table of the elements. Sulphur, selenium and tellurium have been assumed to be divalent, arsenic and phosphorus trivalent. Such an assumption does not contravert the theory of variable valency.

In the case of sulphur, selenium, and phosphorus, the hypothesis would appear to offer a reasonable explanation of the observed facts. In the case of tellurium and arsenic the data are not sufficiently unimpeachable to justify an extension of the argument to their case though it appears probable that they will be found to follow the examples of sulphur and phosphorus respectively. In the case of carbon, silicon, and boron, our inability to visualize the molecule prevents our speculating on these lines.

A point of considerable interest in this connection is that allotropic forms do not exist among the non-metallic elements which are monovalent, (such as hydrogen and the halogens), nor among those which are monatomic (helium, neon, argon, krypton, xenon). All the other non-metallic elements, with the single exception of nitrogen,[1] form allotropes.

These facts tend to support the hypothesis here put forward, since, in the case of monovalent elements, variation in the direction of the discharged electron produces no alteration in the structure of the resulting molecule.

$$^{-1}H \leftarrow H^{+1} \text{ is identical with } ^{+1}H \rightarrow H^{-1}$$

With monatomic molecules there can also be no change of direction. In the case of the metals, allotropy, where it exists, as in tin, is a function of the temperature. Determination of the vapour densities of cadmium, mercury and zinc show that the molecules of these elements are monatomic. Mensching and Meyer have shown that this is also the case with bismuth. Tammann[3] has shown further that at $-40°$ (using the method of depression of the freezing point of mercury) nearly all the metals have monatomic molecules.

My thanks are due to Mr. G. H. Knibbs, C.M.G., Commonwealth Statistician, for his kindness in verifying and abstracting certain references which I was unable to refer to locally. Also to Mr. L. Cohen of the Chemist's Branch of the Department of Agriculture, for preparing the diagrams which illustrated the reading of this paper.

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[1] A chemically active modification of nitrogen has been described by R. J. Strutt, (Bakerian Lecture, Proc. Roy. Soc., 1911, A. 85, 219).

[2] Berichte, 1889, 22, 726.

[3] Tammann, Zeit. Physik. Chemie, 1889, 3, 441.

THE NATURE AND ORIGIN OF GILGAI COUNTRY (WITH NOTES ON QUATERNARY CLIMATE).

By H. I. JENSEN, D.Sc.

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

I. Nature of Gilgais.

Gilgai country is remarkably uneven country, consisting of alternate hummocks and hollows. It occurs in its characteristic form only on the western side of the Dividing Range. Gilgai country has a similar appearance to the 'melonhole' country of the coastal swamps and the 'crab-holey' country of the tablelands, but the irregularity of the surface is much greater than these types. Sometimes in the western country we get the terms 'melonhole' and 'crabhole' applied to the gilgai areas in which the irregularity of the surface amounts only to a difference of two or three feet between the tops of the hummocks to the bottoms of the depressions. The genuine 'gilgai' country is much rougher. The differences in elevation between the knolls and the hollows amount to ten, fifteen and even twenty feet.

The hummocks are sometimes of rounded outline, but more often they are irregular in shape, usually serpentine, vermiform or variously ramified. The depressions have also correspondingly irregular shapes. The depths of the hollows may be very variable within a comparatively small area. For some time after rain they contain stagnant water. The angle of slope from the summit of a knoll to the bottom of the adjacent depression may be anything from 10° to 60°. In typical brigalow gilgai country a section of the surface would consist of a very wavy line, the crests from 25 to 50 feet apart, and the hollows 10 to 20 feet deep, quite deep enough to obscure a horse and its rider from the view of an observer on a hummock 10 yards away. The hollows vary in length from 25 to 50 or even 100 feet. The country is far too rough to ride over even when cleared.

Gilgai country may occur in small areas of only a few acres, but where typically developed a gilgai area has frequently an extent of several square miles, and along the northern edge of the Pilliga Scrub these gilgai areas occur close together, separated from one another by narrow belts of red soil, and of light sands lining the creek courses, over an area about 25 miles long and 5 to 10 miles wide. This portion of the Pilliga Scrub we can call the 'Gilgai Belt.' It has an area of about 200,000 acres, adjacent to the towns of Narrabri and Wee Waa.

The gilgai lands are, I believe, on the average more low-lying than the belts of red soil and the diluvial sands of the aggraded creek banks. I am informed that a heavy flood inundates all the gilgai country before the red soil belts and sandy belts are flooded.

II. Distribution of Gilgai Country.

As far as I am aware no description of 'gilgai' country has ever been published, but it has often been observed by surveyors and scientists in different parts of the State.

Mr. R. H. Cambage, L.S., F.L.S., informs me that he has traversed gilgai country in many districts, and that, according to his experience, it is found in various places along the western slopes, north, central and south. It occurs usually near the white box belt, the zone of *Eucalyptus albens*.

Mr. E. C. Andrews, B.A., has had a similar experience of the distribution of typical gilgai country. He has informed me that he has only met with this type of surface on the aggraded portion of the western slopes and on the plains adjoining the slopes.

Mr. G. H. Halligan tells me that he has seen gilgai country well developed between the Kalga Range and Coonamble (Urawilkie).

The universal experience of scientific workers seems therefore to show that gilgai country occurs at the base of our western slopes in areas where aggradation has been great and often in places where indications of late tertiary subsidences are in evidence. It lies in the zone between the areas of denudation and the great Black Soil Plains and Red Soil Plains of the west.

III. Characteristic Vegetation.

The typical gilgai country of the Pilliga Scrub is covered with dense brigalow and belar scrubs. The brigalow collected was identified for me by Mr. J. H. Maiden as *Acacia harpophylla*, and the belar as *Casuarina lepidophloia*. These two timbers seldom grow intermixed, but in some gilgai areas brigalow is wholly in possession, in others belar. Occasionally on the edges of gilgai country, as near Narrabri West, grey ironbark *(Eucalyptus crebra)* may be sparingly associated with the brigalow. Where such is the case the inequalities of the surface are only slight, amounting to two or three feet at the most. In other places the poplar box *(E. populifolia)* is seen to extend some chains into the gilgai, especially where belar holds sway. Wilga *(Geijera parviflora)* occurs sparingly in both belar and brigalow gilgais even in their centres, but especially where there is a tendency to the formation of red soil on the surface of the hummocks. On 'crabholey' country near the edges of gilgai areas, and also on larger blocks of 'crabholey' and 'melonholey' country, that is, less strongly developed gilgai than the deep gilgai, an oak (*Casuarina* *glauca?)* and two phylloclade bushes *(Leptomeria aphylla* and *Apophyllum anomalum)* occur together with belar, wilga and brigalow.

The only herbs which seem to grow on typical gilgai country in the natural state are members of the saltbush tribe *(Rhagodia* species, *R linifolia* and others).

The vegetation grows mainly on the hummocks sending long surface roots into the depressions. The gilgai vegetation is characterised by abundant surface roots and an absence of tap root.

IV. The Soils of the Gilgai Areas.

The soils of the gilgai country are mostly dark grey or almost black clays which in appearance suggest a considerable degree of salinity. They resemble soils which have been irrigated with saline artesian water for a period of years. A small gilgai belt lying 10–12 miles south of Cuttabri, on the track to Cubbo, has red clay soil, and small patches of crabholey country also occur in the red soil belt along Baradine and Dubbo Creeks.

In mechanical composition (See Table A) the gilgai soils are chiefly heavy stiff clays with a small percentage of rather coarse sand. In dry weather they crack with the formation of deep fissures just like the most heavy clay soils of the Namoi Black Soil Plain. In wet weather they are very boggy, and on drying they become as hard as cement. A crowbar or pick has to be used to get a soil sample.

In the hummocks we find a layer of soil from six inches to two feet from the surface in which white specks and nodules, ranging up to the size of a pea, occur. These white lumps consist of carbonate of lime, chemically precipitated. This precipitation of carbonate of lime in the subsoil of the hummocks indicates a rise of salts by capillarity from the hollows, and their precipitation by the evaporation of the water in a zone where the effects of dew and rainfall by downward percolation are negligible.

The chemical nature of these soils is remarkable. They are alkaline in reaction on the hummocks, but the hollows may be acid. The gilgai soils proved on analysis (Table B.) to be far from well balanced, the amounts of phosphoric acid and sometimes potash being low in proportion to the lime (Table B). They are very high in soda and magnesia, and also in manganese oxide. The amount of soil insoluble in acid is lower than in the case of normal black soils.

The water extract (Table C) contains in addition to colloidal clay a considerable amount of salts, chiefly sodium carbonate and common salt. Water-soluble magnesia and lime are practically absent in the hummock soils, being insoluble in alkaline solution. The sulphuric acid radicle is quite absent, no reaction for that ingredient being obtainable.

The volatile matter in the gilgai soils ranges from 4·50 to 9·86 per cent., averaging 6·42 per cent., but very little of this, probably not more than 3 per cent. is organic. The balance is combined water contained in the colloidal clay. Nitrogen is in most cases low, averaging ·070 per cent.

Occurrence of Manganese.—The manganese oxide (Mn_3O_4) not carried down with iron, was estimated in the gilgai soils and is generally speaking high. Manganese being one of the most soluble constituents of acid soils tends to accumulate in undrained depressions. In the numerous complete analyses of soils given by Hilgaard in his book on the 'Soil,' the percentage of manganese seldom exceeds ·020 in leached soils like the Hawaiian volcanic soils or those of the Californian orchard slopes; in other soils manganese ranges from ·010 to ·300 per cent. averaging ·100, the humid soils giving a slightly higher average than the arid ones. The reason for this is not clear, and the accumulation of further data may reverse the result.

Our own experience in the Department of Agriculture of New South Wales is that leached laterite soils like those of The Dorrigo, the Robertson Range and the Macpherson Range, even when derived from highly manganiferous formations, are low in manganese and high in humus. Coastal marsh soils, highly acid peat soils, are quite free from manganese. Manganese is, on the other hand, high in soil from undrained depressions having a local catchment and no outlet except in flood time.

In alkaline soils an accumulation of manganese might be expected when the alkalinity is due to carbonate of soda. This has been found to be the case, and is due to the fact that manganese enters largely into the composition of colloidal clay (see Hilgaard).

The manganese estimated during the course of my work was only a portion of the total present, for the portion which was carried down with the iron was not separated and added on. The figures given therefore only represent from one-half to at most two-thirds of the manganese present. Clearly these soils are high in manganese, a fact suggesting that they have been accumulated in an undrained basin. The salt and carbonate of soda present are evidences in the same direction. The remarkable thing is that the faintly acid gilgai soils Nos. 5 and 15 are most highly manganiferous, while the strongly alkaline soils Nos. 4 and 11 are least so. This paradox is rendered less startling when it is stated that the chemical work proved the alkalinity due mainly to carbonate of lime, the soda present being never a very excessive amount, though quite sufficient to be injurious.

It appears then that while the lime which creeps into the hummocks by capillarity is precipitated there and accumulates in them, the manganese may creep up too, but is washed back to the depressions every time a spell of wet weather brings about a decay of leaves and a restoration of surface acidity. The manganese therefore tends to accumulate in the less alkaline depressions. The accumulation of manganese in these is evidence of absence of subdrainage, for if any escape existed the manganese would be carried away in the faintly acid soil water which may accumulate here.

The capillary power of most of the gilgai soils is very poor, though the small patches of faintly acid red gilgai country may have very good capillary power. Small as the amount of sodium carbonate is in the alkaline soils it is yet sufficient to destroy their mechanical condition. The water capacity is highest in the case of the alkaline, colloidal clay soils.

V. Origin of Gilgai Country.

A number of theories have been advanced to explain the uneven nature of gilgai country. The most accredited are:

1. Collapse of substrata causing a breaking up and partial subsidence of the top soil.
2. Expansion and contraction due to alternate wetting and drying.
3. Removal of soluble soil ingredients, as for instance lime, by percolation into the underlying sandy, subartesian strata.
4. Wind action.
5. Effect of vegetation.
6. Effect of sodium carbonate in destroying soil crumbs, and causing partial collapse of the soil.
7. Mud springs.

1. The theory that the irregularites in surface are due to faulty substrata, or subsiding substrata, is widely

accepted by surveyors. Support is lent to this theory by the fact that gilgai country occurs only along the belt of heavy Tertiary and Post-Tertiary alluviation, at the western base of our western slopes. The deep detrital accumula-ions of this belt are no doubt settling down and being rendered more compact by their own weight. But a subsidence due to this cause can hardly be expected to give rise to the vermiform depressions and tortuous hummocks observed in the gilgais. The whole surface would be expected to subside at a uniform rate, and if ridges were formed at all, one would expect them to have a definite alignment and to be of a gentle nature.

It has been suggested that the depressions are due to an underlying limestone formation, which is being removed by subterranean waters and causing overlying soils to sink into the hollows so formed. This suggestion can be dismissed with the statement that borings in the district show no limestone in the substrata but only sands and clays. Nor is there a scrap of geological evidence to favour the suggestion. It has also been suggested that subterranean streams in the underlying subartesian strata might be undermining the surface soil, bringing about its collapse. No such streams have been met with, nor could such a cause produce the tortuosity of the gilgais over such a wide area.

2. Alternate expansion and contraction of clay lands from wetting and drying is known to produce an uneven surface. The inequalities produced in this way seldom exceed six or twelve inches. On p. 114, 'The Soil,' by Hilgaard, such country is described under its American name 'hogwallows.' This cause by itself could not produce the gilgais, though it might give a start to the formation of a hummocky surface which might develop into gilgai from other causes.

The coefficient of expansion of gilgai soil on wetting is certainly great as illustrated by the experiment described in Appendix I.

The crabholey and melonholey country of our tablelands and coastal regions is often formed in the same way as 'hogwallows.'

3. The removal of soluble ingredients by downward filtration cannot have produced the gilgais, for the soil is almost impervious, being exceedingly clayey, and if removal by downward percolation were the cause of gilgai formation the hollows should contain less manganese. Drained soils are usually low in manganese; gilgai soils are high in that constituent. There can be little or no downward drainage into subjacent water-bearing strata.

The gilgai holes hold water for many months after rain and appear to lose it only by evaporation.

4. Great inequalities of surface are often caused in arid regions by wind action on loose detrital deposits. One might suppose the gilgai surface to have originated in a quaternary, very arid, cycle prior to any kind of vegetation getting a hold on it, by the wind scooping out the hollows. At the present time the country is too well wooded for the wind to have any such effect.

But hummocks raised by the wind should have definite shape and alignment. The irregularity of the gilgai surface cannot be explained on this hypothesis.

5. In swampy country of our coastal districts and tablelands and in lowlying country frequently flooded, we frequently find a tussocky grass or grasstree (*Xanthorrea*) grass growing in tufts. The roots of each tuft keep on raising the spot on which the tuft grows by their decay and intervening spaces between the tussocks are lowered by nutriment being drawn away from them. The tussocks

also tend to raise the spots on which they stand by catching atmospheric dust and débris. In this way 'melonhole' country often forms in coastal districts. Its formation may be aided by the alternate expansion and contraction of the soil on wetting. Indeed coastal 'melonhole' country is usually on peaty clay soils and the knobs being more peaty than the hollows would probably expand at a more rapid rate and to a greater extent on 'wetting.'

While such causes might have helped to produce the beginnings of gilgai country in the Pilliga Scrub, they are no longer operative, for the soils are not peaty in nature, nor do the roots of the plants existing there at present act as do the tussock grasses of swamps.

The roots of belar and brigalow being mainly surface roots certainly help to maintain the hummocks intact, but I cannot believe that they have produced these irregularities. Indeed belar grows abundantly on country which is not 'gilgai,' and I believe this is the case with brigalow also.

6. Mr. J. F. Campbell, L.S., in a paper on Soil Physics read at a meeting of the Institute of Surveyors on May 18th 1909, suggested that 'melonholes' ('crabholes' or 'small gilgais') are due to the effect of sodium carbonate in destroying soil crumbs and causing the soil to subside by counteracting the cementing crumb-producing properties of carbonate of lime.

Possibly this cause may at times produce 'melonhole' country, but I cannot believe that our gilgai country could have been produced in this way. Chemical evidence is also against this theory, for in my soils the hummock soils had the highest alkalinity, whereas their alkalinity should be least under Mr. Campbell's hypothesis.

7. Mudsprings exist according to the statements of many old pioneers of the Pilliga Scrub in the country lying about

15 to 20 miles south of Brigalow Creek on the back runs of old 'Cubbo' station. These mudsprings are described as mound springs. One is described as being situated in the centre of a round clay pan. The bushmen believe that these clay pans are often formed by the subsidence of country round the vent of a mudspring. Clay pans with a saline soil, studded with extinct mounds built up by mud-springs are reported as numerous in the comparatively unknown parts southward from Brigalow Creek. It has been suggested to me by local men that the gilgais are the result of mudspring action, but while I can readily understand that round mounds and circular depressions can be formed in this way, I fail to see how the labyrinthine courses of the gilgai contours can be formed in this way.

Having now disposed of the various theories advanced by others, I desire, before advancing my own to discuss a question which bears considerably on the result. It is that of Late Tertiary Climate.

VI. Late Tertiary Climate.

In several papers[1] I have given facts in evidence of remarkable changes of climate in our western districts in Late Tertiary and Quaternary times. It is generally agreed by geologists that in the late Tertiary periods large areas of Central Australia consisted of lakes receiving sediments from the high ranges that separated these parts from the coast. Central New South Wales and Queensland constituted a depression in which extensive alluviation took place. Mammalian drift occurs in places and gives evidence in favour of a moist, if not very wet, climate. The remarkable fauna of giant marsupials which existed up to the end

[1] Prelim. Note on the Geol. History of the Warrumbungle Mountains, Proc. Linn. Soc. of N.S.W., May, 1906. Geology of the Warrumbungle Mountains, *loc. cit.*, August, 1907. Geology of the Nandwar Mountains, *loc. cit.*, 1907.

of the Tertiary period was decimated owing to the establishment of desert conditions. Drainage became disintegrated. Arid erosion succeeded normal erosion.

To the west of the Warrumbungle Mountains near Tooraweanah, at Coonamble, at Nyngan, and throughout the Pilliga Scrub I have obtained abundant evidence of a period not far removed from the present, in which drainage was completely disintegrated, and erosion was wholly of the arid type.

The late Tertiary wet period leaves its insignia in the form of old water channels bestrewn with boulders so large that the floods of present streams are unable to account for anything like them in the same districts, and in the form of huge accumulations of sand and coarse gravel underneath the varied soils of the western plains.

The dry cycle which followed levelled up the country, filling former creek beds with windblown drift, and arid erosion added to the accumulation of detritus at the base of the slopes.

The present period can only be described as subarid. There is a sufficient rainfall to permit erosion to take place and the drainage systems have become re-integrated. Additional evidence of increased rainfall is afforded by the present creeks cutting V shaped valleys along their present courses through the heavy thicknesses of Tertiary and Quaternary drift, especially along their upper courses. Along their lower courses over the plain the tendency is largely to aggrade in flood time.

In the Pilliga Scrub gilgai belt the two or three hundred feet of sand, gravel and clay under the surface soil, consist largely of detritus borne down from the Warrumbungle and and Nandewar Mountains in the wet period of the Tertiary.

During the succeeding dry climate the detrital deposits were added to and drainage became disintegrated by the silting up of the outlets of numerous swamps and marshes along the courses of stream channels. Subsequently wind-action filled in these channels. In the Pilliga Scrub the gilgai area, originally a depression, which was during the wet cycle receiving Warrumbungle detritus carried down by large rushing streams, became a sea without outlet, and later, as the streams became extinct, a series of salty marshes into which little trickles of water, highly charged with solids, came from a great abundance of mudsprings in the back country.

The dark (black and dark grey) gilgai soils were laid down at this time. Their peculiar chemical and mechanical nature shows that they are not true alluvial soils like those of the Black Soil plain. Their high lime and magnesia, without correspondingly high potash and phosphoric acid, suggest that they were derived from the evaporation of spring waters. Their salt and soda contents show accumulation in an undrained basin, and this conclusion is strengthened by the high manganese.

Mudsprings might have existed locally over the gilgai area, but probably the muds were chiefly supplied by springs some little distance away on the flanks of the Coghill hills in the centre of the Pilliga Scrub.

In these saline marshes various coarse grasses would grow in tufts and give rise to inequalities of surface, which would be increased by, (1) the greater shrinkage and cracking on drying of the intervals between the tufts than of the knolls which the roots would tend to hold together, and by (2) the chemical deposition of carbonate of lime round the grass roots and stems on every occasion that a particularly droughty spell caused the evaporation of a marsh. This kind of precipitation of lime we often see where sea-water has been carried by spring tides into the small swampy depressions behind the hurricane bank of the shore and undergoes quiet evaporation. In this way the knolls would grow in size especially as the fine matter carried down by the small streams would tend to deposit both its dissolved and suspended material chiefly on the tussocks.

One can state with absolute certainty that the gilgai soils were not deposited by normal streams from the Warrumbungles either in the late Tertiary wet period or in the present semiarid period. Both the floods of the former and of the latter are chiefly responsible for sandy material such as we see along present creek beds or in the alluvial strata underlying the gilgai at a depth of 30 to 40 feet.

While I cannot agree that the hummocky surface of gilgai country is due to subsidence of underlying strata, I am strongly inclined to think that the formation of large basins which developed into gilgai areas was partly due to subsidence of late Tertiary sands and gravels of a loose nature which have a great thickness under these areas. It is true that these depressions always occupy sites along a belt of our western slopes which is largely downfaulted, but the faulting was probably in progress in the wet cycle of our late Tertiary period and responsible for the thick accumulation of detritus deposited along this belt at that time. The amount of subsidence in the arid period was probably very slight, so slight that it can easily be accounted for by the settling down of loose sediments.

Other Evidences.

(a) *West of the Warrumbungles.*—On the plain country westward from Tooraweanah and Tundebrine, on the western side of the Warrumbungle Mountains, it is a common thing to find the present creeks separated by slight ridges, each of which is capped by an old creek bed consisting of boulders and heavy gravel. Almost invariably the highest ground is a gravel ridge marking the course of a former stream. These ridges are usually only from 10 to 15 feet higher at the most than the intermediate gullies. The present streams in this vicinity are denuding the country, otherwise they would not occupy depressions, but the water would come down in a sheet from the mountains, and the old creek gravels as well as the intervening country would be covered with a uniform level sheet of recent silt. In very recent geological times (Quaternary) there was an arid period in which the ancient creeks ceased to run, when débris accumulated in the mountain valleys of the Warrumbungles mainly through arid erosion, when the small spring fed creeks flowed only to the edge of the mountains and became absorbed in the thirsty soil while they deposited their fine silt in the form of small black soil plains. In this period the country immediately north and west of the mountains became a plain, levelled by arid agencies. When again a moister climate came, the streams, though large enough to cut down, were not large enough to remove the boulder beds of the old stream channels, hence we find present streams carving down in the old alluvial plain formed by the floods of the wet cycle leaving the old channels as intervening ridges. This I take as clear evidence of a more arid climate than the present in recent geological time.

(b) *North of the Warrumbungles.*—To the north of the Warrumbungles on the drainage areas of Cubbo Creek, Dubbo Creek, and Baradine Creek, similar facts are in evidence. Great alluviation took place in the wet cycle, the streams depositing most of their sand and gravel as soon as they reached the level country. A dry period followed in which all inequalities were levelled by wind action, the courses of old streams becoming infilled with drift sand. Many of these former courses are easily picked out by their more sandy soil and by gum and apple trees mingling with pine along them instead of the usual association of pine and box. That this arid period has come to a close is evidenced by the deep U-shaped depressions or gullies cut by the present creeks from the Warrumbungles in the deep late Tertiary alluvial. Thus at Baradine, the creek is a deep gully 40 feet below the surrounding level country. The banks of the creek rise steeply, indicating that this gully has been carved and is being enlarged by each successive flood. The same is the case with Bohena or Borah Creek and other creeks until they get 20 or 30 miles away from the mountains. Along their lower courses in the plain country these creeks still occupy depressions, more shallow courses carved by the rare and occasional big floods, and filled up again with sand by smaller floods. The smaller creeks in this plain country do not actually occupy depressions. Their beds are lower than their banks but about the same level as the country passed over. The banks are built up of sand washed down from the hills; is the product of the period of arid erosion redistributed by water in the present cycle.

This is the case in the *gilgai belt* where small creeks like Oakey Hole Creek and Brigalow Creek are entrenched between banks of their own flood products. The fact that streams carrying down sheets of sand have been able to sweep over the gilgai plain indicates a restoration of integrated drainage by the advent of moister conditions.

(c) *The Castlereagh and Coonamble Plains.*—At Coonamble and on the surrounding plains we also get abundant evidence of an arid period having existed prior to the present period. The deep alluvial soils are underlain by great thicknesses of sandy drift and clays deposited over the Coonamble district area in the wet periods of Tertiary time. The lake or swamp in which this alluviation took place dried up on the inauguration of arid conditiens, but when occasional heavy downpours occurred in the Warrumbungles water would come down in a sheet, carrying with it the fine silt now forming the Black Soil Plain. After a period of great aridity, in which wind blown detritus only accumulated, moister conditions again allowed flood waters to come down from the mountains. The larger floods carved shallow beds in the level country. These were promptly infilled with sand by smaller floods, while the finer silts settled on the flooded plains adding to the black soil deposits. The old stream beds formed in this way are known as 'monkeys.' The country being very level, the rivers would continually change their courses as it was easier for fresh floods to sweep across the black soil than to sweep over the old sand beds which were often higher than the intervening country, owing to the greater subsidence on drying of mud than of sand. The continual change of course by the Castlereagh River in the early part of the present cycle was probably aided by the fact that the drainage system had not yet become reintegrated. Occasionally the flood waters would sweep westwards from Coonamble and empty into the Macquarie marshes. At other times they would sweep north-west into marshy country near the present junction of the Castlereagh with the Barwon.

That conditions are moister now is shown by the fact that the present bed of the Castlereagh is a definite U-shaped hollow containing little or no sand.

The Gwydir and Moree Plains.—Similar observations were made on the Gwydir River near Moree.

The Bogan and Bogan Plains.—At Nyngan on a visit about two years ago, I noticed similar evidence of a recent arid period. The red soil plains on the western side of the Bogan are fine grained windblown soils derived from the Cobar massive of metamorphic rocks. The black or rather brown soils on the eastern side of the Bogan consist of a mixture of windblown detritus and silt deposited in a kind of marsh by floods from the Central Tableland in the period of increasing rainfall before integrated drainage was re-established. Evidence of a greater rainfall at the present time is afforded here by two facts, (1) a slight amount of undulation has been produced in the windblown detritus by rainwaters in the present cycle, (2) the Bogan River flows in a slight depression and reaches the Darling in flood time so that the drainage has become integrated.

Under both the red and black soils of the Bogan we get hundreds of feet (from 300 to 1500 feet) of Tertiary gravels and clays which were deposited under wet meteorological conditions, possibly in a lake. The coarseness of the sands and gravels interbedded in this series shows that big streams deposited here the material carried from the central parts of the Cobar massive. The great differences in depth to bed rock in the various bore holes around Nyngan show that the depression in which this heavy alluviation took place was probably formed by downfaulting in a period when the Cobar massive was a rugged mountain group widely different from the smooth and weatherworn aspect it presents at the present time. In fact mesas of Triassic rock occur under the Bogan silts, though to-day no Triassic (Trias Jura) rocks remain on the Cobar massive, proving that a block of country around Nyngan was depressed or downfaulted in early Tertiary period.

Two points of interest might here be briefly touched on.

Firstly—The difference in climatic conditions between the period of aridity and the present is not great, and it might be held that the restoration of integrated drainage is the effect of an uplift of the Central Plains rather than of increased rainfall. Whether this is the case or not I cannot say, but I think that recent conditions are less arid than those of the period of disintegrated drainage.

Secondly—There appears to be good reasons for believing that in quaternary times a number of semiarid periods and arid periods have alternated, just as did the glacial and inter-glacial periods of the last Ice Age. For some of the red clay bands in the upper clay bands interbedded with the late Tertiary alluvials and drifts underlying the plains might well be wind blown deposits of arid intervals between the wet periods which gave us the gravels. Again the numerous 'monkeys' of the Castlereagh and other rivers may each have had its course formed in a wet period, and might have been filled with drift sand in the succeeding dry period. This too is a plausible theory.

VII. Origin of Gilgais.

It is possible that a tussocky herbaceous growth has been aided by the contraction and expansion of clay soils with wetting and drying, and by the chemical precipitation of lime and magnesian salts on plant roots during periods of drying up in the formation of a hummocky surface over the gilgai area of the Pilliga Scrub.

The question arises, if such an origin be assumed, why did the inequalities not vanish when marshy conditions disappeared with the restoration of integrated drainage?

Not only have the hummocks remained, but they have become enlarged and the depressions have relatively deepened. There can be little doubt that the salinity of the Pilliga Scrub gilgais has been reduced by repeated floods in the recent period. There can be little doubt that the present flora of belar, brigalow and saltbush took root as soon as moister conditions commenced and that these plants have helped to preserve the hummocks and to resist their collapse.

But the vegetation could not have performed this work without the assistance of another factor which has done much to produce an accentuation of the hummocky surface.

This factor is the migration of salts and carbonates of lime and magnesia into the hummocks by capillarity. Chemical analysis shows the hummocks to contain a higher percentage of these substances than the depressions. So great has the precipitation of lime been in the hummocks, that at a depth of six inches it forms little pea-shaped nodules or concretions in the soil. Unquestionably the forces of capillarity have in the present cycle done much to enlarge the hummocks. Inequalities of surface must have pre-existed and might have been produced by one or all of the suggested causes, but the main features of gilgai country as distinct from 'melon-hole' country is the augmentation of existing inequalities of surface by capillary action.

Mudsprings.—Some mudsprings are supposed to be still active in remote portions of the Pilliga Scrub. Many extinct ones occur, as well as salt pans formed by mudsprings. These occupy a line along the border between the flat alluvial belt of the north-western plains and the outermost outcrops of Trias Jura formation. Not having seen these mudsprings it is not possible to say anything with confidence about them. Yet their presence along the border between the belt of heavy Tertiary alluviation and the Trias Jura suggests that they might have been produced by the expulsion of enclosed water from the loosely cemented Tertiary débris by the settling down of this material under its own weight. The Tertiary gravels of the Pilliga Scrub are very water bearing, though only pumping supplies are obtained in the bores.

The bearing of the here suggested origin of the mudsprings has an important bearing on the origin of artesian water. The matter is of economic interest and wants further investigation.

VIII. Summary.

In this paper I have given a description of gilgai country, some remarks on the distribution of such lands, and possible mode of origin. It is suggested that in the gilgai zone of the Pilliga Scrub this type of country was a lake without outlet at no distant geological period. In this period the rainfall of our north-western districts was exceeding low, and the gilgai lake was dry at intervals, receiving only small streams from mudsprings in the hilly country twenty miles away.

The contraction of the clay deposits on drying, the growth of tufty grasses in the salt marshes and chemical precipitation on the tussocks gave rise to a hummocky surface. When moister conditions revived the creeks from the Warrumbungle Mountains integrated drainage was restored. The inequalities of surface on the gilgai area were accentuated by capillarity when new conditions had been established.

Various facts of physiographic interest pointing to grave climatic changes in recent and late Tertiary times are recorded in this paper.

Analysis of Gilgai Soils.

Table A.—*Mechanical Analyses.*

No.	Colour.	Reaction.	Water Capacity. Per cent.	Capillarity. Inches in three hours.	Gravel Per cent.	Sand. Per cent.	Clay. Per cent.
4	black	strongly alkaline	good 49	fair 3	10·2	18·3	71·5
5	,,	faintly acid	fair 44	fair 4	7·4	10·7	81·4
6	,,	alkaline	good 47	fair 3	10·7	19·3	70·0
9	,,	alkaline	good 47	fair 4½	10·0	22·3	66·9
11	,,	strongly alkaline	high 63	poor 2	2·4	1·0	96·6
15	red	very faintly acid	low 33	excellent 10	16·4	31·7	51·9

Table B.—*Chemical Analyses.*

No.	Moisture. Per cent.	Volatile. Per cent.	Nitrogen. N. Per cent.	Lime. CaO Per cent.	Potash. K_2O Per cent.	Phosphoric Acid. P_2O_5 Per cent.	Manganese Oxide Mn_3O_4 Per cent.
4	6·52	6·67	·042	1·080	·215	·152	·085
5	6·58	9·86	·142	·446	·225	·188	·155
6	7·55	7·27	·070	·600	·335	·128	·100
9	3·50	4·50	·042	·308	·087	·049	·120
11	6·29	5·21	·014	·712	·126	·079	·062
15	1·94	5·01	·112	·260	·175	·113	·270

Table C.—*Water Soluble.*

No.	Total Solids including colloidal clay Per cent.	Salt. NaCl Per cent.	Alkalinity as Na_2CO_3 Per cent.	Total Solids without colloidal clay Per cent.	Lime CaO Per cent.	Sulphuric Acid H_2SO_4 Per cent.
4	·154	·023	·069	...	trace	absent
5	·106	012	·005	...	,,	,,
6	·100	·041	·010	...	,,	,,
9	n.d.	·006	trace	·058	,,	,,
11	·863	·058	·040	·103	,,	,,
15	...	...	...	...	,,	,,

No. 4 = Belar gilgai hummock, Yarrie Lake. No. 5 = Belar gilgai hollow, Yarrie Lake. No. 6 = Cleared belar gilgai, Yarrie Lake. No. 9 = Belar gilgai, Alexander's, Yarrie Lake. No. 11 = Brigalow gilgai, Trindall's, Brigalow Creek. No. 15 = Red gilgai belt, brigalow and wilga, Cubbo-Cuttabri track.

Appendix I.

Two open cylinders, A and B, each $1\frac{3}{4}$ inches in diameter, were closed at one end with a piece of muslin, and were filled with coarsely powdered soil to a depth of $5\frac{1}{2}$ inches and $5\frac{1}{4}$ inches respectively. In A was placed gilgai soil (No. 11), in B black soil of alluvial origin (Namoi alluvial). Each cylinder was thoroughly drenched with water until the soil in it was saturated.

The soil in A expanded to $6\frac{7}{8}$ inches and then became puddled, that in B expanded to $5\frac{7}{8}$ inches. The soil was then allowed to drain, thereafter it was dried at 100° C., removed from the cylinders, broken up to the same degree of fineness as before, and then replaced in the cylinders and measured. The soil in A had shrunk to 5 inches and that in B to $5\frac{1}{4}$ inches.

The difference in volume between the saturated soil and the same dried at 100° C. was then calculated. The result obtained gave an expansion on wetting of 37·3% for the gilgai soil and an expansion of 17·1% for normal Namoi alluvial. The expansion of gilgai soil on wetting is therefore more than twice as great as that of black alluvial soil.

SOME CURIOUS STONES USED BY THE ABORIGINES.

By R. H. MATHEWS, L.S.

[With Plate XV.]

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

IN the report of the Australasian Association for the Advancement of Science, Vol. XII, pp. 495 – 498, I described some remarkable stones, chipped and ground into shape by the aborigines, discovered over a large area of the north-western part of New South Wales, but which have not been reported from any other part of Australia. The scattered remnants of the tribes in the region indicated are all more or less civilized at the present time, and have ceased to use these stones in their ceremonies. For this reason it is especially important that all available information should be collected and published as widely as possible, in order to bring these relics under the notice of every person who may have opportunities of obtaining further particulars regarding this interesting subject.

These prepared stones vary in length from less than half a foot to more than two feet, in exceptional cases, but the more common lengths range from 9 to 15 inches. They are of different material, including sandstone, clayslate, kaolin, quartzite and such other kinds of stone as might be available. In the majority of specimens the longitudinal axis is practically straight, as in Nos. 1, 2, 8, of Fig. 1. There are others which have a crescent or horn shaped shaft, of which No. 3 is an example. The shaft is generally round in section, but examples are not infrequent where the breadth of the stone is two or three times greater than the thickness. Some are long and slender, as Nos. 2 and 8, whilst others are short and squat like Nos. 4 and 9.

They are thickest at the base and taper gradually upwards to an obtusely pointed apex. Some of them have a large

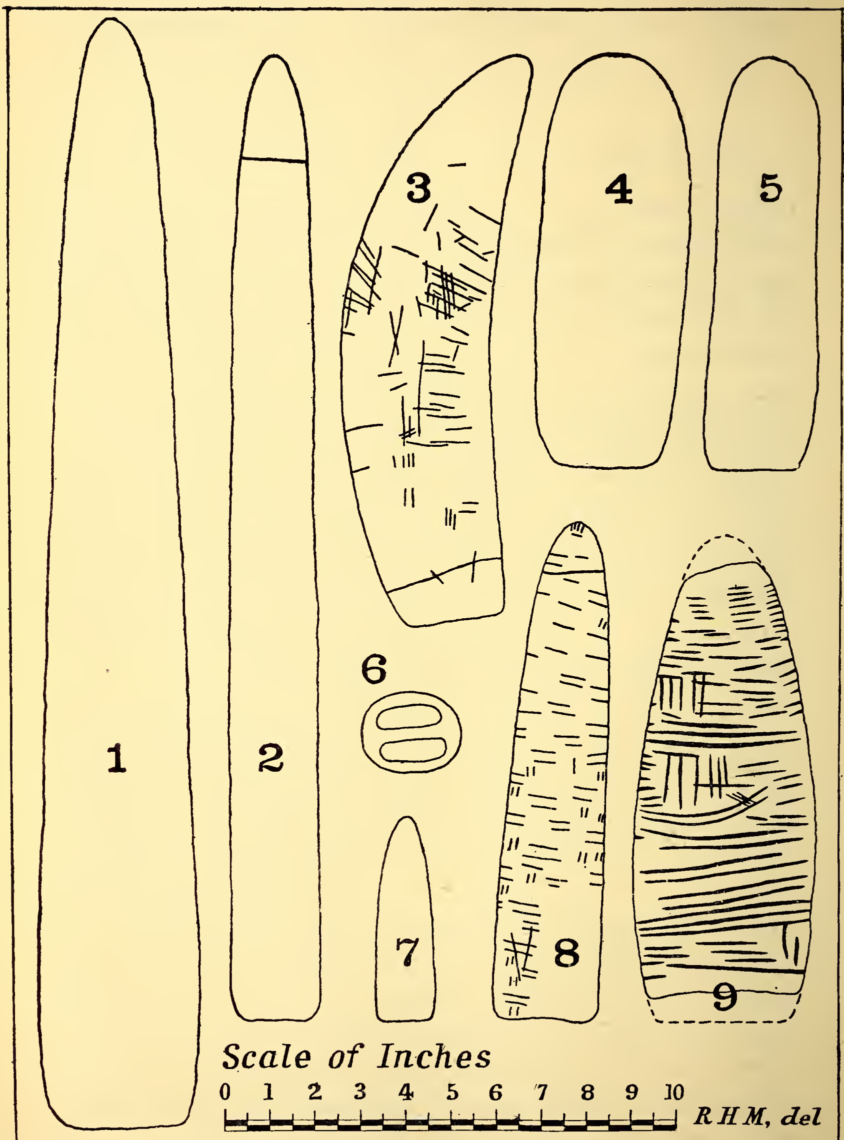

Fig. 1—*Seven Magical Stones.*

number of marks cut into the surface, apparently with a sharp stone, shell, or piece of bone, as Nos. 8 and 9; others have but a few incisions, whilst some are quite plain. A characteristic of this type of native implement consists of a depression worked into the base; in nearly all the specimens, instead of the large end being flat, the central part has been picked out and afterwards ground fairly smooth, forming a concavity resembling a shallow saucer or trough—the shape of the concavity depending upon whether the base is round, or is longer in one direction than in the other. In some specimens, instead of a single hollow, there are two trough-shaped depressions, as in No. 6, and specimens with three troughs in the base are occasionally found. In a few examples, the base is flat or nearly so, with a number of grooved lines reaching right across the diameter; or else starting at the centre and radiating in every direction to the margin. There may be only a few of these lines or there may be a score or more on the base.

It has been supposed that some of the softer specimens of these articles, kaolin for example, are not natural stones but have been artificially manufactured from burnt gypsum by the natives. Mr. R. Hall, curator of the Tasmanian Museum, speaking of a specimen in the museum, says in a letter to me:—"According to Dr. Noething here, it (the specimen) is sulphate of lime, roasted and then wetted to form the required shape. That is also my opinion." I am quite certain that none of the numerous specimens which I have met with have been made in that way, but that all of them, whether kaolin or not, are natural products cut into their present shape by human labour.

No. 1. A decomposed sandstone, 24¼ inches long, with a circumference of 11 inches round the thickest part of the shaft. There are no marks on the surface, nor has it the usual depression in the base. It was found on Murtie Run, Darling River, and weighs a little over 10 ℔s.

No. 2. A slender, cylindrical clay slate, $21\frac{1}{3}$ inches long, with a maximum circumference of $6\frac{3}{8}$ inches. At a distance of $2\frac{1}{4}$ inches from the apex, a well defined groove extends completely round the shaft. There is a slight depression in the base, and a number of marks all along the shaft, but not shown in the drawing. It was found near Wilcannia.

No. 3, a compact grained kaolin, is interesting on account of its very pronounced crescent shape, on the convex side especially. The native workman had perhaps to accommodate the design of the implement to the form of the block from which he obtained it, or the shape may have been intentional. The total length is 12 and $\frac{11}{20}$ of an inch. A section through the shaft about midway would have an elliptical shape, the longer diameter of which would be $3\frac{1}{4}$ inches and the shorter $2\frac{7}{10}$ inches. There are several marks cut into the surface, one of which, near the base, reaches quite round the stone, and there is a well defined hollow an eighth of an inch deep in the base or large end. The specimen was found on the Darling River above Wilcannia, and weighs 3 ℔s. 13 ozs.

Nos. 4, 5, 6. A quartzite pebble, 9 inches long and $3\frac{1}{4}$ broad. No. 5 is a side view showing the thickness of the stone to be $2\frac{9}{20}$ inches. The specimen is evidently just in the condition it was in when picked up by the native artist, with the exception that the basal end was first beaten flat, and then a couple of trough shaped hollows worked into it. No. 6 exhibits the outline of these hollows which lie in the direction of the longer diameter of the base. One of the hollows has been ground into a depth of a thirtieth of an inch, and the other is slightly shallower. This specimen is interesting from the fact that the only labour bestowed upon it consists of the formation of the cavities in the base. Moreover, two concavities in the base are of unusual occurrence, a single depression being the normal condition. The stone was found on Wilcannia Common, and weighs 4 lbs. 3 ozs., which is a great weight for its bulk.

No. 7, a whitish argillaceous sandstone, $4\frac{1}{2}$ inches long and 4 inches in circumference at the larger end. It is uninscribed and is without the characteristic hollow in the base. Found on Murtie Run, Darling River, and weighs 8 ounces.

No. 8 represents a conical shaft of hard clay-slate, 11 inches long by a maximum diameter of $2\frac{7}{20}$ inches. A section through the shaft at right angles to the longitudinal axis would be almost circular. An oval shaped concavity has been ground into the base to a depth of $\frac{7}{40}$ of an inch in the deepest part. The weight of the implement is 2 lbs. 7 ozs. On the side represented in the illustration there are 99 incised marks, many of which are horizontal or nearly so, and are in pairs. About an inch from the pointed end, one of the lines is cut completely round the stone. Attention is also invited to 14 pairs of short, almost vertical incisions, a form of marking which is somewhat uncommon. The regular and symmetrical outline of this specimen, as well as the extensive marking, show that considerable labour has been expended upon it. Found on Tankarooka Run.

No. 9. This profusely incised specimen is a reddish coloured rock, probably derived from basalt, rich in iron, and may be described as a sandy laterite. A small portion has been broken off the base and also off the apex, the supposed extent of the missing parts being indicated by dotted lines. The present length of the stone is $9\frac{1}{2}$ inches, but was probably about $10\frac{3}{4}$ inches originally. The circumference round the thickest part is 11 inches, and a section through the stone at that place would give an elliptical figure, with a longer diameter of 4 inches and a shorter of $2\frac{3}{4}$ inches. There are numerous horizontal lines of exceptional length, as well as some vertical and oblique ones, cut conspicuously into the surface; the total number being 111. All the markings are straight or nearly so, with the exception of two near the middle of the specimen, which have a graceful curve. Found near the southern end of Poopelloe Lake, and about 20 miles south from the Darling River, and weighs 4 lbs. 2 ozs.

The uses of the stones above described are not fully known, but sufficient evidence has been gathered by me to show that they were employed in magical incantations connected with causing the food supply to increase, making rain, injuring an enemy, and other occult functions. The object of the present article is to promote and encourage inquiry by station owners, managers, and others residing in the north-western districts of New South Wales, where there are still a few old aborigines who could perhaps increase our knowledge respecting these curious native productions.

For the purpose of enabling the reader to obtain a more realistic conception of what the stones look like, I have added a photograph of six specimens (Plate XV, Fig. 2). The crescent or horn shaped stone, No. 5 in the photograph is identical with No. 3 in the diagrammatic drawing. Another stone, No. 1, also has a crescent form outline, especially on one side. In all of the specimens the shaft is practically round and would give an almost circular section. The material in these specimens is kaolin, sandstone and clay-slate, and each of them has a shallow hollow in the base.

The six specimens in the photograph are different from those shown in the diagrammatic drawing, with the exception of No. 5 as stated above. On the floor of the photograph are six stone hatchets of different sizes, three of which have a very distinct deep groove around them, for the purpose of attaching the handle. They are not numbered.

Another photograph (Plate XV, Fig. 3), shows six magical stones, all of which are different from those described, excepting No. 3, which is the same stone depicted as No. 9 in Fig. 1. Nos. 1, 2, 3, and 4, are of the same material as No. 9 in Fig. 1. Nos. 8 and 10 are clay-slate, while the rest are grey sandstone. The three small articles on the floor of the picture are stone hatchets used by the aborigines, and are without numbers.

ON THE AUSTRALIAN MELALEUCAS AND THEIR ESSENTIAL OILS, Part IV.

By Richard T. Baker, F.L.S. and Henry G. Smith, F.C.S., Technological Museum, Sydney.

With Plates XVI – XXIV.

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

Melaleuca genistifolia, Sm.

Historical.—This species was described as far back as 1796, by Dr. Smith, in Trans. Linn. Soc., London, III, 277.

Bentham in his Flora Australiensis, Vol. III, p. 144, (1843, 1858) synonymises *M. lanceolata*, Otto. and *M. bracteata*, F.v.M. under it.

In our third paper on the Melaleucas published in this Journal, Vol. XLIV, it is shown both botanically and chemically that *M. bracteata* is quite distinct from *M. genistifolia*, and further it will be demonstrated in a later paper that *M. lanceolata* is all that is claimed for it as a species.

Remarks.—As Bentham's description, *loc. cit.*, may now be regarded as a composite one, and Smith's a little too brief perhaps to mark clearly the tree indicated, a description is added (*infra*) in order to definitely place the species, and to show upon what material the histological and chemical work is based. Smith after his short description in Latin *loc. cit.*, states *inter alia* :—"It is in some respects like *M. nodosa.*" This evidently refers to the infloresence, which in some instances is rather in a close cluster than a spike.

Mr. C. F. Laseron in his field notes states that at Gosford it is a small very crooked tree rather straggling in growth, growing in flat localities among other "tea trees." Diameter very rarely above 5 or 6″, timber reddish.

Description of Plant.—A shrub attaining 30 feet in height with a thick papery bark. Leaves ovate, blunt or obtuse, slightly concave, trinerved, shortly petiolate, about 3 lines long and 1½ lines wide. Flowers in short terminal spikes or clusters. Calyx pubescent. Fruit sessile, cup or urn shaped, constricted below the rim, which is sometimes contracted, valves not exserted.

Leaf Histology.—The leaf being slightly concave, a cross section is boomerang in shape. The structure is uniform, the two parenchymas being in equal proportion. The palisade layers are of equal thickness on both sides with rather more delicate cell walls than generally obtains in the Melaleucas examined by us. The spongy parenchyma cells are circular in cross section, through the middle of which run the vascular bundles, three in this case being most prominent, these give the trinerved feature mentioned by Smith when first describing the species.

The main bundle is normally orientated, the phloem being towards the under side. A circle of sclerenchymatous fibres more numerous on the outer sides surrounds it (and similar tissues of the other two) but occasionally a few parenchyma cells extend around it to the cuticle. The epidermal cells are small and irregularly rectangular in shape. The lysigenous oil glands are few and scattered throughout the leaf tissue. Some sections show the presence of the manganese compound in the cells.

Essential Oil.—The results obtained with the oil of this species again illustrate the fact brought forward in our last Melaleuca paper (Part III of this series), that the chemical characters of ordinary "Cajuput" oil are not representative of the group of essential oils obtainable from the Melaleucas. The constituents of the oil of each species appear to be representative and characteristic for that species wherever found growing naturally. Since our last paper we have obtained material of *M. bracteata* from Kinbombi in Queensland, hundreds of miles from the previous locality, and the oil distilled at the Museum from that material was identical in character with that described for this species (Proc. this Society, Dec. 1910).

The oil of *M. genistifolia* was distilled in Victoria in 1862 by Mr. Bosisto, but he only obtained 0·07 per cent. of oil from the leaves and branchlets, and no data are given as to the character of the oil. Our results as to yield do not agree with the above, as we obtained over half per cent. of oil from our material, which also consisted of the leaves and terminal branchlets like that which would be used commercially.

The oil of *M. genistifolia* consists very largely of dextrorotatory pinene—which has a very high rotation—and is almost devoid of cineol, less than 2 per cent. of that constituent being present in the crude oil. As the oil contains between 80 and 90 per cent. of pinene, it might have some economic value as a "turpentine" producing plant, providing the yield of oil was greater than it is.

Experimental.—The material was collected at Gosford in this State, and distilled in January, 1911. The amount of material was 214 lbs., and the oil obtained was 18 ounces, equal to 0·526 per cent. The crude oil was reddish brown in colour, due to the small quantity of iron present, but it was readily cleared to a light yellowish colour when agitated with two or three drops of phosphoric acid, well washed and dried. It had a marked turpentine odour, and cineol could hardly be detected in it.

The crude oil had the following characteristics:—

Specific gravity at 15° C. ... ... = 0·8807.
Optical rotation a_D ... ... = + 32·7°
Refractive index at 22° C. ... ... = 1·4702.
Cineol (determined by the resorcinol method in the second fraction) ... = 2 per cent.
Saponification number of ester + free acid = 6·8.
Insoluble in 10 volumes 80 per cent. alcohol.

For distillation, 100 cc. were taken. The amount of acid water and volatile aldehydes distilling below 155° C. (cor.) was very small indeed. Between 155 – 162° 79 cc. distilled; between 162 – 183° 6 cc. The thermometer then quickly rose to 250° and between that temperature and 263° 11 cc. came over. The specific gravity of the first fraction at 15° C. = 0·8661; of the second = 0·881; of the third = 0·9293. The rotation of the first fraction a_D = + 36·8°; of the second = + 19·6°. The refractive index of the first fraction at 22° C. = 1·4645; of the second = 1·4671; of the third = 1·4967.

Another distillation was undertaken with comparable results.

The first two fractions (145 cc.) were then added together and again distilled, when between 154 – 156° C. 114 cc. distilled, and between 156 – 158° 13 cc. more. The quantity of oil boiling within two degrees of temperature from

200 cc. was 114 cc., = 57 per cent. The specific gravity of the first fraction at 15° C. = 0·8638; of the second = 0·8667. The rotation of the first fraction a_D = + 39·1°, or a specific rotation $[a]_D$ = + 45·27°, of the second fraction = + 36·3°, or a specific rotation $[a]_D$ = + 41·88°. The refractive index of the first fraction at 23° C. = 1·4636; of the second fraction = 1·4638.

The nitrosochloride was readily prepared with the oil of the first fraction; it was purified by dissolving in chloroform and precipitating with methyl alcohol. It melted at 104° C. (uncorr.).

The higher boiling constituents of this oil consisted largely of the sesquiterpene, and gave the characteristic colour reactions for that substance. It also contained some ester, the saponification number being 16·7, equal to 5·8 per cent. of ester calculated as terpinyl-acetate.

Melaleuca gibbosa, Labill.

Historical.—This species was first described by Labillardière, Pl. New Holland 1799, presumably from a Tasmanian specimen, and has since been recorded from the mainland in Victoria and South Australia.

Remarks.—It stands in the happy position of having no synonyms, so that after these years its systematic status must be regarded as unchallengeable. The fruits perhaps call for a little notice, for as soon as maturity is reached they are then a little distance from each other, but gradually become immersed in woody tissue by a thickening of the rhachis. Although it appears to be a constant feature of the species, yet it may be pathological and is worthy of investigation, for perhaps here we may have a host species of either the animal or vegetable kingdom. We are indebted to Mr. E. Rodway, F.L.S., Government Botanist of Tasmania for fresh material for dissecting purposes.

Leaf Histology.—Amongst Melaleucas there are several differences which characterise the structure of the leaf texture of this species. The palisade parenchyma is not a distinct feature in a cross section, although it is more in evidence on the underside of the leaf than towards the top surface. The cells of the spongy parenchyma have circular walls in a transverse section, as against the angular shape of those of *M. leucadendron*, and this particular leaf substance is in greater proportion towards the petiole, although in other parts of the leaf it is in equal proportion to the palisade parenchyma. Near or close to the petiole, the palisade parenchyma gives place entirely to spongy parenchyma. Stomata occur mostly in the lower portion of the leaf and more especially on the inner or upper surface at that portion of the blade. Another distinguishing feature in this part is the strong development of papillose projections on the cuticle of the epidermal cells of that surface. The vascular bundles are normally orientated, the phloem facing the outer or under surface of the leaves, and are entirely surrounded by a compact or coalesced body of sclerenchymatous tissue exceeding in area that of the bundle. These were doubtfully regarded as transfusion tissue under *M. uncinata*, Part I of this series. The median bundle is finally bounded towards the cuticle by spongy mesophyll which thus makes a complete break in the continuity of the palisade parenchyma.

Essential Oil.—The oil of this species consists largely of dextro-rotatory pinene, cineol, a small quantity of ester, and a sesquiterpene. It belongs to the pinene-cineol group of Melaleuca oils, and resembles somewhat in general characters the oil of *M. nodosa*, although it is richer in cineol than the oil of that species. The yield of oil is somewhat small, so that *M. gibbosa* cannot be considered of value as an oil producing tree.

Experimental.—The material was collected at Little Swanport, on the east coast of Tasmania, and distilled in June, 1908. The leaves and terminal branchlets were alone used, and 316 lbs. of material gave 8 ounces of oil, equal to 0·158 per cent. The crude oil was of a dark lemon yellow colour, and had an odour resembling the cineol-pinene oils of the Melaleucas, as for instance that of *M. thymifolia.* The crude oil had the following characters:—

Specific gravity at 15° C. ... ... = 0·9138.
Optical rotation a_D ... ... = + 4·5°
Refractive index at 20° C. ... ... = 1·4703.
Cineol (determined by the resorcinol method) = 61·5%
Saponification number of ester + free acid = 9·9.
Insoluble in 10 vols. 70 per cent., but soluble in 1 vol. 80 per cent. alcohol.

This comparative insolubility is evidently due to the presence of the pinene and the sesquiterpene.

For distillation 100 cc. were taken. The usual small amount of acid water, and volatile aldehydes, were first obtained, and these reminded strongly of valeric aldehyde. Between 165–173° (corr.) 28 cc. distilled, and between 173–195° 52 cc. came over. The thermometer then quickly rose to 245° and between that temperature and 265° 16 cc. distilled. The specific gravity of the first fraction at 15° C. = 0·8963; of the second = 0·9045; of the third = 0·9252. The rotation of the first fraction a_D = + 6·8°, of the second = + 3·9°. The refractive index of the first fraction at 20° C. = 1·4621; of the second = 1·4630; of the third = 1·4954. The cineol in the first fraction was removed by resorcinol, the residue again rectified, and the portion distilling below 158° C. utilised for the preparation of the nitrosochloride. This substance was readily formed; it was purified by dissolving in chloroform and precipitating with methyl alcohol. It melted at 104° C. The active terpene in the oil of this species is therefore dextrorotatory pinene, and the limonenes appear to be absent.

The high boiling fraction consisted largely of the sesquiterpene, which is so pronounced a constituent in the oil of *M. pauciflora*, and the characteristic colour reactions were readily obtained with it. It also contained a fair quantity of ester, the saponification number being 20·7. The odour of the separated oil, after saponification, reminded of terpineol, and the acid was determined as acetic, so that the ester is probably terpinyl-acetate, and the fraction thus contained 7·24 per cent. of that substance.

Melaleuca pauciflora, Turcz.

Historical.—This species was described by Turczaninoff in Bull. Mosc. in 1847, and so far its systematic position or rank has not been challenged, nor has it any appendages in the form of synonyms.

Remarks.—This Melaleuca is characterised by leaf features found to occur only in one other species of the genus, viz., *M. hypericifolia*, which latter species has, however, other specific differences sufficient to warrant a systematic differentiation. The inflorescence of the two also shows marked distinctiveness. The leaves of this species have the peculiarity of incurving unless pressed as soon as gathered.

Leaf Histology.—As this plant has a convex leaf a transverse section gives a vinculum figure. The leaf is channelled above so that two convex surfaces form the upper cuticle, which is characterised below by a very much thicker development of palisade parenchyma than the upper surface, as shown in the plate. The spongy parenchyma is fairly limited in area, the cells being circular in cross section. Stomata occur on both surfaces, and are rather more numerous than obtains in other species of

Melaleuca examined, and what might be expected, more so in the channel of the midrib. Bundles occur through the median line of the spongy parenchyma, the central vascular bundle,—the midrib, of course, being the largest. It is normally orientated and entirely surrounded by a thin layer of sclerenchyma fibres. The medullary rays being well defined, the cells increasing outwards in size.

Essential Oil.—The oil of this species is another instance of the differences in the characters and constituents of those obtainable from the various species of Melaleuca, as it has little resemblance to that of ordinary "cajuput." There appears to be an entire absence of pinene in this oil, the terpene present being limonene and probably dipentene. The principal constituent is a high boiling one, and no less than 67 per cent. of the total oil came over between 260–276° (corr.). This high boiling fraction consisted principally of a sesquiterpene, and as it occurs in the oil of this species in such large quantity it should be possible to work out its chemical characteristics and combinations, and so determine whether it is new to science. It is dextro-rotatory, and the optical rotation of the purest sample so far obtained, was $a_D = +8{\cdot}5°$. Its specific gravity is somewhat high $= 0{\cdot}9364$ at 15° C., and its refractive index at 21° C. $= 1{\cdot}5004$. It boils between 260 – 270° C. It has marked colour reactions when two drops of oil are dissolved in 10 cc. solvent, and shaken with one or two drops of sulphuric acid.

(*a*) If the solvent is glacial acetic acid the colour is pink at once, soon changing to crimson, and then to purplish-brown on long standing.

(*b*) If the solvent is acetic anhydride the colour is bright green at once, soon becoming darker green, and deep blue on long standing.

(c) If the vapours of bromine are passed over a film of the oil on a watch glass, the colour is bright blue and violet at once, changing to green on standing.

(*d*) If the vapours of bromine are allowed to fall down a test tube on to a solution of two drops in glacial acetic acid, a violet colour at once forms, changing to indigo-blue on standing.

This sesquiterpene appears to be present in the high boiling portions of the oils of many species of Melaleuca, and the above colour reactions are readily obtained with them.

The amount of cineol in the crude oil is but small, it was determined by the resorcinol method in the first fraction, and calculated for the crude oil. The whole of the cineol was removed from the first fraction by the aid of 50 per cent. resorcinol, and the separated terpenes again rectified. Nothing distilled below 175° C. (corr.), so that pinene cannot be present but in traces. The greater portion of the terpenes distilled between 175 – 178° C., and gave other indications for limonene or dipentene.

The ester in this oil is probably terpinyl-acetate, as the acid was determined as acetic, and the odour of the separated oil, after saponification, reminded strongly of terpineol. Free terpineol is probably also present, as on boiling the oil with acetic anhydride and anhydrous sodium acetate in the usual way, over 5 per cent. of an alcohol was shown to be present.

The high boiling fraction when agitated with acetic anhydride did not easily dissolve, so that it was possible to remove largely the ester and the free alcohol from the sesquiterpene by the method of agitation.

Experimental.—The material was collected at Gosford, in this State, and distilled in January, 1911. 208 lbs. of material (leaves and terminal branchlets) gave 10 ounces of oil, equal to 0·3 per cent. The crude oil was of a dark amber colour, somewhat viscous and greasy in appearance —similar in this respect to the oil of *M. bracteata*—and left a permanent stain on paper. It had a somewhat pleasant odour, probably due to the terpineol present. The crude oil had the following characteristics:—

Specific gravity at 15° C. ... ... = 0·9302.
Optical rotation a_D ... ... = + 3·3°
Refractive index at 24° C. ... ... = 1·4921.
Cineol (determined by the resorcinol method) = 8·7%
Saponification number of ester + free acid = 8·25.
Scarcely soluble in 10 volumes 80 per cent. alcohol.

For distillation 100 cc. were taken. A few drops only of acid water and volatile aldehydes came over below 177°C. (corr.). Between 177 – 218° 29 cc. distilled. The thermometer then quickly rose to 260°, and between that temperature and 276° 67 cc. came over. The specific gravity of the first fraction at 15° C. = 0·8801; of the second = 0·9382. The rotation of the first fraction a_D = + 3·4°; of the second = + 7·8°. The refractive index of the first fraction at 24° C. = 1·4767; of the second = 1·4991. After the removal of the cineol in the first fraction by resorcinol, the portion of the terpenes distilling between 175 – 178° C. had specific gravity at 15° C. = 0·8572; rotation a_D = + 4·9°; refractive index at 22° C. = 1·4769. The fraction had the odour of limonene. When tested for the tetrabromide a few crystals formed, but they were difficult to separate, neither phellandrene nor sylvestene were present, and all the indications go to show that the terpene in this oil is limonene, or dipentene.

The saponification number for the ester in the large high boiling fraction was 9·2, equal to 2·16 per cent. of terpinyl-acetate in the crude oil. A portion was then esterised in the usual manner when the S.N. had risen to 36·6, representing 5·05 per cent. of free alcohol as terpineol in the crude oil. Methyl eugenol and the ester of cinnamic acid appeared to be both absent in the oil of this species.

Material of this species was also received from Port Macquarie, in this State, and distilled November 1910. In general appearance and characters it resembled the oil from the Gosford sample, and was even more viscid. The specific gravity at 15° C. = 0·9552, which is higher than that of the sample from Gosford. The refractive index at 24° C. = 1·4923. The saponification number of ester + free acid = 8·1. The rotation was not sharp, but it was between two and three degrees to the right.

Explanation of Plates.

Plate XVI.

Melaleuca genistifolia.

Figs. 1 and 2. Flowering twigs.
,, 3. Individual flower.
,, 4. Individual bundle of stamens.
,, 5. Individual leaf.
,, 6. Individual early fruit.
,, 7. Individual fruit with contracted rim.
,, 8. Cluster of fruits. 1, 2, and 3, natural size.

Plate XVII.

Fig. 1. A cross section through the centre of a complete leaf, showing the general disposition of the parenchymatous tissue, oil glands and vascular bundles. × 110

Fig. 2. A cross section through half a leaf, towards the upper portion. × 110.

Plate XVIII.

Fig. 3. A transverse section through little more than half a leaf. The midrib on the extreme right is surrounded by sclerenchymatous fibres shown black in the plate; a smaller bundle is on the extreme left towards the edge of the leaf. Other rudimentary bundles are seen in the median line but not surrounded by fibres as in the case of the other two. A few oil glands are seen. × 140.

Plate XIX.

Fig. 4. This is a higher magnification of the midrib or main bundle in Fig. 3. The dark cells are sclerenchymatous tissue, and this is now seen to much greater advantage here than in that figure. The larger crescent shaped cluster is towards the underside of the leaf, the concave face butting on to the phloem with its cell walls scarcely discernible. The xylem cells succeeding these upwards have thicker cell walls and are quite distinct. The larger cells in the outer field are those of the spongy parenchyma. × 450.

Plate XX.

Fig. 5. This is another section of a leaf cut without bleaching out the cell contents, consequently the presence of manganese compound is marked by the dark substance in the lumen of the spongy parenchyma. Three oil glands are shown. The chloroplastids are distinctly seen in each cell. × 140.

Melaleuca gibbosa.

Fig. 6. A transverse section of just a little more than half a leaf, the midrib or central vascular bundle being on the left of the picture, to the left of which is a large oil gland. × 140.

Plate XXI.

Fig. 7. A slightly larger section of a portion of a leaf between the midrib and edge, and showing chloroplastids in the cells of the palisade parenchyma. The upper surface of the leaf has the papillose projection of the cuticle. × 150.

Fig. 8. Similar to figure 7, but a large oil gland is to the right of the main bundle in this case, thus showing how irregularly the oil glands are distributed throughout the leaf. × 140.

Plate XXII.

Fig. 9. A cross section through more than half a leaf, towards the petiole. × 110.

Plate XXIII.

Fig. 10. A cross section through the centre of a leaf towards the petiole, showing how the palisade parenchyma is displaced by

the spongy parenchyma in the upper portion of the leaf over the central vascular bundle, and beyond. Only one whole oil gland comes into the field of vision. × 140.

Plate XXIV.

Fig. 11. A cross section through the central bundle of a leaf and surrounding tissue cut from the upper portion of the leaf. Here the palisade parenchyma is in its normal position, and the mass of sclerenchymatous fibres surrounding the central bundle are distinctly seen. This section also shows clearly the papillose projections of the cells of the cuticle on the ventral surface, and these are the first so far met with in Melaleucas. In a few of the spongy parenchyma cells calcium oxalate crystals can be seen. × 225.

Melaleuca pauciflora.

Fig. 12. A cross section through a two-thirds portion of a leaf. The bundle is normally orientated, the channel denoting the upper or ventral surface, towards which it will be noticed that the palisade parenchyma is more strongly developed than on the dorsal surface. The oil glands it will also be seen are not numerous. Here also as in *M. gibbosa* the spongy parenchymatous cells bound the central bundle on the dorsal side. Several bundles occur on the median plane of the leaf texture, two at the extremities of the picture being cut obliquely. Four crystal sacs occur in the palisade parenchyma of the upper surface towards the right, and in two, rhomboidal crystals are well outlined. × 110.

THE GEOLOGY OF THE ERUPTIVE AND ASSOCIATED ROCKS OF POKOLBIN, NEW SOUTH WALES.

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With Plates XXV – XXVIII.

[Read before the Royal Society of N. S. Wales, December 6, 1911.]

I. Introductory.
II. Physiography and Preliminary.
III. Faults.
IV. Geological Age of the Formations.
V. Geology—A. Carboniferous Rocks.
Drake's Hill Area.
Mount Bright Area.
Matthews' Gap Area.
B. Permo-Carboniferous Rocks.
VI. Order of Succession.
VII. Petrology.
VIII. Summary.
IX. Conclusion.

Introductory.

The district which it is proposed to deal with in this paper is situated in the County of Northumberland, about six miles from the town of Cessnock. The eruptive rocks lie in the Parishes of Rothbury, Pokolbin and Milfield, and comprise an area about six miles long by about two miles broad at the widest part, the longer axis being roughly north and south.

So far as we are aware, no detailed description of the igneous rocks of this district has hitherto been published. In Professor David's "Geology of the Hunter River Coal-field of N.S.W.," Part I,[1] there are allusions to Pokolbin, and the eruptive complex is referred to as a Carboniferous inlier. A sketch map is given, and some sections indicate suggested relationships between the rocks, which are referred mainly to Carboniferous times, with some contemporaneous lava flows in the Lower Marine of the Permo-Carboniferous. This is, to the best of our knowledge, the only place in geological literature where reference is made to the igneous rocks of Pokolbin. We propose to treat the district in some geological detail, since, though it is of no very great extent, it possesses a very interesting geological history.

For convenience of treatment and reference the district will be divided into three areas:—

(i) The Drake's Hill area, extending from a point about half a mile north of the southern boundary of the Parish of Rothbury to "Maluna" homestead.

(ii) The Matthews' Gap area, from Maluna to Matthews' Gap.

(iii) The Mount Bright area, from Matthews' Gap as far south as the "Jerusalem Rock" and Mount View School, including the northern portion of Mount Bright.

These areas are by no means to be separated geologically or petrographically, as we shall endeavour to show that the rocks of the whole district, with a few exceptions, are to be considered as forming part or all of a geological unit.

Physiography and Preliminary.

The northern portion of the district forms a chain of foothills to the Brokenback Range, whose steep scarp runs in a general E.S.E. direction as far as Matthews' Gap, where it takes a sudden turn to the east. Continuing thus

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[1] Memoirs of Geol. Surv. N.S.W., Geology No. 4, 1907.

as far as Mount Bright, it once more turns E.S.E. and follows an irregular course. The range forms part of the boundary of the old Hunter Valley, which extends for many miles to the east as a generally level plain. This range probably represents the remnant of a ge-anticline of Permo-Carboniferous rocks which had a roughly meridional axis. It is composed of Permo-Carboniferous sediments dipping to the west, capped by gently dipping Triassic sediments—the Narrabeen Series and Hawkesbury Sandstone.

At Matthews' Gap, where the range turns eastwards, the eruptive rocks are encountered, and of these the range is composed as far as the southern boundary of the district we have to deal with. Professor David considers that, subsequent to the eruption of the lavas of this district, marine conditions obtained, and the eruptive masses existed as islands or at all events as submarine elevations in the Permo-Carboniferous sea. Elevation and denudation have laid them bare again, above sea level. At present the physiography is a mixture of maturity and youth. It is evident on the one hand that a considerable amount of dissection and denudation took place before the deposition of the Permo-Carboniferous sediments, as conglomerates can often be traced filling in what were Permo-Carboniferous valleys and containing pebbles of the Carboniferous rocks. Furthermore some of the hills of to-day must be substantially as they were at the close of Carboniferous times, as we find the conglomerate dipping off their flanks with comparatively little evidence of further denudation. Drake's Hill is a case in point.

On the other hand, Post-Triassic erosion has in many places cut into the eruptive rocks, and the work of dissection is still proceeding. In the Matthews' Gap area the youthful physiography of the country is particularly evident, V-shaped valleys being formed with eruptive rocks on either side, while the steep eastern scarp of the range from Mount Bright to Mount View also betrays youthful physiographic conditions.

Two examples of imminent stream capture on a small scale are to be seen near Matthews' Gap, within a quarter of a mile of one another, where two parallel branches of Moogering Creek are eroding back towards Flying Fox Gully which is flowing at a higher level than the other creeks, in a direction perpendicular to them and with a much gentler grade. A reference to the contour map will make evident the very short distance which remains to be eroded in both cases.

Faults.

Although there is evidence of extensive and complicated faulting very little can be definitely determined with regard to it. This is due to the fact that much of the faulting occurred probably as early as Mesozoic times, so that all surface evidence has long been obliterated, and the existence and position of the faults must be inferred from geological considerations.

Professor David has determined, on stratigraphical grounds, a series of faults affecting the beds of the Permo-Carboniferous, and it is quite likely that in connection with these main movements minor faulting occurred in the eruptive rocks of the district. A very marked line of faulting is that along the eastern face of the range from Mount Bright to Mount View. In fact two almost parallel faults seem to be indicated here. The evidence is both physiographic and geological. The bold scarp of rhyolite, perpendicular in places, and towering to a height of 600 feet above the plain, is a very marked feature of the landscape, and at once suggests a very recent fault-scarp, while the fact that rhyolites and Permo-Carboniferous conglomerate are found along the top of the range on its western side,

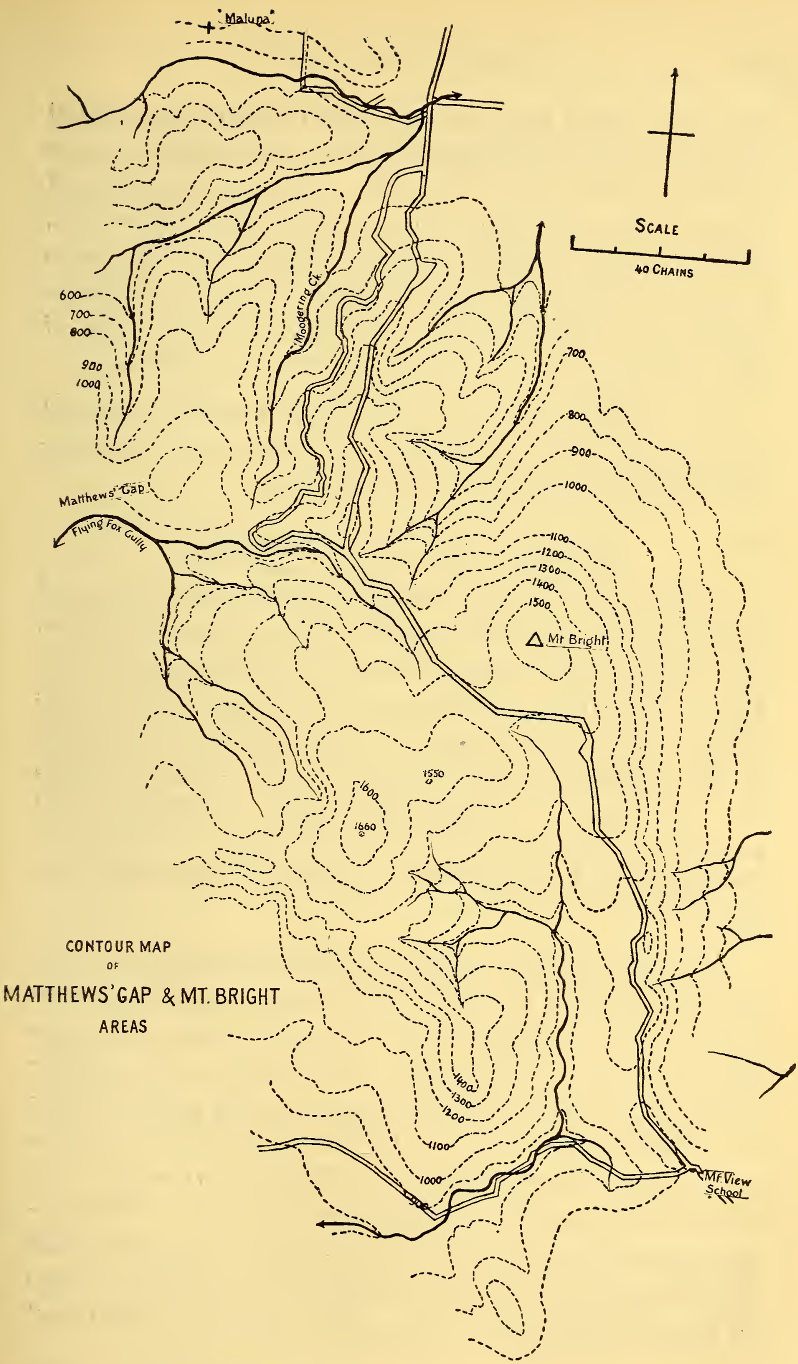


Fig. 1.—*Contour Map of Matthews' Gap and Mount Bright Areas.*

and at the plain level on the eastern side, is undoubted evidence of local vertical movement. This fault, the more easterly of the two, is the older. Two other small and doubtful faults are shown on the map, at Post Office Hill, and at the place named Jerusalem Rock. In both cases the throw is probably small and the evidence for the faulting is mainly physiographic, showing that such faults, if they really exist, are of comparatively recent origin.

Other faults, postulated on geological grounds and noted on the map, will be referred to as they occur, in dealing with the general geology of the district.

Geological Age of the Formations.

In this district there are representatives of two, and possibly three, geological periods. The principal and most interesting series, comprising acid, intermediate and basic lavas, is of Carboniferous age: in the Lower Marine of the Permo-Carboniferous, basic lavas and tuffs are developed: while underlying the Carboniferous lavas of Mount Bright is a long narrow outcrop of grano-diorite which is either Lower Carboniferous or Pre-Carboniferous. It is with the Carboniferous lavas that we are chiefly concerned in this paper.

Round the gently sloping elevations comprised in the Drake's Hill area the basal conglomerates and sandstones of the Lower Marine can be traced in such a way as to leave no doubt that they actually surround it. They appear dipping at a low angle off the igneous rocks, so that it may be concluded that Drake's Hill was an isolated elevation on the floor of the Permo-Carboniferous sea, against the sides of which these sediments were deposited. This conglomerate contains pebbles of the rocks of which the inlier itself is composed, so that the eruptives are anterior in age to the Permo-Carboniferous. The age of the Matthews'

Gap rocks has been determined on similar evidence, and by the fact that a tuff bed has been found containing Carboniferous fossils.

A very definite and persistent horizon of Lower Marine conglomerate can be traced in many places from "Maluna" homestead as far as Mount View; this forms a very convenient datum bed, as it immediately overlies the Carboniferous rocks. The conglomerate is unfossiliferous and, apart from local inclusions of the underlying rocks, is characterised by very much rounded pebbles of quartz-porphyry and quartzites from some unknown locality. The conglomerate can be traced on both the eastern and western sides of the Mount Bright area. At one point on the western side, about one and a-half miles north of Mount View School, a beautiful section shows the sequence from the Carboniferous rhyolite through Carboniferous conglomerate, shales and grits to Permo-Carboniferous conglomerate and sandstone. At this point the latter are at least 200 feet thick, the unconformity between them and the Carboniferous being very slight.

That the Mount Bright grano-diorite is considerably older than the Carboniferous rhyolites has been definitely proved by the finding of pebbles of grano-diorite in the rhyolite and tuffs at different points along the junction of the two rocks. Since considerable denudation must have been necessary to lay bare the plutonic rock before the rhyolite flowed over it, the grano-diorite must be referred to the Lower Carboniferous or some anterior period.

Geology of the Three Areas.

A—Carboniferous Rocks.

The Drake's Hill Area.—The rocks consist mainly of rhyolite, rhyolite breccias and tuff, trachyte, and a number of isolated patches of andesite. The rhyolitic rocks are mostly on and around the Post Office Hill, and have undergone very violent and extensive contortion, apparently when in a plastic condition and also subsequent to consolidation. The rhyolite is as a rule strongly banded, and the even course of the banding is often broken by folds varying from a fraction of an inch to several feet across. Persistent tilting of the rock mass is observed, the flows dipping at various angles in an average direction of about N. 10° E. The beds are cut off abruptly by the small submeridional fault already referred to, which also at its southern end throws down the trachyte against the rhyolite.

The rhyolite is mainly of the glassy type, no porphyritic quartz crystals being seen as is the case with the Mount Bright rock. What appears to be secondary material of a jasperoid nature, dark brown to black in colour, is of frequent occurrence. There is evidence of several successive flows in this area, the earlier of which were brecciated by the later eruptions. Fine rhyolite tuff also occurs in considerable abundance, and a hard green tuff which is sparingly found seems to be a modification of the rhyolite tuffs. Trachyte overlies and partly surrounds the rhyolite. It is in places of a tuffaceous nature, and is of the leucocratic or acid type, light brown in colour. The andesite probably represents the remnants of former flows on top of the trachyte or intrusive into it.

An outcrop of chocolate shales and dark coloured conglomerate is exposed in the bed of a creek on the Rothbury Road, not far from the Post Office. These are entirely different in appearance and constitution from the known Permo-Carboniferous rocks, for which reason they have been put down as Carboniferous and correlated with similar occurrences in the other areas.

Monnt Bright Area.—Here a very much older formation is met with in the shape of grano-diorite; as its age may be Carboniferous, it may be conveniently be treated here. It outcrops in a long narrow band along the eastern face of the range between Mount Bright and Mount View. The typical rock is medium-grained, with a slight preponderance of light over dark coloured minerals. At the northern limit of the occurrence two extremely well marked types of local differentiation products occur, the first being a basic modification, much darker in appearance than the general type. From examination of hand-specimens the ferro-magnesian constituents hornblende and biotite are seen to predominate, forming about 80 per cent. of the rock, while the remainder consists of plagioclase, pink orthoclase and a little quartz. A short distance away a further modification appears in the shape of a pink aplite, consisting of porphyritic laths of plagioclase, showing albite and carlsbad twinning, in a fine-grained base of quartz and felspar with subordinate biotite. Pyrites in very small crystals is abundantly distributed. The aplite in places also contains irregular small patches of tourmaline, and large segregations of the same mineral showing fibrous radial structure also occur, probably as a result of pneumatolytic action. The final phase of differentiation of the grano-diorite magma is represented by a pegmatite. This rock is extremely coarse in texture and consists of an intimate intergrowth of allotriomorphic to subidiomorphic quartz and pink felspar. At this northern end the grano-diorite is cupriferous, the copper minerals being in close association with the pegmatite. Azurite, malachite, peacock ore, pyrites, etc., have been obtained near the upper boundary of the grano-diorite, but the workings are now abandoned. Attempts to find copper near the Mount View end of the outcrop have proved unsuccessful.

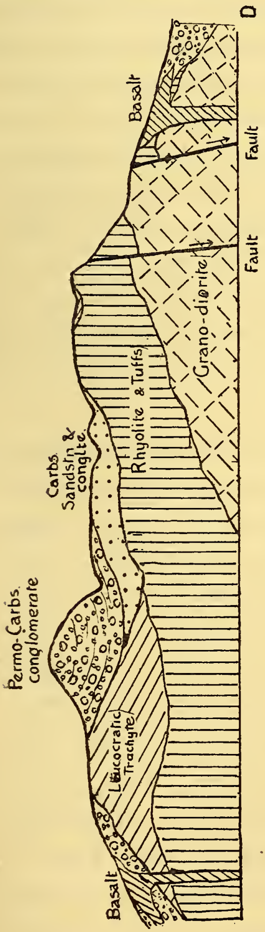
Rhyolite and rhyolite tuffs are the earliest of the Upper Carboniferous volcanic series, and form the greatest part of the rocks of this area. The rhyolite here does not appear to have suffered so severely from earth movements as that of Drake's Hill, and in appearance differs from it in many respects. Typically the Mount Bright rock is whitish to dark red in colour, sometimes, but not invariably, strongly banded and containing small idiomorphic quartz and felspar crystals sparsely distributed. Secondary chalcedony is found, opaque yellowish to red in colour.

On the edges of the area a coarse agglomerate is developed, containing boulders of banded rhyolite up to about a foot in diameter. This may have been produced towards the close of the rhyolite eruptions or may represent the result of the first explosive outbursts of trachytic lava. Overlying the rhyolite, and filling in eroded hollows in it, are flows of trachyte of considerable extent, generally yellowish-brown in colour and containing small laths of felspar in an aphanitic base. The relations of this trachyte to the rhyolite are very definite.

Only three very small occurrences of basic rocks have been observed among the Carboniferous eruptives, in the shape of what appear to be small necks of basalt and dolerite. The mineralogical and structural points of similarity connecting these occurrences suggest that they should be correlated, but as the occurrences are isolated from other basic rocks their precise geological age is difficult to determine; all that can be said is that they are post-trachyte.

Resting directly upon the acid lavas and underneath the Permo-Carboniferous conglomerate is a Carboniferous sedimentary series, consisting of conglomerates, fine grained friable chocolate shales and tuffaceous sandstones: some or all of the members of this series can be traced at many points around the area, and up into the Matthews' Gap area. They are well seen on the road about half a mile

N.W. of Mount View School, where the whole sequence from the rhyolite to Lower Marine conglomerates can be traced, the Carboniferous sediments dipping at about 12° off the rhyolite and attaining a thickness of 400 feet. On the western side the formation appears as tuffaceous sandstones, in close association with rhyolite agglomerate, and containing obscure plant remains. On the eastern side the greater part of the sediments has been faulted out of sight, save in a few places where small outcrops of chocolate shales are seen.



Section 1

The exposure of the grano-diorite in this area is probably the effect of the older Mount Bright fault. A glance at the maps and at Section 1 will serve to explain how the faulting has brought down the rhyolite to a much lower level and thrown it against the grano-diorite, at the same time exposing the latter.

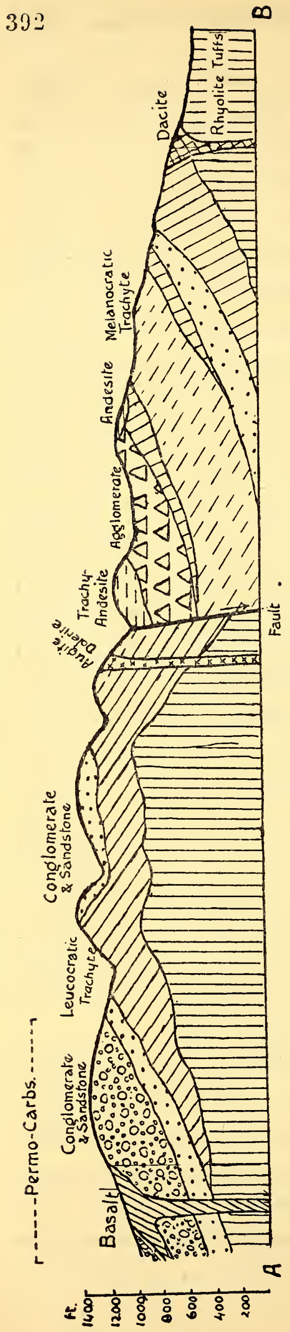
Matthews' Gap Area.—While this area is continuous with the others in respect of the more acid lavas, the occurrence of more basic rocks is better marked as regards both extent and variety. The rhyolite tuffs appear as isolated outcrops mostly confined to the northern end, but nearer Matthews' Gap itself the rhyolites are completely hidden under trachytes, basalt, agglomerate, trachy-andesite, and dacite, with patches of Permo-Carboniferous quartz-porphyry conglomerate dipping off the eruptives or filling in old valleys. The tuffs or breccias are of a somewhat different variety from those occurring at Drake's Hill and Mount Bright. They are medium in texture, the fragments being up to about two inches long, and ranging down to microscopic dimensions. The inclusions comprise fragments of cherty rock, rhyolite of various colours, trachyte of a kind not met with in the flows of the district and therefore probably of much earlier date, and fine-grained green siliceous-looking rock probably closely related to the green tuff of Drake's Hill and to another tuff found elsewhere in the Matthews' Gap area. The latter seems to be a variety of the rhyolite tuff. It is extremely fine-grained, of a blue-green colour, hard and compact. Its chief difference from the Drake's Hill green tuff consists in the presence of abundant felspars, largely idiomorphic, but often with the appearance of angular fragments, suggesting that they are of extraneous origin—not crystallised in the tuff.

Some other very fine grained tuffs are found occurring on top of the coarser rhyolite tuffs, in particular that already referred to as containing the Carboniferous plant fossils *Rhacopteris* and *Cardiopteris*, also an extremely fine-grained greenish-white cherty tuff which is to be found on the N.W. end of Mount Bright. Both of these are stratified, and the Rhacopteris tuff is in places fractured and shattered; the pieces having slipped on each other, excellent miniature examples of different kinds of faulting have been produced.

Trachyte is very abundant, and has followed directly on the rhyolite and tuffs. It may be divided into two varieties, leucocratic and melanocratic, this division being based on a microscopic comparison of the two types. It is more fully discussed below. The leucocratic trachyte is of a brownish colour, similar to that in other parts of the district, with small phenocrysts of felspar showing macroscopically. The melanocratic variety is much finer and more even grained, and is of a bluish colour, having the general appearance of a rather light-coloured basalt. The leucocratic type has the wider distribution, and is the older of the two types: on top of it the Carboniferous sedimentary rocks, represented by sandstones and conglomerates, have been deposited. On top of the conglomerate are further flows of trachyte, both the leucocratic and melanocratic varieties, accompanied by dykes and sills in the conglomerate. More basic rocks succeed, the most extensive and important being a coarse agglomerate associated with basic looking tuffs, which are capped by trachy-andesite and andesite. The blocks in the agglomerate are often rounded, giving the appearance of a coarse conglomerate; they include rocks of a felsitic nature, with pebbles of a green tuffaceous-looking rock, and the cementing material is of a dark basic appearance, but of undetermined composition. The whole of this series is well exhibited on the long ridge along which run the old and new roads to Matthews' Gap.

Probably connected with the same outbursts is the intermediate glassy rock or pitchstone, of which a couple of isolated outcrops are found and of which an analysis is given below, and the andesite in the N.W. portion of the area. The most basic portions of the Matthews' Gap area series are a flow of basalt and associated tuffs.

The last phase of the volcanic activity of Carboniferous age is represented by a flow of dacite, which partially conceals the outcrop of many of the earlier rocks, and which is immediately under the Permo-Carboniferous conglomerate in some places. Dykes of leucocratic trachyte in the agglomerate and trachy-andesite may belong to the same phase.



Section 2

The western extension of the agglomerate outcrop is cut off under this dacite, but on the eastern side it abruptly joins the Mount Bright trachyte, and is seen no further south. A similar sharp boundary exists for the trachy-andesite and Mount Bright trachyte, and these circumstances indicate a faulted junction. (Vide Section 2.)

Another small fault is probably to be placed to the east of the old road, letting down the Carboniferous conglomerate and trachyte a vertical distance of about a hundred feet. No great extension of this fault can be traced, whence it may be argued that it antedated the agglomerate and consequently the dacite. A line of fracturing and crushing is developed in the dacite, whereby a typical crush-breccia has been produced. Every phase can be traced, from the unjointed rock, through a highly jointed zone to a zone of intense fracture and lateral movement. This is however, merely a local phenomenon.

A fault on the extreme west of the area which has brought the Upper Marine sandstones into juxtaposition with the Carboniferous formations is probably part of the Elderslee fault of Professor David which has caused the burying of the Greta coal measures to a considerable depth.

B. Permo-Carboniferous Rocks.

These have not been studied in detail, but their relationships have been noted where they are contiguous with the Carboniferous rocks. The most notable among the sedimentary series is the quartz-porphyry conglomerate, which in this district appears to form the lowest of the Permo-Carboniferous strata. It has been suggested, however, that any possible lower beds have been concealed through overlapping. The conglomerate sometimes disappears and then the eruptives are immediately overlain by the Lower Marine sandstones.

The igneous rocks are confined to basalt and tuffs contemporaneous in the Lower Marine. The position of these is indicated in the geological map, and it will be observed that in the southern portion of the district they exist as a marginal belt to the Carboniferous rocks. They occur some distance up in the Lower Marine, intrusive through the basal conglomerate and some of the overlying sandstone. Their contemporaneity is proved by the presence of *Stenopora* and *Fenestella* found by Professor David in the associated tuffs on the western side of the Mount Bright area.

A considerable extent of the basalt on this western side is amygdaloidal, the steam holes being filled with zeolites, chiefly radiating aggregates of natrolite, often in fairly large masses, with associated minor development of pinkish datolite and analcite. It is a remarkable circumstance that similar occurrences are not met with in the basalt on the south and east of the area.

The country between the Drake's Hill volcanics and "Maluna" is composed principally of Lower Marine sediments—conglomerate, sandstone and foraminiferal limestone. A belt of basaltic or andesitic lava can be imperfectly traced by means of the resulting soil and by a few obscure and decomposed outcrops, but this has not been accurately mapped, as the boundaries are impossible of delimitation.

North of the Drake's Hill area, in the Parish of Rothbury, is a small low conical hill composed of basalt, with a few short dykes radiating from it. The relations of this outcrop are much obscured by recent alluvium, but it is in all probability contemporaneous in the Lower Marine. It is surrounded by Lower Marine sandstones which a short distance away are distinctly dipping towards the outcrop.

Order of Succession of the Lavas.

As a result of our investigations we are inclined to advance the following order of succession for the rocks of the district :—

Carboniferous :

i. Rhyolite and rhyolite tuffs.
ii. Trachyte, beginning with leucocratic, and followed by melanocratic.
iii. Agglomerate, trachy-andesite and andesite.
iv. Dolerite and olivine basalt necks, and basalt flows.
v. Dacite and (?) dykes of trachyte.

Permo-Carboniferous :

vi. Basalt.

The positions of the rocks under iv, and of the trachyte dykes are of course not certain, but there is little doubt that the general character of the succession is correct. There seem to have been several eruptions of rhyolite, both as quiet flows and as explosive outbursts. The trachyte followed on the rhyolite apparently without any considerable interval. Succeeding the trachyte was a period of quiescence in the vulcanicity and of gradual subsidence, during which the Carboniferous conglomerates, shales and sandstones were laid down, before volcanic action recommenced. The longest period of volcanic inactivity was probably that between the dacite and the Lower Marine basalt. During this interval the Permo-Carboniferous sedimentation began and advanced to a considerable degree.

Petrology.

The rocks found in the district include, as has been already shown, a wide range of types. They may be divided up as follows:—

A. Plutonic,

B. Hypabyssal, and

C. Volcanic (i) acid
(ii) intermediate, and
(iii) basic.

The only plutonic representative is the grano-diorite mass exposed along the eastern face of Mount Bright. Hypabyssal rocks are represented by the dolerite at Matthews' Gap which occurs as a (?) volcanic neck, and the small neck of ophitic dolerite in the Mount Bright area. The acid volcanics include the rhyolites and the dacite, both occurring as flows, and probably the leucocratic trachytes can be classed with these. The intermediate volcanics include the melanocratic trachyte (which in hand-specimens resembles very closely a light coloured-basalt), trachy-andesite, andesite and pitchstone. Among the basic rocks there are olivine basalt, and basalt.

One of the most noticeable features of the volcanic series is the extremely limited development of ferro-magnesian constituents. This is very marked in the trachytes and andesites, which are almost devoid of such minerals. In some cases, however, a good deal of alteration has taken place, and it is possible that a good deal of the ferro-magnesian mineral has been replaced by secondary material. The norms of the two analyses of quite fresh rocks (andesite and pitchstone) calculated according to the American classification, show respectively 16·78 and 11·80 per cent. of pyroxene; from this it seems probable that there is a good deal of ferro-magnesian constituent present in the base though it cannot readily be distinguished under the microscope.

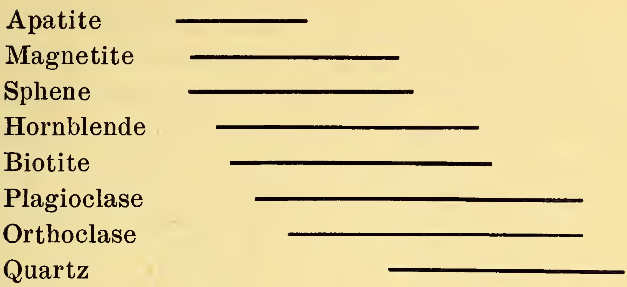
A. *Plutonic.*

Grano-diorite.

Coarse-grained phanerocrystalline rock, consisting of quartz, felspar, hornblende and biotite as far as can be seen in hand specimen. Quartz and felspar form more than half the rock. Under the microscope the rock is holo-crystalline. Its grainsize is even and coarse, and the grains have an average diameter of about 2 mm. The fabric is hypidiomorphic granular.

The minerals present are:—Plagioclase, orthoclase, quartz, biotite, hornblende, magnetite, apatite and sphene.

Plagioclase is the most abundant mineral; it is subidio-morphic and is twinned after the albite law. It is a good deal decomposed. The orthoclase is not so abundant but is present in fair quantity. Both the felspars are crowded with inclusions of tiny fragments of biotite, hornblende and magnetite. Quartz is present but not abundantly. The biotite is slightly decomposing to chlorite in places, and has a rather fibrous appearance. The hornblende is the green variety and is decomposing to chlorite. Apatite and magnetite are fairly abundant and sphene is sparingly present. The order of consolidation is:—



B. *Hypabyssal.*

Dolerite, Matthews' Gap.

A greenish coloured greasy-looking rock; phanerocrystalline and fine-grained. Felspar and a dark ferro-magnesian mineral can be seen in hand specimen. Porphyritic crystals of pyroxene showing hour-glass structure are also visible. Under the microscope it is holocrystalline with a few porphyritic crystals. The base has medium grainsize. The fabric is hypidiomorphic granular.

The minerals present are:—Plagioclase, augite, magnetite, chlorite and calcite.

The plagioclase is in tabular idiomorphic crystals, zoned and twinned after the albite, carlsbad and pericline laws. It is partly decomposed to kaolin, the decomposition often being zonal. A symmetrical section showing both albite and carlsbad twinning gives two symmetrical extinctions viz.:—$24\frac{1}{2}°$ and $37\frac{1}{2}°$, indicating that it is labradorite with composition Ab_2An_3. Augite is in large subidiomorphic crystals with zonally arranged inclusions. A good deal of chloritic material is present as decomposition product, probably from biotite. Magnetite is present in idiomorphic crystals. A little secondary calcite is also present.

C. *Volcanic*, (i.) acid.

Rhyolite.

The rhyolite varies a good deal from place to place. Typically in hand specimen it is light in colour, with small phenocrysts of clear glassy quartz and pink felspar in an aphanitic groundmass. Flow-structure is well developed in places, but is more often absent. Cavities in the rock are of frequent occurrence and are almost always filled with secondary material—this is generally chalcedony, agate or some other form of secondary silica. Such secondary material is plentiful in the Mount Bright area, but is of less frequent occurrence at Drake's Hill. At Drake's Hill, however, the rhyolite has been brecciated and very numerous cracks, transverse to the lines of flow as well as parallel to it, have been filled with a deposit of black jasperoid material.

Under the microscope it is markedly banded, and has a cryptocrystalline to microcrystalline base with few phenocrysts. The phenocrysts are felspar and quartz; the felspar is idiomorphic and somewhat decomposed. Drusy cavities are present and are generally filled with fine quartz grains and in places microscopic quartz crystals can be seen projecting from the sides of the cavities. Minute cracks transverse to the direction of the banding are filled with quartz. At Drake's Hill there is a good example of brecciation of the rhyolite. The rock has been much crushed and crumpled; the original banding of the rhyolite is generally still visible, but the cracks have become filled with dark coloured secondary jasperoid material.

An analysis of rhyolite from half a mile south of Mount Bright by Mr. J. C. H. Mingaye,[1] is as follows:—

SiO_2	77·82	H_2O +	1·40
TiO_2	0·02	H_2O −	0·36
Al_2O_3	11·46	CO_2	0·03
Fe_2O_3	0·30	P_2O_5	0·04
FeO	0·09	SO_3	0·07
MnO	(< 0·01)	BaO	0·02
MgO	0·23	Li_2O	trace
CaO	0·22		
K_2O	7·19		100·11
Na_2O	0·86		
		Sp. gr.	2·596

[1] Kindly furnished by the Department of Mines.

Rhyolite Tuffs.

These occur abundantly throughout the whole district. They are generally light in colour and are very solid. Their texture varies from very fine to very coarse. In the coarser ones angular fragments varying from half an inch to several inches in diameter are cemented together by extremely fine grained siliceous material; the very fine ones on the other hand are composed completely of crypto-crystalline to microcrystalline siliceous material, with a small amount of felspathic material and glass. The base in places shows obscure traces of lamination and contains fragments of felspar crystals and quartz. Occasionally large quartz grains are corroded and much granulated.

Dacite, Matthews' Gap Road.

These rocks vary in colour from a light brown to dark reddish-brown. The lighter coloured varieties appear to be slightly more acid than the darker ones. They are porphyritic in texture with aphanitic ground mass. The phenocrysts in the lighter coloured ones are chiefly quartz and felspar; biotite is only sparingly present. In the darker ones quartz and felspar are abundant, as is also biotite, the latter being well developed in hexagonal plates. In places they are somewhat tuffaceous.

Under the microscope they are all hypocrystalline, with porphyritic texture. The phenocrysts vary in size from medium to large. The base is generally made up of brown glass, but occasionally it is partly cryptocrystalline; the fabric of the ground mass is fluidal. Plagioclase and quartz form the bulk of the phenocrysts; plagioclase is the more abundant of the two. The quartz is in corroded subidiomorphic to idiomorphic grains. It contains inclusions of the ground mass and shows very little evidence of strain. Plagioclase is abundant, but rather decomposed.

It shows albite twinning and sections in zone perpendicular to (010) give symmetrical extinctions up to 21° showing that it is a labradorite of composition about Ab_4An_3. It shows a variety of decomposition products—some of it is decomposed to kaolin, some shows a development of sericitic aggregates along twinning planes, and still other pieces are almost completely pseudomorphed by calcite; in the latter case there is considerable development of hematite along the cleavage and twinning planes. Biotite is present as small long ragged flakes, some of which are considerably bent. Magnetite and apatite are also present and there is a small amount of chlorite.

Dacite (dyke rock) New Matthews' Gap Road.

This is a dyke related to the dacite. It is porphyritic with a glassy base and showing well marked flow-structure. The phenocrysts are generally coarse, with an average diameter of 2 to 3 mm. They consist chiefly of quartz and felspar. The quartz is in some cases beautifully corroded and contains inclusions of the ground mass. The felspars are much decomposed and there is a heavy deposit of hematite along the cleavage and twinning planes. Flakes of biotite are present and also ilmenite.

Trachyte, Drake's Hill.

This is a brown, fine-grained rock. It is slightly drusy and secondary minerals are developed in the druses. Crystals of a pinkish-coloured felspar can be recognised in hand specimen. Under the microscope it is hypocrystalline and porphyritic. The phenocrysts' average size is medium. There are two generations of felspar. Those of the larger generation are medium-sized subidiomorphic crystals. They consist of both orthoclase and plagioclase, the former being the more abundant. The plagioclase is twinned after the albite law. The smaller ones consist of very fine needles scattered throughout the base. The larger ones are considerably dusted with kaolin. Patches of the rock are stained with iron oxide. Magnetite is the only other mineral visible.

Trachyte, top of Matthews' Gap Road.

Light brown coloured, vesicular rock. The steam holes are flattened and have their longer axes all lying in one direction. Pink crystals of felspar can be seen in hand specimen, making the rock slightly porphyritic. The base is fine-grained, aphanitic. Under the microscope the rock is hemicrystalline, hypocrystalline, slightly porphyritic and with a slightly fluidal fabric. The minerals are:—Orthoclase, plagioclase, quartz, and magnetite, and a small amount of glass is present. The orthoclase is most abundant and is also considerably decomposed. There is a second generation of felspar in the form of minute microlites in the base. Quartz is present in somewhat rounded grains. Magnetite is not abundant. The base consists mostly of a brownish-coloured glass.

C. *Volcanic*, (ii) intermediate.

Melanocratic trachyte, New Matthews' Gap Road.

Bluish-black in colour and very solid. Fracture subconchoidal; fine-grained, aphanitic. Very small felspars can be recognised in hand specimen, and the rock resembles a light-coloured basalt. Under the microscope it is hypocrystalline; the fabric is trachytic and somewhat fluidal. Both orthoclase and plagioclase are present, the former being the more abundant. It is in rather decomposed tabular crystals. The plagioclase is an acid labradorite. There are two generations of the felspar, the larger ones averaging about ·75 by ·25 mm., and the smaller ones are only fine needles. Magnetite is abundant in small grains. There is a very dark mineral present in small grains which are slightly pleochroic but too small to be accurately determined—they are probably pyroxenes. The base forms about 20 per cent. of the rock and contains a moderate proportion of light-coloured glass.

Trachy-andesite, Matthews' Gap Road.

Fine-grained rock, appearing rather tuffaceous in parts. A pink secondary mineral is present. Under the microscope it is hypocrystalline and slightly porphyritic; the fabric is trachytic. The phenocrysts are of felspar and magnetite; the felspar is in idiomorphic tabular crystals, somewhat decomposed, and is mostly orthoclase. The base is composed of minute felspar microlites and numerous small magnetite grains. There are a few grains of pale green mineral with low D.R., probably chlorite.

Andesite, Old Road.

Dark blue rock, slightly porphyritic with fine-grained base. Very hard and fresh and weathers into spheroidal lumps. Minerals visible in hand specimen are lath-shaped glassy felspars and a small amount of dark ferro-magnesian mineral. Under the microscope the texture is porphyritic. The phenocrysts average about 1 by 1·5 mm., the base is hypocrystalline. Plagioclase constitutes the great majority of the phenocrysts and a section parallel to (010) gives an extinction of -20° measured from the cleavage parallel to (001) and the plagioclase is therefore labradorite (Ab_3An_4). There are a few large grains of magnetite. The base is made up of small lath-shaped felspars, very numerous grains of magetite, minute apatite prisms, small dark grains, almost opaque, too small to identify but probably pyroxene, and a fair amount of light coloured-glass. This has been analysed, with the following result :—

	Per cent.	Molec. propor.		Per cent.	
SiO_2	55·20	920	Quartz ...	4·98	$\frac{Sal}{Fem} = \frac{81·46}{18·16} < \frac{7}{1} > \frac{5}{3}$
TiO_2	1·17	15	Orthoclase ...	5·56	Class ii (Dosalane)
Al_2O_3	20·14	197	Albite ...	40·34	$\frac{Q}{F} = \frac{4·98}{76·48} < \frac{1}{7}$
Fe_2O_3	3·55	22	Anorthite ...	30·58	Order 5 (Germanare)
FeO	3·46	48	Diopside ...	9·27	$\frac{K_2O + Na_2O}{CaO} = \frac{87}{164} < \frac{3}{5} > \frac{1}{7}$
MnO	0·09	2	Wollastonite	1·51	Rang 4 (Hessase)
MgO	1·10	28	Magnetite ...	5·10	$\frac{K_2O}{Na_2O} = \frac{10}{77} < \frac{1}{7}$
CaO	9·17	164	Ilmenite ...	2·28	Subrang 4
K_2O	0·96	10	Water ...	1·36	
Na_2O	4·80	77		100·98	
H_2O +	1·25				
H_2O −	0·10				
CO_2	absent				
P_2O_5	trace				
	100·99				

Andesite, Drake's Hill.

Dark-coloured fine-grained rock. Well-developed flow-structure shown by the parallel orientation of slightly porphyritic felspar crystals. Very small amount of ferro-magnesian mineral visible in hand specimen. Considerable amount of variation from place to place, the chief points of variation being the size of the felspars, the amount of ferro-magnesian constituent and the degree of development of flow-structure.

Under the microscope it is hypocrystalline and porphyritic. The base is mostly glassy. Felspar is present in two generations; the larger are idiomorphic and twinned after the albite law; a number of symmetrical sections gave a maximum extinction angle of 26° so the felspar is labradorite (Ab_1An_1). The smaller ones are fine needles and they accentuate the flow-structure. There is a good deal of magnetite present. Very little ferro-magnesian mineral is present, but a certain amount of pale green chlorite is developed, and this seems to be probably from the alteration of ferro-magnesian minerals. In one example there is a small amount of decomposed biotite present.

Pitchstone, Portion 42, Parish Pokolbin.

In hand specimen a black vitreous rock, almost completely glassy, a few small crystals of felspar being visible.

Under the microscope the rock is hypohyaline; the base is mostly of glassy material and contains a large number of extremely small felspar microlites. The glassy material is dark in colour, probably on account of the fairly large amount of magnetite distributed in very minute grains. The small microlites exhibit a parallel arrangement, bringing out the flow structure present. There is also a larger generation of felspars having a size of about 1 mm. by ·5 mm. It is twinned after the albite law and is labradorite. There are a few small grains of another mineral almost colourless, with only very slight pleochroism. Its D.R. is negative and approx. ·010 and the R.I. is considerably higher than that of Canada balsam. It has parallel extinction and is biaxial. There seems to be no doubt that it is hypersthene. Magnetite is the only other mineral visible. This rock has been analysed with the following result:—

	Per cent.	Molec. propor.		Per cent.	
SiO_2	58·79	980	Quartz ...	11·46	$\frac{Sal}{Fem} = \frac{80·40}{17·10} > \frac{5}{3} < \frac{7}{1}$
TiO_2	1·21	15	Orthoclase	3·89	
Al_2O_3	17·51	172	Albite ...	40·87	Class ii (Dosalane)
Fe_2O_3	2·11	13	Anorthite ...	24·18	$\frac{Q}{F} = \frac{11·46}{68·94} < \frac{3}{5} > \frac{1}{7}$
FeO	3·87	54	Diopside ...	5·29	
MgO	2·23	56	Hypersthene	6·51	Order 4 (Austrare)
CaO	6·18	110	Magnetite...	3·02	$\frac{K_2O+Na_2O}{CaO} = \frac{85}{110} < \frac{5}{3} > \frac{3}{5}$
K_2O	0·68	7	Ilmenite ...	2·28	
Na_2O	4·84	78	Water ...	3·32	Rang 3 (Tonalose)
H_2O +	2·61			———	
H_2O -	0·71			100·82	$\frac{K_2O}{Na_2O} = \frac{7}{78} < \frac{1}{7}$
CO_2	trace				
	———				Subrang 5 (Placerose)
	100·74				

C. *Volcanic*, (iii) basic.

Basalt, west of Moogering Creek.

Dark aphanitic rock with uneven fracture. Tiny lath-shaped felspars can be recognised in hand specimen.

Under the microscope it is hypocrystalline, pilotaxitic. A small amount of interstitial glass is present in the base. Felspar is present in lath-shaped crystals with their longer axes in a generally parallel direction. Magnetite is abundant in small grains. A light-coloured ferro-magnesian mineral is present in small grains, probably augite. Chlorite is sparingly present. A good deal of secondary calcite is present.

Olivine basalt, Portion 78, Parish Milfield.

Dark, rather heavy rock. Felspar and a dark mineral can be seen in hand specimen. Microscopically it is hypocrystalline, the amount of glass being very small. Radiate fabric is fairly well developed and ophitic structure is present. The minerals are:—Plagioclase, olivine, augite, magnetite and serpentine. The plagioclase is quite fresh in idiomorphic lath-shaped crystals whose maximum extinctions in sections perpendicular to (010) is 39°, indicating a bytownite of composition near Ab_3An_7. The augite is titaniferous, violet in colour and with fairly marked pleochroism. It is abundant, but only in small pieces, and ophitically encloses plagioclase. Olivine is present in fair quantity and is partly altered to serpentine, the alteration having taken place round the periphery and along the numerous cross cracks present. Magnetite is present in numerous small grains mostly included in other minerals.

Basalt, Portion 55, Parish Milfield.

Under the microscope it is hypocrystalline. The fabric is somewhat fluidal. The minerals are:—Plagioclase, augite, biotite, magnetite and a pale green zeolite. The plagioclase is in lath-shaped crystals and a good deal decomposed to kaolin. The augite is titaniferous and slightly pleochroic. Biotite is dark reddish-brown in colour, idiomorphic, often in hexagonal sections, with parallel extinction and pleochroic. Sometimes the central part is altered to a greenish aggregate. There is also a fairly large amount of pale green zeolitic mineral present.

Rhacopteris tuff, Matthews' Gap Road.

Fine grained, very compact and laminated. It has a bluish-grey colour when freshly fractured, but after short exposure (a few weeks) to atmospheric weathering it becomes brown. It has evidently undergone considerable local movement, as seen from the large number of perfect miniature faults which are present. It contains scanty remains of *Rhacopteris* and *Cardiopteris*.

Under the microscope it consists of rounded and angular fragments of felspar and quartz, mostly very much iron stained, cemented together by light-coloured glassy material. A good deal of calcite is present.

Cherty tuff, North of Mount Bright.

Light-coloured greyish-green, fine-grained rock; laminated and considerably jointed. Under the microscope it is extremely fine-grained and is composed of minute grains of quartz, and felspar and small amounts of magnetite and probably rutile and pyroxene, with a cementing material which appears felspathic.

Summary.

In the foregoing remarks we have endeavoured to establish the following main points:—

i. Partly underlain by earlier plutonic rocks, a complex of Upper Carboniferous volcanic lavas exists in the Pokolbin District constituting a series of inliers in the Permo-Carboniferous sediments, the formation being substantially continuous from a point about half a mile north of Drake's Hill to the outcrop known as Jerusalem Rock.

ii. A series of basaltic rocks occurs contemporaneous in the Lower Marine of the Permo-Carboniferous.

iii. The two series of rocks together form a succession showing a gradual order of differentiation from rhyolite to basalt, with a second phase of three components, dacite and trachyte, followed by basalt.

iv. The rocks have been much faulted, the period of disturbance ranging from (?) Carboniferous possibly to Tertiary times.

It is suggested that the lava extrusions were in the nature of fissure eruptions, the axes of extrusion being roughly meridional, and that this accounts for local modifications in the rock types. A petrological description of the typical rocks has been given.

Conclusion.

Our first geological acquaintance with Pokolbin was made at a University camp four years ago under the leadership of Professor David, and we wish to acknowledge our indebtedness to him for kind permission to make use of his maps of the district, for advice as to the general trend of our work and for his kindly and encouraging interest. Our sincere thanks are also due to Mr. W. Eustace Wilkinson of "Maluna," Pokolbin, who at all times generously placed at our disposal his extensive and practical knowledge of the geology of the district. The good people of the district in which our field work lay we always found ready and willing to assist us by any means in their power, a circumstance which often lightened our labours and added to the pleasure with which we pursued our investigations.

Explanation of Plates.

Plate XXV., Geological Map of the eruptive and associated rocks of Pokolbin, New South Wales.

Plate XXVI., Fig. 1. Banded rhyolite, from Post Office Hill, showing contortion ($\times \frac{2}{3}$).

„ „ 2. Brecciated rhyolite, Post Office Hill ($\times \frac{3}{4}$).

Plate XXVII., Fig. 3. Rhacopteris tuff, showing miniature faulting (× $\frac{3}{4}$).

Plate XXVIII. ,, 4. View of Drake's Hill and Post Office Hill from New Matthews' Gap Road.

,, ,, 5. View looking towards Mount Bright from "Maluna."

Plates XXVI and XXVII from polished specimens kindly lent by Mr. W. Eustace Wilkinson.

The VALUE of the NITRATE FIGURE in DETERMINING the FITNESS of WATER for DRINKING PURPOSES.

By C. S. Willis, M.R.C.S., D.P.H., etc.

Principal Assistant Medical Officer of the Government of New South Wales.

With Plate XXIX.

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

The necessity for considering all the figures obtained by the usual chemical analysis of a water before giving an opinion as to its fitness for drinking purposes cannot be too strongly insisted upon. One frequently finds, even at the present day, text books and analysts taking one figure, *e.g.* the albuminoid ammonia figure, as a standard, and stating that the water is fit or unfit for drinking purposes according as it contains less or more than so many parts of this particular substance per 100,000. Such a course necessarily frequently leads to serious errors. There are, however, exceptional cases where one has to give an opinion on one figure only, such as (a) when we have a group of wells in a circumscribed area with one substance, say, N as nitrates, large in quantity and vastly different in amount in each well; and (b) where in the same well water some figure, such as chlorine or N as nitrates, varies at different analyses out of proportion to variation in some figures such as the total solids.

Most authorities appear to almost ignore the quantity of nitrogen as nitrates in a water in forming an opinion as to its fitness for drinking purposes.

Nitrates and nitrites in water represent, almost exclusively, the oxydized nitrogen derived from the decomposition of nitrogenous organic matter. When organic matter undergoes decomposition, much of the N passes off in the free state, the remainder combining with hydrogen to form ammonia. As the polluted water containing this ammonia continues on its course in the earth, the N, mainly through the action of so called "nitrifying organisms" in the soil, becomes partially oxidized to nitrous acid, which combining with bases (commonly lime, and less often soda and potash), forms nitrites. Owing to the further action of the same agencies, the nitrites then combine with more oxygen to form nitrates.

It has been held that by the time the organic contamination in the water has been oxydized to nitrates the water would be rendered sufficiently pure for drinking purposes. But, allowing for the sake of argument that this is so, the water would still have to be regarded as dangerous for drinking purposes, for at any time the agencies responsible for the purification may be overtaxed, and dangerous pollution pass unchanged into the water. In this connection the following paragraph from "Hygiene and Public Health," Parkes and Kenwood, 2nd Ed., might be quoted: "Although it is now generally believed that the bacillus of typhoid loses its vitality and dies out when discharged into ordinary sewage, it would appear that this is not the case when sewage finds its way out of a sewer, and percolates through the ground. Under these conditions basic nitrates are formed by oxidation of ammonia and nitrogenous matters, which favour the life and growth of the bacillus of typhoid, and enable it to persist for long periods."

In 1908-9, a small country town in this State forwarded to the Health Department, for analysis, samples of water from ten wells. These waters were analysed in the Department's Chemical Laboratory, with the results shown in the accompanying tables I and II. Eight of these were condemned by me as unfit for drinking purposes, and in seven cases the condemnation was made chiefly, or entirely on the N as nitrates figures, which were 0·480, 0·800, 1·100, 1·200, 1·700, 1·700 and 4·300 parts per 100,000 respectively.

Fresh samples from some of the wells were then submitted by the residents to a private analyst, who, although obtaining similar figures to ours, gave an opinion to the effect that the waters were fit for drinking purposes. There then followed a good deal of local agitation, and I was despatched to the town in question to see the actual state of the wells. The following conditions were found. The town is traversed from north to south by a creek. Much the larger portion of the town is built on the east side of the creek, and here the ground has a distinct slope towards the creek; all the condemned wells were in this portion of the town; also, there were 18 cesspits situated for the most part on a slightly higher level and directly above the wells. The relative situations of wells and cesspits will be seen by reference to attached map of the town. The two wells not condemned were found in the west portion of the town where there were no cesspits. The soil at this town is very porous, so much so that although the rainfall is very heavy (45 inches a year), I was informed "gardens require a lot of water and require watering a day after heavy rainfall, owing to the rapid manner in which water percolates through the earth."

Most of the cesspits were found to be merely holes dug in this porous ground. One or two had brick sides, but the joints between the bricks were open. All the cesspits were in fact in direct communication with the ground water. This connection was well seen in the cases of the cesspits at the Public School and the Convent. At the Public School (average daily attendance 100) there were two cesspits, both lined with open jointed bricks; at the Convent (average daily attendance 44) there were three cesspits, mere holes dug in the ground. It was found that the height of the contents of these cesspits rises and falls with the rainfall (subsoil water). These observations were made by the Shire Sanitary Inspector, and confirmed, in the case of the Public School, by the School Teacher. Also, although the Public School cesspits had not been emptied for at least three years, they did not contain any more nightsoil than they did three years before. The same drainage of nightsoil into the ground was taking place from the other cesspits.

Seven of the wells were found to be in the line of the flow of, and receiving their supplies from, the subsoil water which was being contaminated by the cesspits. The ammonia from the nightsoil in the cesspits was oxidised in its passage through the soil, and thus the pollution of the wells by the cesspits was shown by the nitrates in the water. The variation in the quantity of nitrate in the water corresponded with the position of the well relatively to the cesspit.

If the analyses of wells 1, 2, 3, 4, 5, 7, and 8, in Table I (wells near cesspits) be compared with the analyses of

TABLE I—*Shewing Chemical Characters of the Waters of those Wells Found Contaminated.*

Date of Analysis.	(1)	(2)		(3)		(4)	(5)	(6)		(7)		(8)*
	5.1.09.	5.1.09.	29.10.08.	5.1.09.	29.10.08.	29.10.08.	3.12.08.	3 12.08.	26.10.09.	3.12.08.	26.10 .09.	3.12.08.
1. Total solid residue	67·44	23·24	37·00	61·96	66·84	43·28	26·28	10·16	16·64	24·52	31·72	42·88
2. Chlorine	11·30	3·30	6·00	11·30	11·70	10·00	3·85	0·70	0·8	3·00	4·15	8·80
3. Organic ammonia	0·008	0·001	0·003	0·017	0·018	0·004	0·009	0·016	0·025	0·005	0·010	0·013
4. Free ammonia ...	0·020	0·006	0·003	0·000	0·004	0·008	0·026	0·010	0·026	0·005	0·005	0·009
5. Nitrites	0·000	0·000	0·001	0·001	0·001	0·000	0·004	0·000	0·000	0·000	0·000	0·003
6. Nitrates	4·30	1·20	1·100	1·70	1·200	1·100	0·800	0·006	0·004	0·960	1·70	0·480
7. Oxygen absorbed 15 minutes	0·014	0·004	0·012	0·082	0·106	0·018	0·016	0·106	0·046	0·012	0·010	0·054
8. Oxygen absorbed 4 hours	0·028	0·008	0·022	0·170	0·212	0·036	0·028	0·196	0·092	0·022	0·020	0·104
9. Permanent hardness	28·8	6·7	...	16·2	...	...	14·0	2·5	0·4	10·4	14·3	10·0
10. Total hardness ...	31·0	10·0	...	29·0	...	...	15·0	7·0	5·0	12·0	16·0	21·0
11. Poisonous metallic contamination	none	none	none	none	none	none	none	none	none	none	none	none
12. Alkalinity... ...	2·2	3·3	...	12·8	...	...	1·0	4·5	4·6 phosphates 0·15 water fleas	1·6	1·7 traces of phosphates	11·0

Figures equal to parts per 100,000, * This water had a slight organic odour.

wells in Table II (wells well away from cesspits) the marked way in which the cesspit contamination has affected the nitrogen as nitrate figure will be seen.

TABLE II.—*Showing Chemical Characters of Two other Well Waters for comparison with Waters from the Eight Condemned Wells.*

	(9) Analysed		(10) Analysed
	3.12.08.	29.10.08.	3.12.08.
1. Total solid residue	10·40	13·24	14·64
2. Chlorine	0·90	0·95	0·90
3. Organic ammonia	0·001	0·004	0·001
4. Free ammonia	0·002	0·006	0·002
5. Nitrites	0·000	0·000	0·001
6. Nitrates	0·200	0·272	0·050
7. Oxygen absorbed 15 minutes ...	0·008	0·012	0·008
8. Oxygen absorbed 4 hours	0·012	0·020	0·012
9. Permanent hardness	4·8	...	1·5
10. Total hardness	6·0	...	10·5
11, Poisonous metallic contamination	none	none	none
12. Alkalinity	1·2	...	9·0

Figures equal to parts per 100,000.

The following epidemiological evidence also pointed to these wells being contaminated:—Population of the town 508, living in 125 houses. During the twelve weeks 17th December 1908 to 7th March 1909 twenty-one cases of typhoid fever occurred at this town, equal to an attack rate of 41 per 1,000 of the population for less than a quarter of the year. During the twelve months, March 1908 to February 1909, thirty-seven cases of typhoid fever occurred, equal to an attack rate of 72·8 per 1,000 of the population. The attack rate for the whole of New South Wales for the same twelve months was about 1·19 per 1,000 of the population. Moreover, twelve cases occurred in one month, February 1909, constituting almost an "explosion" in such a small population. It will thus be seen to what an excessive degree this town suffered from typhoid fever.

The possible effect that the contaminated water had on the typhoid incidence is shown by the next mentioned facts:

(a) Of the 37 cases occurring in the twelve months, 30 occurred on premises where there were wells;

(b) A large number of the cases occurred amongst people who, it is reasonable to suppose, had access to the wells actually condemned.

Reference to attached map will show the relative positions of cesspits, wells and houses in which typhoid occurred.

SUMMARY:

(1) Personal inspection of the cesspits and the wells, combined with local evidence, proved that seven of the condemned wells were being polluted by soakage from cesspits.

(2) Epidemiological evidence supported the conclusion that these wells were being contaminated by the cesspits.

(3) Chemical evidence of the pollution of seven of the wells was furnished mainly by the large and the varying (in different wells) quantity of N as nitrates present in the well waters.

The HAEMATOZOA of AUSTRALIAN BIRDS, No. II.

By J. Burton Cleland, M.D., Ch.M., Government Bureau of Microbiology, N.S.W., and T. Harvey Johnston, M.A., D.Sc., Queensland University, Brisbane.

With Plates XXX - XXXIII.

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

In a communication that we submitted to the Royal Society of South Australia last year, we detailed the results of an examination we had undertaken of the blood of various Australian birds for haematozoa. Since then, we have continued our observations, being greatly helped by the kindness of Dr. T. L. Bancroft, of Queensland, who has so materially assisted us with valuable material. To this pioneer of parasitology in Australia, science is indebted for much important work. The results of these further examinations are incorporated in the present paper, including descriptions of halteridia, trypanosomes, embryo filariæ, and other (presumed) parasites. Appended are lists of the additional positive and negative findings. The numbers (M. 7) etc., refer to the Hand-list of the Birds of Australasia published by Mathews in "The Emu," (Vol. VII, 1907-8).

Halteridia in Australian Birds.

In this further examination of Australian birds, halteridia were met with in 16 species. In 14 of these, they have not been recorded before, whilst in the other two, *Zosterops cœrulescens* and *Tropidorhynchus corniculatus*, we have recorded their presence in our former paper and now extend their geographical distribution.

In these halteridia, we have not attempted to define specific differences, merely stating the outstanding features noticed. We believe, however, that specific differences do exist between many of the forms, in as much as we find considerable variation in the size of the parasites, the amount of melanin, and the presence or absence of granules in the protoplasm. These differences are slight and hard to define and the question of specificity is perhaps best left to the future to decide.

Halteridium of *Catheturus Lathami* (M. 7). In this megapode, the 'Brush Turkey,' these parasites were found in five out of six birds obtained by Dr. Bancroft near Eidsvold, Queensland. They were numerous in a specimen obtained in November and one in March: in four other March specimens, they were few in three and absent in one. The parasites themselves showed conspicuous male and female forms. They occupied one side and the ends of the host cells but did not overlap the nucleus on the far side. Pigment was prominent as coarse grains or rods, sometimes collected at one end. Vacuolar spaces (? artefacts) were often present at one or both ends. Rounded forms, bulging the host-cell opposite its nucleus, were seen.

Halteridium of *Platycercus adelaidæ* (M. 336). In a bird of this species shot near Adelaide in May, 1911, halteridia were found occupying nearly all the available space in the host cells except on the far side of the nucleus.

Halteridium of *Merops ornatus* (M. 396). In the Bee-eater, halteridia were found in three out of four specimens sent by Dr. Bancroft from Eidsvold, Q. The birds were secured in October, December and March. The parasites were present in moderate numbers and presented characters differing considerably, more especially as regards granules in the protoplasm. In the first specimen, the halteridia were half-grown and oval with very little pigment; in the second, they extended a little beyond the nucleus of the host-cell and were either pale or finely granular. Melanin was present in small amount, either as a few fine grains near the centre, or one end, or as a rounded ball of grains at one end. In the third bird, deep blue granules were conspicuous, crowded at or near the ends; and the parasites were elongated, occupying one side and most of the ends of the red cells. Melanin was again scanty in amount, being either in the centre near the nucleus or between it and the end. The special characteristics of this halteridium were the small amount of pigment and the deep blue granules.

Halteridium of *Micrœca fascinans* (M. 433). A series of nine specimens of this bird were obtained from Eidsvold, Q., of which eight, obtained in February, April and May, showed halteridia. In one of these obtained in April, trypanosomes were also present, whilst in two others, peculiar bodies elsewhere described, were present in the leucocytes. The parasites were, as a rule, fairly numerous and male and female forms were conspicuous. The melanin appeared as a few small grains or rods. The parasites occupied a large area of the host-cell, occasionally pressing the host-nucleus nearly against the opposite side, thus filling up practically all the available space. In films from two birds, specimens were found in which the parasite occupied one side and one end only of the host-cell. Another parasite, stained a fairly deep blue, showed a rounded nucleus located at one end with a few grains of pigment near it, whilst most of the pigment was located as a ball at the other end. Several oval forms were present in one bird, bulging the host-cell opposite its nucleus. Both blue and pale parasites were noted.

Halteridium of *Petrœca phœnicia* (M. 440). In a specimen of this bird, shot on Mount Kosciusko (at 5,000 feet) in December, 1910, scattered halteridia, containing very little pigment, were seen. This bird is a wanderer, frequenting mountainous areas in summer time and plains, often far away, in winter. The locality of infection is not necessarily that where the bird was shot.

Halteridium of *Grallina picata* (M. 646). Halteridia were found in one bird out of three obtained at Eidsvold, Q. The affected subject was obtained in April. There was a very heavy infection of the red cells, reaching ten or more per cent. The grains of melanin were small; many of the parasites were of an elongated oval shape, others typical halter forms.

Halteridium of *Aphelocephala leucopsis* (M. 689). This bird was obtained on the Murray Flats, 14 miles west of Blanchetown in South Australia, in May, 1911. In the red cells, halteridia were detected. The melanin appeared as large rods or granules. There were many rounded pale or deeper blue forms.

Halteridium of *Zosterops cœrulescens* (M. 712). In our previous communication, we have already recorded the occurrence of halteridia in birds of this species obtained in Sydney. We have now to record its presence in a bird obtained at Adelaide in May, and at Eidsvold, Q., in April 1911. Deep blue and pale forms were present. The parasites occupied one side and most of the ends of the host-cells. The melanin appeared as small rods and granules.

Halteridium of *Pardalotus melanocephalus* (M. 729). Fairly numerous halteridia were present in six out of ten (numerous in four) of these birds obtained in April at Eidsvold, Q. Trypanosomes, but no halteridia, were present in a bird taken in March, and filariæ, but no halteridia, in a specimen shot in May. The parasites were large, occupying one side and nearly all the ends of the host-cells. Melanin appeared as a few large grains near the centre or towards one end. The forms were deep blue or pale blue, some being almost colourless. In a bird taken in March, halteridia alone were found, while in two shot in May no halteridia were detected, though microfilariæ were present in one.

Halteridium of *Myzomela sanguineolenta* (M. 746). In one of four specimens of this bird, obtained at Eidsvold in June, halteridia, as well as very long thin filariæ and intracorpuscular trypanosomes, were present. The parasites occupied the side and both ends of the host-cells and had fairly abundant coarse grains of melanin.

Halteridium of *Ptilotis fusca* (M. 769). A few halteridia, together with intracorpuscular trypanosomes in two instances, were present in three out of nine specimens of this bird, obtained at Eidsvold in March, and in one bird obtained in April. The parasites occupied a relatively large area of the red cells.

Halteridium of *Ptilotis sonora* (M. 772). A few halteridia were present in the blood-cells of a specimen of this bird obtained on the Murray Flats near Blanchetown, S.A., in May. The parasites occupied one side and most of the ends of the host-cells, and had a few coarse grains of melanin.

Halteridium of *Myzantha garrula* (M. 804). Eight birds from Queensland were examined—seven came from Eidsvold and one from Gladstone. Halteridia were present in three of the Eidsvold specimens, obtained in December (1) and February (2). The February birds also had filariæ.

Halteridium of *Myzantha flavigula* (M. 806). In a bird shot at Rowena, in the north of New South Wales, in November 1910, halteridia were found. Melanin was present as fairly large rods.

Halteridium of *Entomyza cyanotis* (M. 813). In a bird shot at Eidsvold, Q., in October by Dr. Bancroft, a few halteridia were seen. This bird also showed 'intracorpuscular trypanosomes' (elsewhere described in this paper) and a small species of embryo filaria.

Halteridium of *Tropidorhynchus corniculatus* (M. 818). We have already described[1] the halteridium present in this bird as *H. philemon*. We have found it in a bird shot at Eidsvold, Q., in March, which extends its geographical distribution from New South Wales to Queensland.

Halteridium of *Oriolus sagittarius* (M. 850). Halteridia were found in three of these birds obtained at Eidsvold in January, March and April. They contained moderately-sized scattered melanin granules. In two of these birds, 'intracorpuscular trypanosomes' were also present, in one of the two, free trypanosomes as well: the third bird had filariæ.

Trypanosomes in Australian Birds.

In our previous paper we described the presence of trypanosomes, which we called *T. anellobiæ*, in the honey-eater *Anellobia chrysoptera*, the birds being obtained by Dr. T. L. Bancroft in Queensland. A further study of films from some of these birds, together with a series of specimens from other birds shot near Eidsvold, Q., also forwarded by Dr. Bancroft, has shown us a phase of these trypanosomes that we had previously overlooked. This consists in an intracorpuscular stage, the organism being a parasite *(Leucocytozoon?)* of the red corpuscles. That these intracorpuscular bodies are really stages of a trypanosome, we think there can be no doubt. Not only is their body protoplasm stained in exactly the same way as that of free trypanosomes present in some of the films, but the macronucleus is also similar, and in a few favourable examples, the micronucleus has also been visible. It may be well, first of all, to describe the free and encysted forms in general.

The free trypanosomes varied in form, some being very broad and others extremely narrow. Though the parasites

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[1] This Journal, 1909.

in any particular film were usually of one or other of these types, in some films both forms were present as well as others of intermediate size.

The intracorpuscular forms were more or less globular, and lay in the protoplasm of the host-cell, embayed in the nucleus which sometimes surrounded the parasite so as to envelop three-fourths of its circumference. The bodies were usually deeply stained blue, but occasional much paler forms were seen. As already stated they possessed a central macronucleus, and occasionally, near the periphery, what appeared to be a micronucleus was present.

Considerable doubt existed for a long time as to the nature of the host-cell. Though the tinting of its nucleus was similar to that of an injured red cell (having the same reddish colour), irregular corona-like projections on the far side of the host-nucleus suggested that the cell might be a leucocyte. The question was, however, finally set at rest by detecting, in a film from *Ptilotis fusca*, very early intracorpuscular forms, without question parasitizing red cells. In one the protoplasm of the red-cell was still quite distinct, and its nucleus was being indented by the parasite so as to form a kind of cap to it. Of course it is not impossible that mononuclear leucocytes may also act as host-cells.

It is of much interest to note that our intracorpuscular trypanosomes (or 'leucocytozoa'), while distorting the nucleus of the host-cell by indentation and stretching, in no instance cause the extraordinary elongation of host-cell and nucleus seen in *Leucocytozoon ziemanni*. This alone shows that the species are distinct.

We think it highly probable that the trypanosomes and intracorpuscular bodies we have found in several Australian birds are all referable to the same species, and this we have already designated as *Tryp. anellobiae*. It will be seen that we have found free trypanosomes in five species of birds. In only one of these species have we failed so far to find intracorpuscular bodies. In addition, in four other species we have found the latter bodies without trypanosomes. Trypanosomes, when present, have always been few and more easily overlooked, whilst intracorpuscular bodies have usually been found with ease.

Trypanosomes—Free and Intracorpuscular.

Free Trypanosomes of *Microeca fascinans* (M. 483). In one of these birds, obtained in May at Eidsvold, Q., free trypanosomes as well as halteridia were found. The parasites were very broad and similar to those described later under *Pardalotus melanocephalus*. The posterior end was broad and irregular, the latter perhaps the effect of distortion; the body then narrowed rapidly to end in a short beak at the anterior end. The body was a deep blue, in some cases having an alveolar arrangement, in others showing streaky lines of fine bluish granules. There was a central macronucleus: the micronucleus appeared near the posterior end as a very conspicuous large deep purple dot or rod. A narrow undulating membrane was visible, but the flagellum was not definitely recognisable. No intracorpuscular phases were seen. Other specimens, four in number, obtained in April and May showed halteridia in three cases, but no trypanosomes.

Free and Intracorpuscular Trypanosomes of *Pardalotus melanocephalus* (M. 729). In a bird obtained at Eidsvold, Q., in March, a few fine specimens of trypanosomes were found. The parasites were large and conspicuous, with a broad blunt posterior end from which the body narrowed uniformly to end in an elongated anterior end. The body was a deep blue with an alveolar appearance: a large macronucleus occupied the centre: a deep purple spot close to the posterior end indicated the micronucleus, from which the flagellum, surrounded by the undulating membrane, arose and wound round the body to end in a short free flagellum.

In addition, two pale oval bodies, about the size of the red corpuscles of the host, were seen with a small purple dot near one end: no macronucleus was detected: in one specimen was a short tapering 'tail.' The bodies suggested small phases of a trypanosome.

No intracorpuscular bodies were seen in this specimen, though in one out of seven birds obtained in April, one of these bodies, embayed in the nucleus, was noted ; this bird had halteridia as well. Another of these seven birds showed bodies which probably also were intracorpuscular trypanosomes. In two May specimens filariæ alone were found.

Intracorpuscular Trypanosomes of *Myzomela sanguineolenta* (M. 746). In three out of four specimens of this bird obtained at Eidsvold in June, intracorpuscular trypanosomes were present. One of these also contained halteridia and filariæ. Pale and deep blue forms were present.

Free and Intracorpuscular Trypanosomes of *Ptilotis fusca* (M. 769). Of nine birds of this species shot at Eidsvold in March, one showed free trypanosomes alone, four showed free and intracorpuscular forms, in three, intracorpuscular forms alone were detected, while in one no trypanosomes but a few halteridia were seen. In an April bird, intracorpuscular trypanosomes and halteridia were present. The free trypanosomes varied from moderately narrow, through a fusiform shape, to broad forms. The macronucleus was a little in front of the centre. The micronucleus was in some specimens close to the posterior end, in others decidedly further forward. The undulating membrane wound round the body, ending in a moderately short flagellum. The protoplasm took a deepish blue colour and corresponded in this and in its appearance to that of the deeper-coloured intracorpuscular bodies. In one specimen, the micronucleus seemed to be dividing. The intracorpuscular bodies were numerous in one bird, in which there were seen also occasional halteridia. Both full-sized dark and pale forms were present and also a number of much smaller forms, the smallest being about a fourth of the size of the largest. In the earliest form seen, the parasite was at one pole of the red cell, and the host nucleus was not yet distorted. The central macronucleus of the parasite was present and there was no pigment. In a specimen a little larger, the parasite was towards one end of the red cell, and, in the protoplasm of the latter beside it, was a small vacuole; beyond the vacuole, the host's protoplasm showed a few scattered red dots. The nucleus of the host cell was redder than in an uninjured cell, slightly enlarged, not distorted but pressed to one side. In still larger parasites, the gradual embaying of the parasite in the nucleus of the host-cell was traceable through all its stages, from slight cupping onwards. In most of these young forms, the host-cells were clearly recognisable as red cells, about which there could be no mistake. In this film was also seen an apparently free vermicular form, rather like a hæmogregarine with one edge slightly curved; the body was about as long as the red cells and as broad as their nuclei; its nucleus was nearer one end of the parasite.

Intracorpuscular Trypanosomes of *Myzantha garrula* (M. 804). Four out of eight specimens of this bird from Eidsvold, Queensland, showed intracorpuscular trypanosomes. Two were obtained in February, one in December and one in May. In two specimens, the parasites were few, but in the other, a February bird, they were numerous. The parasites were, in many cases, pale in colour; two large examples showed bodies like micronuclei in addition to the macronuclei.

Intracorpuscular forms were found in the films from *Anellobia chrysoptera* from which we had previously described the free form. We had overlooked the presence of this phase.

Free and Intracorpuscular Trypanosomes of *Entomyza cyanotis* (M. 813). Both of these forms were present in two blue-faced honeyeaters obtained at Eidsvold in April. In one bird the trypanosomes were very narrow, in the other they were broad, approaching those of *Micrœca fascinans* and *Pardalotus melanocephalus.*

Bird 1.—The free trypanosomes were very narrow, with a sharp-pointed posterior end and a similar anterior end. The body was vacuolated with a few deep blue granules : the macronucleus was near the centre, and the micronucleus near the posterior end. The flagellum and undulating membrane were not recognisable. Intracorpuscular bodies, similar to those to be described in *Oriolus sagittarius*, were present. In some of these parasites were a number (a dozen or so) of scattered small deep bluish granules. One early form was seen in a red cell; it was oval, pale blue compared with the whitish host protoplasm, and lay to one side of the host nucleus, being as yet not embayed. It had a reddish elongated macronucleus, and two dark blue dots. Some pale, irregularly oval free forms were also seen, as if they had escaped from their host-cells. One of these was pale blue and slightly vacuolated; it had central purplish nuclear fragments, and at one end a broad deep purple dot resembling a micronucleus.

Bird 2.—This bird showed much broader trypanosomes than the previous bird, approaching those of *Pardalotus melanocephalus*, though not quite so broad. The posterior end was broad, narrowing however rapidly at the extreme end: the parasite narrowed rapidly anteriorly. The body was alveolar-looking and deep blue, being of the same tint as the intracorpuscular bodies which were also present. The micronucleus was prominent near the posterior end: the undulating membrane was just recognisable with a short flagellum anteriorly. Another trypanosome was paler and less broad. One of the intracorpuscular forms had a definite deeply-stained micronucleus.

Short filariæ were present in one of these birds, but halteridia were not detected, though found in another specimen.

In another bird, obtained in March at Eidsvold, a few free trypanosomes and intracorpuscular bodies were found. The trypanosomes were of the half-broad and narrow types with well-marked undulating membranes and moderately short flagella. The posterior end in one was shortly beaked. A few deep blue granules were seen in the protoplasm of a narrow form. Some of the large intracorpuscular forms showed a deeper blue outer zone and a central paler area in the protoplasm, within which was the macronucleus. Short filariæ were also present.

In a fourth bird shot in October at Eidsvold, besides a few halteridia, intracorpuscular trypanosomes were also present. In one pale form, a few fine deep blue granules were present in the protoplasm. One free body was seen somewhat resembling a broad trypanosome without undulating membrane or flagellum; its body was pale blue and vacuolated with purplish nuclear fragments near the centre and at one end a broad deep purple dot (micronucleus).

Free and Intracorpuscular Trypanosomes of *Oriolus sagittarius* (M. 850). Free trypanosomes were found in a bird of this species shot at Eidsvold in January, and intracorpuscular forms in the same bird and also in two obtained in April and May. The free trypanosomes were deep blue and very narrow; they showed a central macronucleus and a marked micronucleus near the posterior end: a narrow undulating membrane and a short free flagellum were also present. The intracorpuscular phase in this bird occurred as deep blue spherical bodies embayed in the nuclei of red cells. The protoplasm was finely granular or alveolar with an occasional small vacuole: the macronucleus appeared as a pale purplish-red central mass: in one specimen, the macronucleus appeared as a purplish mass at the side of the parasite, whilst near the centre, in a clear ring, the micronucleus was distinct as a deep purple dot. The nucleus of the host cell was stretched round the parasite, extending from half way to beyond this. The protoplasm of the host cell could be traced beyond the parasite and host nucleus as a faint rim. Occasionally an earlier phase or a male form of intracorpuscular body was seen embayed similarly in a nucleus; its tint was a pale blue with a pale purplish central mass.

In the April bird a single intracorpuscular body was seen. Halteridia were present also in this bird and in the January one, but were not seen in the May specimen.

Intracorpuscular Trypanosomes of *Sphecotheres maxillaris* (M. 852). In two birds shot in April, a few typical intracorpuscular bodies, like those found in *Oriolus*, were seen. Micronuclei were not noticed.

Intracorpuscular Trypanosomes of *Corcorax melanorhampus* (M. 883). In two specimens obtained at Eidsvold, Q., in April, a few typical intracorpuscular trypanosomes without centrosomes were seen, also one doubtful injured free trypanosome. Filariæ were present in both of these.

Peculiar Bodies, Free and in the Leucocytes, in the Blood of *Micrœca fascinans*.

In the large mononuclear cells of a specimen of this bird obtained in May, in which halteridia but no intracorpuscular trypanosomes were present, some small rounded bodies were seen. Four cells were found thus affected in a few minutes search; the bodies lay in the protoplasm, sometimes over the nucleus, and were from 3 to 9 in number. They were small (about the size of human blood-platelets), rounded, and seemed to lie in small vacuoles. They stained reddish with Giemsa, and, in favourable specimens, the staining showed about 7 chromatic dots arranged in a ring with a clear space between the ring and the host protoplasm.

In another bird obtained in April, several small purple bodies, perhaps a further stage of the above, were seen in a mononuclear cell. A larger phase, with bodies bluer, was also seen, and groups of considerably larger free spherical bodies of a pale bluish tint with a deep blue thickened edge round one half were fairly numerous. The last were quite possibly artefacts derived from the injured nuclei of red cells, though we have not seen the same appearance before.

The blood films containing these various bodies were rather poor and the parasitic nature of the bodies is questionable. We record what we have seen, however, so that other investigators may be on the lookout for similar appearances in other specimens of this bird.

Bodies (Degenerated Red Corpuscles) from a Galah.

In a galah, *Cacatua roseicapilla*, which died in a Sydney shop in April from a peculiar nervous affection to which these birds are subject, some peculiar bodies were found in the blood. The bodies, which were about as long as but considerably narrower than the host red-cells, had elongated somewhat pointed ends and were spindle-shaped. Their protoplasm was bluish and somewhat granular, and was occupied by one to three rounded spherical bodies, showing in a clear area reddish chromatin masses. What appeared to be a larger form was also noticed; this was oval, the protoplasm was reduced to a peripheral ring and the centre was occupied by a large spherical pinkish body showing scattered chromatic granules.

A further examination revealed the presence of other forms of these bodies which seemed to link them up with degenerated forms of red cells, in which the nuclei became separated into spherical portions and gradually degenerated. At first sight the bodies suggested a parasitic origin.

Spores of a Mould mistaken for Parasites.

In the Second Report of the Wellcome Research Laboratories at Khartoum appears in a coloured plate (Plate XXI, b.c.) a representation of elongated bodies supposed to have been found in the blood of a guinea-fowl, and these are referred to in the text (p. 196). The bodies are elongated and divided into four or more parts by partitions. On several occasions we have noted bodies identical with these while examining dried films of blood from birds, notably so in that of a Roller Bird (*Eurystomus pacificus*, M. 381). Their true nature was not realized until many months afterwards, when one of us was examining a small specimen of liquid blood forwarded in a bottle from a horse. This had become slightly mouldy, and on staining films, bodies indistinguishable from those mentioned above were numerous. The mould would seem to be a species of *Fusisporium*, a not uncommon saprophyte, and finding the spores in dried slides of blood may be easily accounted for either by their entanglement in the blood from the surroundings when the film was made or by the occurrence of mould in the surroundings of the film while stowed away.

Microfilariæ from Australian Birds.

Filarial embryos have been detected in films from the following additional birds:—(1) *Phalacrocorax melanoleucus;* (2) *Accipiter cirrhocephalus;* (3) *Glossopsittacus pusillus*; (4) *Podargus strigoides;* (5) *Eurystomus pacificus;* (6) *Psphodes crepitans;* (7) *Artamus leucogaster;* (8)

Artamus tenebrosus; (9) *Cracticus nigrigularis;* (10) *Cracticus destructor;* (11) *Pardalotus melanocephalus;* (12) *Myzomela sanguineolenta;* (13) *Plectorhampus lanceolatus;* (14) *Stigmatops ocularis;* (15) *Ptilotis fusca;* (16) *Myzantha garrula;* (17) *Entomyza cyanotis;* (18) *Oriolus sagittarius;* (19) *Corvus coronoides;* (20) *Struthidea cinerea;* (21) *Corcorax melanorhampus.*

(1) Microfilaria sp. from the Little Cormorant, *Phalacrocorax melanoleucus*, Vieill. (Hawkesbury River, N.S.W. Nov. 1910).

These embryos were rather long, stout forms reaching from 116 to 140 μ in length by about 6 μ in width. The anterior end was bluntly rounded and of about the same diameter as the main portion of the worm. The posterior region tapered somewhat to end in a broadly rounded extremity. Faint transverse striations were recognised. The various breaks were situated as indicated. (Figs. 60, 61).

(2) Microfilaria sp. from the Sparrow Hawk, *Accipiter cirrhocephalus*, Vieill. (Dr. Bancroft, Eidsvold, Q., June 1911).

These parasites were relatively long (100 to 130 μ) and thin, possessing a uniform breadth of 3·3 μ, excepting at the posterior end which tapered somewhat to terminate in a bluntly rounded tail. The "spots" were situated at about 36, 74 and 94 per cent. of the body length distant from the head end. (Figs. 65, 66.)

(3) Microfilaria sp. from the Little Lorikeet, *Glossopsittacus pusillus*, Shaw. (Dr. Bancroft, Eidsvold, Q., June 1911; L. Harrison, Gladstone, Q., Oct. 1910).

In a blood film made from this host by Dr. Bancroft, there were abundant embryos, but they did not take up the stain satisfactorily. They were fairly short (66 to 75 μ long), the anterior region being a little wider (4 μ) than the remaining portion, which gradually tapered to end in a sharply-pointed tail. In some specimens there was also a narrowing anteriorly, the rounded head end being not quite as wide as the succeeding portion. No distinct "spots" were recognisable, nor were annulations detected.

The parasites present in a film made by Mr. Launcelot Harrison from a specimen shot near Gladstone stained rather better. They were slightly longer (68 to 100 μ) and showed the presence of annulations. The anterior clear area was larger than that seen in the Burnett River specimens. The forms from both districts were of the same shape and probably belong to the same species of nematode. The spots were situated at about 25 to 28, 34 to 38, and 80 per cent. of the body length respectively. (Figs. 38, 39.)

(4) Microfilaria sp. from the Frogmouth, *Podargus strigoides*, Lath. (Dr. Bancroft, Eidsvold, Dec. 1910).

Length 90 to 100 μ, breadth about 5 μ. The parasites were relatively short and thick, with a rounded anterior end and a short rapidly-tapering tail. Delicate transverse markings were present. The spots lay at about 27, 53 and 80 per cent. of the body length distant from the head end. (Figs. 53, 54).

(5) Microfilaria sp. from the Roller, *Eurystomus pacificus*, Lath. (Dr. Bancroft, Eidsvold, Dec. 1910).

Length 130 μ, breadth 3·5 μ. The head end was slightly rounded, the posterior end tapering to a fine point. The specimens did not allow of further examination. (Fig. 59.)

(6) Microfilaria sp. from the Coachwhip, *Psophodes crepitans*, Vig. and Horsf. (Dr. Bancroft, Eidsvold, April 1911).

Length 200 μ, breadth 5 μ. Very few specimens of this large Microfilaria were detected. The worms stained fairly evenly throughout. The extremities were almost alike, both being broadly rounded. In a few embryos, the tail end was slightly narrower than the rest of the body. (Figs. 55, 56.)

(7) Microfilaria sp. from the White-rumped Wood-swallow, *Artamus leucogaster*, Valenc. (Dr. Bancroft, Eidsvold, April 1911.)

Length 90 to 120 μ, breadth 4 μ. Each end was bluntly rounded, the tail tapering slightly. Annulations were readily recognisable. The nerve ring lay in the anterior sixth and the excretory spot in the fourth sixth of the body. (Figs. 50, 51.)

(8) Microfilaria sp. from the Wood-swallow, *Artamus tenebrosa*, Lath. (Dr. Bancroft, Eidsvold, Febr. 1911).

Length 120 μ, breadth 5 μ. Very few parasites were detected. The head end was somewhat truncate, the tail end gradually tapering to terminate bluntly. Transverse striæ were not recognised (figs. 72, 73). This form is probably specifically identical with that found in *Artamus leucogaster*.

(9) and (10) Microfilaria sp. from the Butcher Birds *Cracticus nigrigularis*, Gould (L. Harrison, Gladstone, Oct. 1910), and *C. destructor*, Temm. (Dr. Bancroft, Eidsvold, April 1911).

The two above mentioned species of *Cracticus* were found to be parasitised by a short thick microfilaria possessing distinct annulations. Each extremity was bluntly rounded, the tail being only slightly narrower than the head in most of the specimens seen. In a few (from *C. nigrigularis*) the tail was rather more pointed. The length of the embryo varied from 80 to 110 μ, the breadth being from 5 to 6 μ. A few smaller forms of 58 μ by 2·5 μ possessing a somewhat pointed tail were seen in the film from *C. nigrigularis*. The various spots were not distinctly recognisable in most specimens, though in some from the latter host their location appeared to be at about 30, 70 and 90 percentage of the body length distant from the head end. (Figs. 52, 57, 58.)

(11) Microfilaria sp. from a Pardalote, *Pardalotus melanocephalus*, Gould. (Dr. Bancroft, Eidsvold, April 1911.)

Length 90 to 125 μ, breadth 5·5 μ. This parasite was found in only one out of many birds of this species examined by us. They were rather long and of an almost uniform breadth, the tail end being only slightly narrowed. Each extremity was broadly rounded. The "spots" were at about 33, 60, and 90 per cent. of the body length. (Figs. 62, 63.)

(12) Microfilaria sp. from the Blood Bird, *Myzomela sanguineolenta*, Lath. (Dr. Bancroft, Eidsvold, June 1911.)

Filarial embryos were detected in films from one out of four forwarded recently by Dr. Bancroft. The same film contained, in addition, both halteridia and intracorpuscular trypanosomes. The filariæ were relatively extremely long and delicate, measuring 270 μ, or even more, in length, while the breadth only reached 1·5 μ. The width was uniform. Each end was bluntly rounded. The spots were situated as indicated in fig. 75. A figure of a red corpuscle (fig. 74) is shown for comparison.

(13) Microfilaria sp. from *Plectrorhamphus lanceolatus*, Gould. (Dr. Bancroft, Eidsvold, April 1911.)

Length 40 to 57 μ, breadth about 5 μ. These embryos were short thick forms with a blunt rounded anterior end, and rapidly-tapering tail. They appear to belong to the same species as the parasite found in *Entomyza cyanotis*. The nerve ring lay at about the junction of the first and second fourths of the worm. (Figs. 36, 37.)

(14) Microfilaria sp. from *Stigmatops ocularis*, Gould. (L. Harrison, Gladstone, Oct. 1910.)

Length 120 μ, breadth 3·5 μ. The anterior end was rounded, the tail being short and pointed. The specimens did not allow of the location of the various spots being made out with certainty. The excretory pore (?) was fairly close to the anterior end, the anus being near the posterior extremity. (Fig. 71.)

(15) Microfilaria sp. from *Ptilotis fusca*, Gould. (Dr. Bancroft, Eidsvold, March 1911,)

Length 45 to 66 μ, breadth 5 μ. Filarial embryos were detected in films made from one out of eleven honey-eaters belonging to this species. The parasites are of about the same size and possess the same characters as the flariae found in certain other Meliphagidæ e.g., *Entomyza cyanotis* and *Plectrorhamphus lanceolatus*. (Fig. 45.)

(16) Microfilaria sp. from the Noisy Minah, *Myzantha garrula*, Lath. (Dr. Bancroft, Eidsvold, Feb. 1911, May 1911).

Length from 70 to 120 μ, breadth 3·5 μ. These parasites have been detected in four out of eight birds. They varied considerably in length. The anterior extremity tapered slightly, the posterior end becoming narrowed rather more. Each end was rounded. The nerve ring lay at the end of the anterior fifth, the excretory vesicle lying at about halfway between this point and the end of the body. The anus was fairly close to the posterior extremity.

In several films there was a multiple infection. In one case, halteridia and intracorpuscular trypanosomes (leucocytozoa) were also present, in other films either halteridia or leucocytozoa accompanied the filariæ. (Fig. 49.)

(17) Microfilaria sp. from the Blue-faced Honey-eater, *Entomyza cyanotis*, Swainson. (L. Harrison, Gladstone, Oct. 1910; Dr. Bancroft, Eidsvold, Oct. 1910, March 1911.)

Length about 70 μ, breadth between 5 and 6 μ. The embryos met with in this bird are specifically identical with those seen in *Ptilotis fusca* and *Plectrorhamphus lanceolatus*. (Fig. 34.)

(18) Microfilaria sp. from the Oriole, *Oriolus sagittarius*, Lath. (Dr. Bancroft, Eidsvold, March 1911).

A single coiled form was detected but no details could be made out.

(19) Microfilaria sp. from the Crow, *Corvus coronoides*, Vig. and Horsf. (Dr. Bancroft, Eidsvold, March 1911).

Length 150 μ, breadth 5·5 μ. These embryos were long, the head rounded in front, the posterior end tapering to a finely pointed tail. The "spots" were situated as indicated in fig. 68.

(20) Microfilaria sp. from the Grey Jumper, *Struthidea cinerea*, Gould. (Dr. Bancroft, Eidsvold, Feb. 1911.)

There were at least two different forms of larvæ, one a large form, the other fairly long but more delicate.

Larger form:—Length about 190 μ, breadth 5 μ. The body was of a fairly uniform breadth for the greater part of its length, but the posterior region tapered gradually to end in a pointed tail (fig. 70). Annulations were recognised. The spots were at about 16, 28, and 90 per cent. of the body length. A smaller parasite of the same type measured 140 μ by 5 μ.

Smaller form :—Length 85 to 100 μ, breadth 3·5 μ. There was a gradual tapering posteriorly, the tail extremity being rounded. Delicate annulations were present. The anus was not recognised. The other "spots" lay at 23 and 30 per cent. of the body length. (Fig. 64.)

In some films both kinds were present, while in films from other birds only one kind was found.

(21) Microfilaria sp. from the White-winged Chough, *Corcorax melanorhamphus*, Vieill. (Dr. Bancroft, Eidsvold, April 1911, May 1911.)

Length 58 to 120 μ, breadth 3·5 to 4 μ. There appeared to be two different kinds of embryos from this host, but as the difference was mainly in regard to size, we have regarded them as belonging to the same species. The anterior end was rounded, the tail short and tapering. Transverse striations were distinctly recognisable. The spots lay at about 32, 54 and 83 per cent. of the body length.

We desire to thank Dr. Bancroft of Eidsvold, Queensland, and Mr. L. Harrison of Sydney, for their kindness in forwarding films, and the latter gentleman for identifying many of the birds for us; also Mr. W. A. Birmingham of the Bureau of Microbiology, Sydney, who drew the figures from our originals.

The following is a summary of the results given in the accompanying tables.

Haematozoa were not detected in 84 species of Australian birds, comprising 146 individuals, as well as 2 introduced species comprising 3 individuals.

In 17 species of Australian birds found to be harbouring halteridia, these were found in 44 individuals out of 87.

In 9 species of Australian birds, various phases of trypanosomes were found. Of 66 individuals examined, 3 showed free trypanosomes, 17 intracorpuscular forms, and 8 both forms, *i.e.* 28 out of 70 were infested.

In 21 species of Australian birds filariæ were found, being present in 31 individuals out of 70.

Out of 70 birds belonging to the 9 species in which trypanosomes in various phases were found, 15 showed halteridia alone, 18 phases of trypanosomes alone, 10 both and 27 neither.

I.—List of Birds in which Haematozoa were not found.

Ocydromus sylvestris, Sclater, Lord Howe Island, Oct. (1).

Ptilopus Swainsoni (M. 24) Eidsvold, Q., May 1911 (1).

Geopelia humeralis (M. 33) Gladstone, Q., Nov. 1910 (1).

—— *placida* (M. 34) Eidsvold, Q., Dec. 1910 (1), Feb. 1911 (1), March 1911 (1). Gladstone, Q., Nov. 1910 (1).

Phaps chalcoptera (M. 37) Eidsvold, Q., March 1911 (1), Murray Flats, S.A., May 1911 (1).

Geophaps scripta (M. 42) Eidsvold, Q., Dec. 1910 (1), Jan. 1911 (2), March 1911 (2), May 1911 (1).

Ochyphaps lophotes (M. 46) Rowena, N.S.W., Nov. 1910 (2).

Leucosarcia picata (M. 47) Hawkesbury R., Nov. 1910 (1), Eidsvold, Q., Dec. 1910 (2).

Podiceps novæ-hollandiæ (M. 65) Bathurst, Feb. 1911 (1).

Eudyptula minor (M. 71) Broughton Island, March 1911 (1).

Micranous leucocapillus (M. 135) Gladstone, Q., Nov. 1910 (1).

Hæmatopus fuliginosus (M. 145) Gladstone, Q., Nov. 1910 (1).

Charadrius dominicus (M. 151) Lord Howe Island, Oct. 1910 (2).

Ægialitis melanops (M. 158) Eidsvold, Q., May 1911 (1).

Numenius cyanopus (M. 164) Gladstone, Q., Nov. 1910 (1).

Burhinus grallarius (M. 190) Eidsvold, Q., Nov. 1910 (1).

Ibis molucca (M. 194) Eidsvold, Q., June (1).

Herodias timoriensis (M. 203) Eidsvold, Q., May 1911 (1).

Baza subcristata (M. 273) Eidsvold, Q., Jan. 1911 (1).

Hieracidea orientalis (M. 279) Bathurst, Feb. (1).

Trichoglossus novæ-hollandiæ (M. 301) Sydney shop, Feb. 1911 (1), Eidsvold, Q., May 1911 (1).

Psitteuteles chlorolepidotus (M. 304) Gladstone, Q., Nov 1910 (1), Eidsvold, Q., April 1911 (1), May 1911 (2).

Cacatua leadbeateri (M. 321) Sydney shop, April 1911 (1).

—— *roseicapilla* (M. 324) Sydney shop, Feb. 1911 (1), April 1911 (1).

Aprosmictus cyanopygius (M. 332) Eidsvold, Q., Jan. 1911 (2), April 1911 (3).

Platycercus pallidiceps (M. 339) Eidsvold, Q., March 1911 (1), April 1911 (1).

—— *eximius* (M. 343) Gunnedah, Feb. 1911 (1).

Ægotheles novæ-hollandiæ (M. 379) Eidsvold, Q., April 1911 (1).

Dacelo gigas (M. 386) Jindabyne, Dec. 1910 (1), Eidsvold, Q., Dec. 1910 (1), April 1911 (1).

—— *leachii* (M. 387) Eidsvold, Q., May (1).

Halcyon vagans Lord Howe Island, Oct. 1910 (2).

Cacomantis flabelliformis (M. 407) Gladstone, Q., Nov. 1910 (1).

Chalcococcyx plagosus (M. 412) Eidsvold, Q., Jan. 1911 (1).

Hirundo neoxena (M. 429) Eidsvold, Q., May 1911 (1).

Smicrornis brevirostris (M. 449) Eidsvold, Q., April 1911 (2), Murray Flats, S.A., May 1911 (1).

Rhipidura albiscapa (M. 476) Eidsvold, Q.. March 1911 (1), April 1911 (1).

—— *tricolor* (M. 487) Eidsvold, Q., March 1911 (1).

Myiagra nitida (M. 490) Kosciusko, Dec. 1910 (1).

Sisura inquieta (M. 493) Eidsvold, Q., May 1911 (1).

Piezorhynchus gouldi (M. 499) Gladstone, Q., Nov. 1910 (1).

Coracina robusta (M. 504) Eidsvold, Q., May 1911 (1), Hawkesbury River, Nov. 1910 (1).

—— *mentalis* (M. 507) Eidsvold, Q., Feb. 1911 (1), March 1911 (1), April 1911 (1).

Edoliisoma tenuirostre (M. 509) Eidsvold, Q., March 1911 (1).

Lalage tricolor (M. 510) Eidsvold, Q., May 1911 (2).

Cinclosoma punctatum (M. 515) Sydney, Oct. 1910 (1).

—— *castanonotum* (M. 516) Murray Flats, S.A., May (1).

Pomatostomus frivolus (M. 529) Eidsvold, Q., Nov. (1), March (1), Rowena, N.S.W., Nov. (1), Gladstone, Q., Nov. (1), Gunnedah, Feb. (1).

Chthonicola sagittata (M. 558) Eidsvold, Q., April (1), June (1).

Acanthiza pyrrhopygia (M. 568) Coonalpyn, S.A., May (1).

—— *lineata* (M. 569) Sydney, Oct. 1910 (1); Locksley, N.S.W., Feb. 1911 (1).

Acanthiza uropygialis (M. 573) Murray Flats, S.A., May (1).

—— *reguloides* (M. 575) Locksley, Feb. 1911 (1).

Malurus cyanochlamys (M. 593) Eidsvold, Q., Jan. 1911 (1), March 1911 (1).

—— *cruentatus* (M. 608) Eidsvold, Q., March 1911 (1).

Stipiturus malachurus (M. 610) Sydney, Oct. 1910 (1), April 1911 (1).

Artamus superciliosus (M. 625) Eidsvold, Q., March 1911 (1).

Collyriocincla harmonica (M. 636) Hawkesbury River, Nov. 1910 (1), Eidsvold, Q., Feb. 1911 (1).

Oreoica cristata (M. 662) Coonalpyn, S.A., May 1911 (1).

Pachycephala rufiventris (M. 674) Eidsvold, Q., March 1911 (2).

—— *gilberti* (M. 676) Murray Flats, S.A., May (1).

Eopsaltria chrysorrhoa (M. 684) Eidsvold, Q., March 1911 (1).

Neositta chrysoptera (M. 694) Gunnedah, Feb. 1911 (1).

—— *leucocephala* (M. 695) Eidsvold, Q., March 1911 (1).

—— *pileata* (M. 697) Murray Flats, S.A., May (1).

Climacteris scandens (M. 705) Locksley, N.S.W., Feb. 1911 (1), Eidsvold, Q., Feb. 1911 (1).

Pardalotus punctatus (M. 726) Eidsvold, Q., Feb. 1911 (1), April 1911 (1).

Melithreptus albigularis (M. 734) Gladstone, Q., Nov. 1910 (1).

—— *gularis* (M. 373) Eidsvold, Q., April 1911 (1).

—— *brevirostris* (M. 741) Coonalpyn, S.A., May (1).

Glyciphila melanops (M. 756) Coonalpyn, S.A., May (1).

Ptilotis chrusotis (M. 770) Eidsvold, Q., Feb. 1911 (1), March 1911 (1).

—— *fascigularis* (M. 777) Gladstone, Q., Nov. 1910 (1).

—— *penicillata* (M. 791) Murray Flats, S.A., May 1911 (1).

Meliornis pyrrhoptera (M. 797) Adelaide, May 1911 (1).

Philemon citreogularis (M. 819) Eidsvold, Q., March 1911 (1).

Anthus australis (M. 822) Mount Kosciusko, Dec. 1910 (1), Eidsvold, Q., May 1911 (2).

Stictoptera bichenovii (M. 832) Eidsvold, Q., March 1911 (2).

Ægintha temporalis (M. 838) Eidsvold, Q., April 1911 (1).

Poephila cincta (M. 843) Eidsvold, Q., March 1911 (1).

Chibia bracteata (M. 854) Eidsvold, Q., Jan. 1911 (1), March 1911 (1), April 1911 (1).

Aplonis fuscus (M. 855) Lord Howe Island, Oct. (1).

Chlamydodera maculata (M. 861) Eidsvold, Q., May (5).

Strepera graculina (M. 875) Lord Howe Island, Oct. 1910 (4); Colo Vale, N.S.W., June 1911 (1).

—— *versicolor* (M. 878) Kosciusko, Dec. 1910 (1); Colo Vale, June 1911 (1).

INTRODUCED BIRDS.

Passer domesticus (House Sparrow) Sydney, Oct. 1910 (2).

Sturnus vulgaris (Starling) Sydney, Nov. 1910 (1).

II.—List of Species Harbouring Halteridia.

Catheturus lathami (M. 7) Eidsvold, Q., Oct. (1) numerous; April (6) in one numerous, in four few, in one nil.

Platycercus adelaidae (M. 336) Adelaide, May (1).

Merops ornatus (M. 396) Eidsvold, Q., Oct. (2) one nil; Dec. (1); April (2) both nil.

Micrœca fascinans (M. 433) Eidsvold, Q., Feb. (1); April (7) halteridia in six, one with trypanosomes; May (2) one nil.

Petrœca phœnicia (M. 440) Mount Kosciusko, Dec. (1).

Grallina picata (M. 646) Eidsvold, Q., Dec. (1) nil; March (1).

Aphelocephala leucopsis (M. 689) Blanchetown, S.A., May (1).

Zosterops cœrulescens (M. 712) Adelaide, May (1); Eidsvold, Q., April (1); Sydney, June (2) both nil.

Pardalotus melanocephalus (M. 729) Eidsvold, Q., March (1) no halteridia, tryps.; April (11), halteridia in six; May (2) no halteridia, filaria in one.

Myzomela sanguineolenta (M. 746) Eidsvold, Q., June (4) halteridia with intracorpuscular tryps. and filariæ in one.

Ptilotis fusca (M. 769) Eidsvold, Q., Jan. (1) nil; March (9), halteridia in three, with tryps. in two of these; April (1), halteridia, intracorpuscular tryps.

—— *sonora* (M. 772) Blanchetown, S.A., May (1).

Myzantha garrula (M. 804) Gladstone, Q., Oct. (1) nil; Eidsvold, Q., Dec. (2) one with halteridia and intracorpuscular tryps., one nil; Feb. (3) two with halteridia and intracorpuscular tryps.; April (1) no halteridia, intracorpuscular typs.; May (1) nil.

—— *flavigula* (M. 806) Rowena, N.S.W., Nov. (1).

Entomyza cyanotis (M. 813) Gladstone, Q., Oct. (1), filaria, no halteridia; Eidsvold, Q., Oct. (1); March (3) no halteridia, tryps. in one; April (3) no halteridia, tryps. in two.

Tropidorhynchus corniculatus (M. 818) Eidsvold, Q., (2) one nil.

Oriolus sagittarius (M. 850) Eidsvold, Q., Jan. (1) halteridia and tryps.; March (1) halteridia and filaria; April (1) halteridia and intracorpuscular tryps; May (2) no halteridia, intracorpuscular tryps. in one.

III.—List of Species Harbouring Trypanosomes.

Micrœca fascinans (M. 433) Eidsvold, Q., Feb. (1) no tryps., halteridia; April (7) free trypanosomes and halteridia in one, halteridia in five others; May (2) no tryps., halteridia in one.

Pardalotus melanocephalus (M. 729) Eidsvold, Q., March (1) free trypanosomes; April (11) no tryps., halteridia in six; May (2) no tryps., filaria in one.

Myzomela sanguineolenta (M. 746) Eidsvold, Q., June (4) intracorpuscular tryps. in three, with halteridia and filaria in one of these.

Ptilotis fusca (M. 769) Eidsvold, Q., Jan. (1) nil; March (9) halteridia only in one, filaria and free and intracorpuscular trypanosomes in one, halteridia and free and intracorpuscular tryps. in one, free trypanosomes in one, intracorpuscular trypanosomes in two, halteridia and intracorpuscular tryps. in one, free and intracorpuscular tryps. in two, intracorpuscular tryps. and filaria in one; April (1) intracorpuscular tryps. and halteridia.

Myzantha garrula (M. 804) Gladstone, Q., Nov. (1) nil; Eidsvold, Q., Dec. (2) intracorpuscular tryps. and halteridia in one;

Feb. (3) intracorpuscular tryps. in two, in one very numerous, filaria in all, and halteridia in two (with intracorpuscular tryps.); April (1), intracorpuscular tryps.; May (1) nil.

Entomyza cyanotis (M. 813) Eidsvold, Q., Oct. (1) nil; March (3) free and intracorpuscular tryps. in one; April (3) free and intracorpuscular tryps. in two, filariæ in one, no halteridia.

Oriolus sagittarius (M. 850) Eidsvold, Q., Jan. (1) free and intracorpuscular tryps. and halteridia; March (1) no tryps., halteridia and filaria present; April (1) intracorpuscular tryps. and halteridia; May (2) intracorpuscular tryps. in one.

Sphecotheres maxillaris (M. 852) Eidsvold, Q., April (4) two with intracorpuscular tryps.; May (1) nil.

Corcorax melanorhamphus (M. 883) Eidsvold, Q., Oct. (2) no tryps., filaria in one; Jan. (1) nil; April (2) intracorpuscular tryps. and filaria in both; May (1) no tryps, filaria.

IV.—List of Species Harbouring Filaria.

Phalacrocorax melanoleucus (M. 241) Hawkesbury River, Oct. (1); Bathurst, Feb. (1) nil.

Accipiter cirrhocephalus (M. 260) Eidsvold, Q., June (1).

Glossopsittacus pusillus (M. 209) Gladstone, Q., Oct. (1); Eidsvold, Q., Nov. (1) nil; March (2) nil; June (1).

Podargus strigoides (M. 376) Eidsvold, Q., (Dec. (1).

Eurystomus pacificus (M. 381) Eidsvold, Q., Dec. (2) nil.

Psophodes crepitans (M, 526) Eidsvold, Q, April (1).

Artamus leucogaster (M. 624) Eidsvold, Q., April (2) one nil.

—— *tenebrosus* (M. 634) Eidsvold, Q., Oct. (1) nil; Feb. (2) nil in one.

Cracticus nigrigularis (M. 654) Eidsvold, Q., Oct. (1).

—— *destructor* (M. 658) Eidsvold, Q., March (1); April (1) nil; Sydney, June (1) nil.

Pardalotus melanocephalus (M. 729) Eidsvold, Q, March (1) no filaria, tryps.; April (11) no filaria, halteridia in six; May (2) nil in one.

Myzomela sanguineolenta (M. 746) Eidsvold, Q., June (4) filariæ with halteridia and intracorpuscular tryps. in one.

Plectrorhamphus lanceolatus (M. 745) Eidsvold, Q, April (2) one nil.

Stigmatops ocularis (M. 765) Gladstone, Q., Oct. (1).

Ptilotis fusca (M. 769) Eidsvold, Q., Jan. (1) nil; March (9) one with filaria and intracorpuscular tryps.; April (1) no filaria.

Myzantha garrula (M. 804) Gladstone, Q., Oct. (1) nil; Eidsvold, Q., Dec. (2) no filaria, halteridia in one; Feb. (3) all with filaria, halteridia and tryps. also in two; April (1) nil; May (1) filaria.

Entomyza cyanotis (M. 813) Gladstone, Q., Oct. (1); Eidsvold, Q., Oct. (1) filaria and halteridia; Dec. (2) no filaria, halteridia in one; March (2) filaria in one; April (3) no filaria, tryps. in two.

Oriolus sagittarius (M. 850) Eidsvold, Q., Jan. (1) no filaria but halteridia and tryps.; March (1) filaria and halteridia; April (1) no filaria but halteridia and tryps.; May (2) no filaria, intracorpuscular tryps. in one.

Corvus coronoides (M. 872) Rowena, N.S.W., (1) nil; Jindabyne, N.S.W., Dec. (1) nil; Eidsvold, Q., March (2) nil in one.

Struthidea cinerea (M. 882) Eidsvold, Q., Dec. (1) nil; Feb. (4) filariæ in three; March (1) nil; Gunnedah, Feb. (3) nil in all.

Corcorax melanorhamphus (M. 883) Eidsvold, Q., Oct. (2) filaria in one; Jan. (1) nil; April (2) filaria and intracorpuscular tryps. in both; May (1)

Explanation of Plates.

Reference to lettering:—*c.* = centrosome; *h.n.* = host nucleus; *h.p.* = host protoplasm; *p.* = parasite; *p.n.* = nucleus of parasite.

All figures have been drawn to the same scale with a camera lucida.

Plate XXX.

Figs. 1 – 5 *Trypanosoma anellobiæ* from *Pardalotus melanocephalus.*
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,, 40 Red cell from *Ptilotis fusca.*
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,, 44 Ditto (Leucocytozoon) from ,,
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ISSUED SEPTEMBER 30th, 1912.

Vol. XLV. **Part IV.**

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1911

PART IV., (pp. 445-555).

CONTAINING PAPERS READ IN

DECEMBER.

WITH EIGHT PLATES.

(Plates xxxiv, xxxv, xxxvi, xxxvii, xxxviii, xxxix, XL, XLI.)

Also with Abstract of Proceedings; Title Page, List of Publications, Contents, List of Members etc., and Index.

SYDNEY:
PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1912.

F. WHITE Typ., 344 Kent Street Sydney.

THE GEOLOGY AND PETROGRAPHY OF THE PROSPECT INTRUSION.

By H. STANLEY JEVONS, M.A., B.Sc., F.G.S.,
H. I. JENSEN, D.Sc.,
T. GRIFFITH TAYLOR, B.A., B.Sc., and
C. A. SÜSSMILCH, F.G.S.

[With Plates XXXIV - XXXIX.]

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

Part I. General Geology and Shape of the Mass.

By T. GRIFFITH TAYLOR and H. STANLEY JEVONS.

1. Introduction.
2. Bibliography.
3. General description of the mass.
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Part II. Petrography of the main mass and evidence of differentiation.

By H. I. JENSEN and H. STANLEY JEVONS.

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Part III. Segregation Veins.

By C. A. Süssmilch and H. Stanley Jevons.

17. Distribution of the Segregation Veins in the mass.
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I. Determination of the mode.
II. Restoration of the original mineral composition.

I. General Geology and Shape of the Mass.

By T. Griffith Taylor and H. Stanley Jevons.

1. Introduction.

In the midst of a gently undulating well wooded country, composed of Triassic (Wianamatta) shales, and almost at the centre of the great Permo-Carboniferous and Triassic basin of New South Wales, there occurs a massive intrusion of essexite (or dolerite) which displays many features of extreme interest, and which has been so well exposed by quarrying operations that it seems to merit a detailed description. The mass forms a conspicuous elevation—

named Prospect Hill—rising about 200 feet above the level of the surrounding country, and flanked on the west by the Prospect Reservoir, which conserves the water supply of Sydney. The hill covers an area of about 700 acres, and is situated immediately to the south of the main Western Road, some 18 miles from Sydney. It is accessible from Toongabbie station on the Main Western Railway, which lies nearly three miles to the north. The geological sketch map of the country in the vicinity of Sydney, published by the Mines Department of New South Wales, indicates the situation of the mass, and its relation to the neighbouring dykes and necks which are composed of similar basic rocks.

2. Bibliography.

Owing to the position of Prospect Hill on the once much travelled main western road, we find references to it, and brief accounts of its geology, very early in the history of the State. Since the large quarries were opened, Prospect has been a favourite haunt of geologists, yet no systematic description of the whole mass of the eruptive rock has been attempted hitherto. The following is a list of the more important works containing notices or brief descriptions of the igneous mass at Prospect:—

P. Lesson—Voyage autour du monde, Paris, 1826; vol. i, p. 328.

M. Lesson made a journey to the Blue Mountains, and remarked " . . ce fait curieux d'une colline élevée, entièrement de dolérite, dont le pied est enveloppé de grès."

J. D. Dana—Report of United States Exploring Expedition of 1840.

In 1840 Dana spent some months in New South Wales, and made some very interesting investigations into its geology. The results of his work are embodied in the very rare volume giving an account of the above expedition.

Under the heading "Basaltic and Allied Rocks," (Lithological characters, page 497) he distinguished ten varieties of which the four following are found at Prospect:—

Variety (*a*). Tough compact black rock, no traces of crystallisation, ... a few grains of chrysolite may with difficulty be distinguished.

Variety (*e*). A dark bluish rock, finely porphyritic with small points (not tables) of felspar.

Variety (*g*). A porphyritic basalt in which augite and felspar are both distinct and some of the crystals of augite are a quarter of an inch long.

Variety (*h*). A felspathic rock consisting almost purely of thin tables of felspar aggregated into a moderately compact rock, with occasional geodes of smaller felspar crystals. Some small specks of augite appear disseminated through it and more resemble green earth than augite.

Further he made a very interesting note:—"At Prospect Hill the compact black basalt changes to a compact rock with disseminated points of felspar; next to porphyritic basalt with distinct crystals of both augite and felspar, and next to the felspar rock (*h*), in which augite is almost wholly wanting."

Dana also gives a sketch of columnar structure occurring at Prospect, and explains a peculiar type of decomposition, which will be referred to in a later section.

Rev. W. B. Clarke—Report on the Southern Gold Fields of New South Wales, 1860.

Clarke decided that Prospect Hill was composed of "magnetic diorite . . . . which is probably the summit of a concealed mass, submerged during the Carboniferous period;" and assigned the basaltic border variety to a much later intrusion. These views have not been upheld by subsequent investigation under more favourable circumstances.

T. W. Edgeworth David—Proc. Roy. Soc., New South Wales, 1896.

In his Presidential Address, Prof. David corrects Clarke's errors, and shows that "the dolerite graduates into the basalt," and that "both have intruded the overlying Wianamatta shales." There is also some description of the main type of rock, and its decomposition.

M. Morrison—Records of the Geological Survey of New South Wales, Vol. VII, pt. 4 (1904), p. 241.

A list of the dykes, necks and other masses of igneous rock in the neighbourhood of Sydney, with a detailed account of several of the less known localities. A list of literature on the subject is given, which was of service in compiling the present bibliography.

3. General Description of the Mass.

Prospect Hill rises sharply from nearly level country on its western, southern and eastern faces, but its northern slope is more gradual. As regards shape it may be compared in plan to a rude shark-hook, the shank lying to the east, the convex bend to the south. The depression in the centre is drained northwards by a small creek which ultimately finds its way into the Parramatta River. The accompanying map (Plate XXXIV), will convey a more accurate idea of the shape of the surface outcrop of the igneous rock, and indicates by means of rough contour-lines the elevation of the surface. The whole mass is nearly two miles long by one mile wide; and portions lying to the east and south—the "shank" and "bend of the hook"—are somewhat higher than the western part—the "barb."

Inspection of the map shows that there is an isolated area of Wianamatta shale surrounded by exposures of the igneous rock. Numerous sections show that nowhere in this patch is the shale more than a few feet thick, and that the igneous rock is everywhere continuous beneath it. Moreover, it is thickest about the centre and thins out in every direction against the surface of the intrusive, not excepting the direction of the confined valley by which the creek leaves the mass. Here for a short distance there is no actual shale to be found, though there is every reason to suppose that a connecting neck of shale may have existed until comparatively recent times. On its outer edges the intrusive mass abuts nearly vertically against the shale, as will be shown later. In shape, therefore, the igneous mass is a rather elongated irregular oval, its upper surface being depressed in the centre.

In composition the main mass of the igneous rock resembles the olivine-gabbros and dolerites (diabases), though, having only about forty-two per cent. of silica, it is more basic than their average by about four or five per cent. Its composition and association show, however, that, though poor in alkalies, it is in reality an essexite, similar to the essexites of Brandberg and Solvsberg. The essential constituents of the main Prospect rock are a violet-brown titaniferous-augite and an acid labradorite in about equal proportions (roughly 36% each), olivine (about 10%), ilmenite and magnetite (about 13%); and as accessories, sometimes increasing in importance, occur biotite and apatite. The outer envelope of the intrusive mass is a very dark compact grey rock, having the appearance and microscopic characters of basalt. Going inwards from the edge it passes gradually into a rock having the appearance of a very fine-grained dolerite, and the grainsize continually increases until it becomes fairly uniform in the central parts of the mass. Here the rock, when fresh, has a speckled black and white appearance, the individual crystals of augite and felspar being easily visible in the hand specimen; or, where partly decomposed, it has the chloritic green colour so well known in weathered dolerites. Immense veins of lighter coloured rock, reaching four feet thick, nearly white where fresh, but generally light greyish-green from decomposition, traverse the main mass, and catch the eye upon the walls of the quarries. These are aplitic veins, the final product of differentiation resulting from the cooling of the mass. Less obvious, but equally interesting, evidence of differentiation by other processes preceding the aplitic segregation has been obtained by Messrs. Jensen and Jevons in the course of their study of the proportional distribution of the minerals in different parts of the mass, and will be stated in the second part of this paper. An interesting series of decomposed products is found, and analcite occurs in such manner as makes it necessary to discuss the possibility of its being of primary origin.

Exposures of the igneous rock are numerous and good. By far the best section is given by the Old or Reservoir Quarry, situated on the westernmost slope of Prospect Hill, close to the eastern end of the great dam for which it provided the massive stone facings. As shown by the map (Plate XXXIV), a level floor has been cut nearly one hundred yards back into the hill, thus exposing a steep freshly cut face of rock three hundred yards long, by from seventy to eighty feet in height. A sketch of part of its face is given in the transparent sheet overlying Plate XXXV, which is a photograph of a part of its face. Other exposures on the W. and S.W. of the mass are afforded by some shallow workings a few yards S.E. of the south end of the Reservoir Quarry, and by Booth's Quarry a little further to the S.E. These afford excellent sections of the outer envelope of the intrusion and of the overlying shales. A little to the north of the centre of the mass, lies the Emu Quarry (so-called because it has been for some years worked by the Emu Plains Stone and Gravel Company).

The foregoing are the exposures which have provided most of the material, but there are a few other shallow workings, and numerous natural crags and outcrops of weathered rock, especially on the eastern ridge or "shank" of the hill. Our work has been hampered for want of exposures only in connection with determining the outer boundary of the mass, and in trying definitely to decide whether the inner area of shale is connected with the shale outside along the creek or not.

4. Shape and Thickness of the Mass.

The shape of the Prospect intrusion can be inferred from inspection of the map in conjunction with the cross section which accompanies it, and it is found to be peculiar and difficult to explain. The line of section shown upon the map (Plate XXXIV) passes nearly east and west through the centre of the mass, and was chosen as being that along which the exposures gave the most precise information.

In the middle of the intrusion is seen a thin layer of Wianamatta shale resting upon the outer layer of compact igneous rock, which we propose to call pallio-essexite,[1] which in turn rests upon the main mass of essexite. (Figs. 1 – 3). Both to east and west the junction of the intrusive rock with the shale rises, until first the pallio-essexite is uncovered, and then the essexite. Unfortunately no section

[1] The prefix *pallio-* has been adopted by Mr. Jevons as part of his systematic nomenclature of igneous rocks, to denote the compact envelope of rapidly cooled rock which encloses every intrusion, from *pallium*, a mantle or cloak. We see no reason why the use of this term should be confined to a particular system of nomenclature, and believe that it could be compounded with names at present in use with much advantage in clearness and brevity of expression. Thus *pallio-granite* would signify the rock, usually a quartz-porphyry, which occurs on the border of a granite mass a little way within the contact. Further from the junction the rock assumes the character of a granite-porphyry, and it might be denoted *sub-pallio-granite*. It is also convenient to use the word *pallium* to denote the compact outer envelope of a mass without special reference to the kind of rock which composes it.

showing the junction of the igneous rock with the shale on the periphery of the mass is anywhere exposed, hence only hypotheses can be advanced concerning its exact position, or angle of dip, at either end of the section. At the west end there is, however, some evidence, for shale was found *in situ* at the top of the bank of the cutting. Furthermore, one of us was assured by the Waterworks Engineer, Mr. Jacob, that the shaft which is on the line of the section AB was sunk entirely through shale. As an exposure of pallio-essexite occurs something less than 100 yards to the east of where the shale is found *in situ*, and as it is found from this point to follow the slope of the hill upwards until it gives place to the essexite, it seems rational to suppose that here the envelope of compact rock is dipping outwards, *i.e.* west, and at an angle a little steeper than the slope of the hill. If this be so, the junction with the shales must dip more and more steeply as it descends or else it would not avoid the shaft which is 50 feet deep. Probably the periphery of the mass has the vertical section shown by the hypothetical broken lines at the western end of the section. At the eastern end of the section, although there are a few exposures of pallio-essexite on the outer slope of the hill, there is not such clear evidence of the direction of the junction.

The position of the outer junction is difficult to determine on almost every side of the mass; but we have been to some extent guided in mapping by a rather sudden change of surface gradient from a steeper slope above to one more gradual below, which probably indicates roughly the change from harder to softer rock. At first considerable use was made of the change from the red soil of the igneous rock to the buff-coloured soil of the shales. This change is emphasised by the occurrence where the soils mix of peculiarly shaped calcareous nodules varying in size from that of a pea to that of a large compound potato, which latter they resemble in shape. Finding however, that the red soil could be traced in some directions right down to the bed of the creek, draining the valley on that side, we were at a loss to know how much to allow for surface creep, and came to regard the change of slope already mentioned as more trustworthy, except on the S.W. of the hill where the proximity of the Prospect Creek has led to considerable denudation.

The original spacial form of the intrusive mass may be inferred from the map and section. The mass was roughly oval in its horizontal extension. Its upper surface was depressed in the centre, and rose to a ridge all round, or nearly all round. Outside the ridge its surface probably fell everywhere steeply outwards. The under surface is nowhere exposed, and its shape is wholly a matter of conjecture. That the intrusive mass has roughly the form of a sheet seems probable, partly because of the well known tendency of basic magmas to lift strata bodily and spread out in horizontal sheets, but still more because the shales of the overlying central patch are almost everywhere practically horizontal, just as are the undisturbed shales throughout the district. Only in one place has a dip of as much as 10° been observed (in Booth's Quarry), and here the dip is nearly parallel to the surface of the mass. It is impossible that the cavity formed by the mere lifting of a block of strata, without bending or tilting, should have any other shape than that of a sheet of uniform thickness, though if the under surface of the block be not flat, it necessarily cannot be a flat sheet. The best conclusion from the available evidence seems to be that the Prospect mass was originally a sheet, shaped like a round bottomed oval dish with the convexity downwards.

As regards the thickness of the sheet there is no direct evidence; and the unfortunate scarcity of fossils in the

Wianamatta shales precludes the posibility of using palæontological zones to determine the horizon of the central area of shales. Indirect evidence, however, is available. The nearness of the outcrop of the underlying Hawkesbury Sandstone, located about five miles both to east and south, makes it almost certain that the Wianamatta shales which have an extremely small westward and north-westward dip, cannot be here more than at most 300 or 400 feet thick, whilst they may be only 200 feet thick. If the intrusive sheet were more than 300 or 400 feet thick it must therefore have lifted Hawkesbury Sandstone; but there is not the slightest trace of any sandstone beneath the shale of the central area, or even of the shale being of a sandy character. Remembering that the lower surface of the central patch of shale stands about 50 feet above the level of the surrounding country, we thus have 450 feet as the absolute maximum which we can allow for the thickness of the sheet; but a more probable figure would seem to be about 300 feet. There is nothing in the character of the rock exposed on the floor of the Reservoir Quarry, which penetrates deeper into the mass than any other exposure, which would lead one to suppose that this latter figure is an under estimate. The same quarry provides us with a minimum figure of about 150 feet for the thickness of the sheet, for at its northern end it extends at least 80 or 90 feet below the cooling surface, and there is no sign of the grainsize beginning to get finer again at the bottom.

Whether the intrusion more probably took place through a fissure or a pipe we cannot say, for both these forms of conduit are common in the district. The position of the supply pipe or fissure is also uncertain. It may be under the south-east portion of the hill, because this is the most elevated and massive, or it may more probably, as will be shown later, be beneath the central area of shale.

5. Manner and Mechanics of Intrusion.

An attempt to elucidate the manner in which the intrusion took place may not be without interest. The locality is near the centre of the great Permo-Carboniferous basin, and the magma may be presumed to have been forced upwards through about 13,000 feet of marine and coal measures, and about 2,000 feet of Triassic strata, by an earth movement which was probably continuing the warping of the basin, and produced a widespread igneous activity, which will be referred to again. Whether the magma ascended by a fissure or a pipe, soon after leaving the Hawkesbury Sandstone it reached such a level in the shales that the weight of the superincumbent strata became less than the upward lift of the magma. The latter then tended to spread laterally. For some reason, however, it did not follow the horizontal bedding planes, as in an ordinary sill or lacolite, but spread in a conical layer, lifting, through a height of 300 feet or more, an oval portion of shale with a rather rounded shallow conical base convex downwards, 700 acres (280 hectares) in area.

A question difficult to settle is whether the overlying shale was dislocated and faulted up as shown in fig. 1, the corners being rounded off by assimilation or engulfing of of fragments, as indicated by the broken line, or whether the strata were sharply bent as shown in fig. 2. In favour of the hypothesis of bending is the fact that on all sides, wherever the pallio-essexite is visible, it dips outwards gradually. This is particularly noticeable on the northern slope of the mass, and to account for its development by assimilation from a vertical wall, as in fig. 1, would postulate a greater amount of assimilation than petrographical evidence seems to admit. On the other hand, against the hypothesis of bending is the fact that no exposure of shales with an outward dip has been found. It is true that with

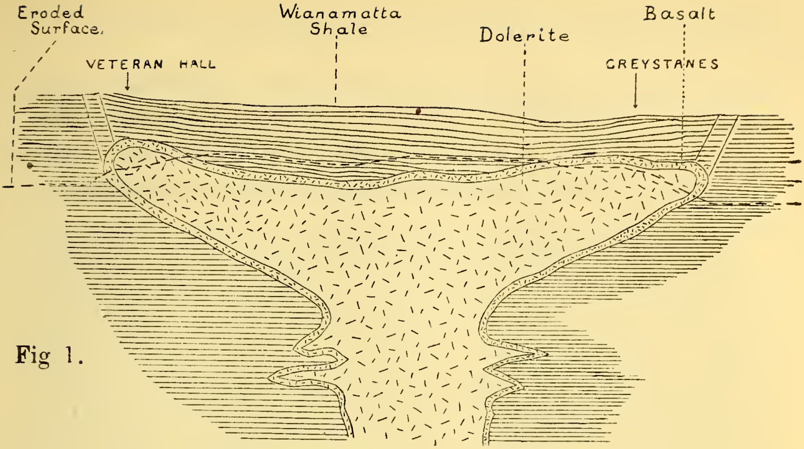

Fig 1.

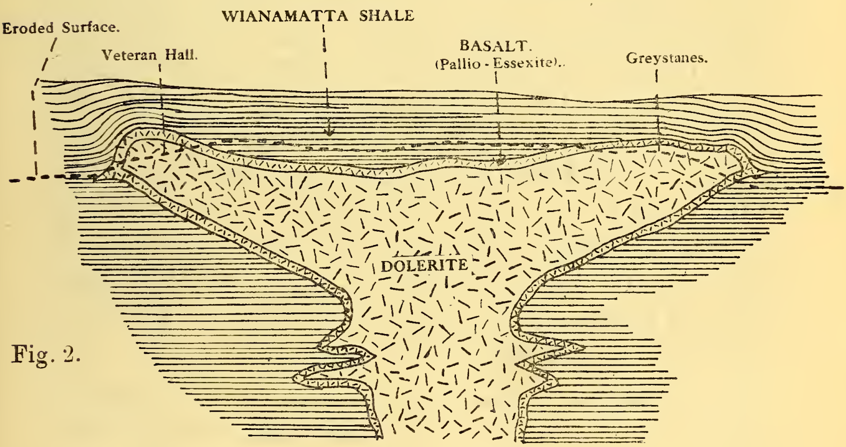

Fig. 2.

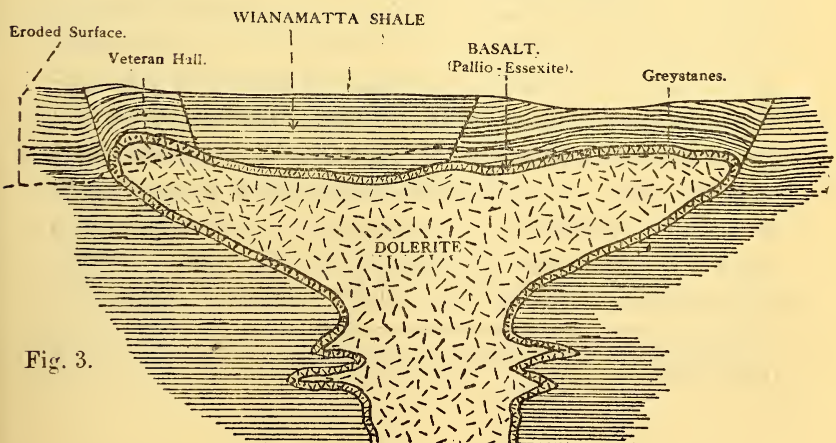

Fig. 3.

the exception of exposures on the western edge of the mass, there are hardly any at all to be found close to where the junction is supposed to lie; but these exposures on the west are certainly very close, and must be allowed due weight.

The most acceptable explanation of the facts would seem to be a combination of bending and dislocation of the shales. As the magma crept outwards and slightly upwards, a point would be reached where the thickness of the shale over the periphery of the intrusive sheet would have become too thin for its cohesive strength to resist the upward lifts of the magma. It would then bend at first, but as the magma continued to rise it might very well be dislocated at the furthest point reached by the magma, that is, where the bent strata abut on the horizontal undisturbed shales. This hypothesis is illustrated by the diagrammatic section in fig. 3. In its favor the principal fact is the outward dip of the upper junction near the periphery. The absence of any existing shales with an outward dip is easily accounted for by the extent of the denudation which has taken place, which, as the line indicating the eroded surface will show, must have entirely removed them.

The mechanics of intrusions are as yet but very partially understood. The magma may apparently either flow into a cavity or fissure which is being opened by earth movements, or it may make its own cavity, and this in several ways. It may shatter the rocks, and dispose of the fragments by assimilation or engulfing;[1] it may force the strata gradually upwards, either by faulting, acting like a hydraulic ram, or by folding, producing a kind of huge blister as in laccolites; or it may float up a block of strata when it reaches a level determined by the relative specific gravities of the country rock and the magma, as is supposed

[1] See Daly, Mechanics of Igneous Intrusion, Amer. Journ. Sci., Vol. xv, (1903) p. 272.

to have been the case in the great dolerite (diabase) sills of Tasmania, and others. There was undoubtedly a certain amount of assimilation of the country rock by the magma at Prospect, as will be shown later by petrological evidence. The shales cannot, however, have been melted up in quantity sufficient to make any appreciable difference in the size of the chamber, for the main mass of the rock is distinctly basic (about 42% SiO_2) and the shales are rather siliceous containing probably over 65% of silica.[1] The engulfing of fragments torn from the roof by their sinking through the magma is not a way in which the cavity can be enlarged, but by which the latter may rise through overlying strata, for what is taken from the roof is added to the floor. We do not think such overhead stoping a probable feature of the Prospect intrusion. A large fragment of shale, twisted as it was torn from the roof, may be seen in the Reservoir Quarry suspended in the solidified magma only one metre or so below the rock from which it was torn (Plate XXXV). This mass must have been wrenched from the roof before consolidation of the magma on the outer surface began, and already then the specific gravity of the magma had become too great to allow the shale to sink, for the viscosity of a basic and hydrous magma soon after intrusion cannot have been great enough to prevent sinking. It would be strange then, if many such masses were torn off, that we find no others, either high or low in the reservoir quarry or elsewhere. If on the other hand, engulfing had taken place when the magma was still much too hot for solidification to begin even at the edges, it would have been hot enough to produce more assimilation than we observe.

[1] We have no analysis of the shale in the immediate vicinity of the Prospect mass, but analyses of Wianamatta shale, quoted in Pittman's Mineral Resources of N.S.W., p. 433, from near Parramatta and from Cook's River, both within eight miles of Prospect, show 85·3 and 71·0 per cent. respectively. The shale at Homebush contains 65·96%.

The formation of the chamber containing the Prospect rock would seem to have been due to the hydrostatic (or magmastatic) pressure produced in the magma by compression of a deep-seated reservoir by earth movement. As the shales did not fracture, and thus allowed the magma no way through them, they were forced up. The pressure of contained gases cannot, of course, become effective in moving a magma or containing rock until the pressure has fallen sufficiently for the gases to be released in steam-holes, which often never happens. The escape of contained gases played a very unimportant part at Prospect for vesicles, empty or filled, are found but rarely, and consequently pressure caused by deep-seated compression must be regarded as having been the operative force. The action might be well illustrated by filling a strong india-rubber bag completely full of soda-water under pressure (to represent the contained gases), so that no gas-filled space remained. Then, if the lower part were squeezed, the upper part would perforce swell out wherever it were weakest. The squeezing produces an increase of pressure, which is thus at once relieved, and the contained gas plays no part whatever in the expansion of the upper part of the bag.

On the other hand, should a fracture form in the overlying strata a magma will rise through it to the surface, or as high as the pressure will raise it. The fissure must be about 60 cm. (two feet) wide at the least, however, or the magma cools so rapidly that the passage is soon sealed up. Any block of strata surrounded by fissures wide enough to contain liquid magma may be floated up if the magma rises high enough. At Prospect, if the strata were fractured after being bent, as suggested, (fig. 3), it is unlikely that the fracture would produce a fissure wide enough to allow the magma to rise high enough in it all round to float the block of shale. The only condition which would seem to permit floating up would be the formation of a conical fracture by the forcing up of the magma, so that any raising of the block of shales would widen the fissure. Calculation shows that taking the density of the liquid magma as high as 2·9 (solid 3·06), and that of the cold shale as low as 2·5, and assuming the thickness of the sheet at that minimum possible, viz. 150 feet, the top of the intrusive sheet must have been more than 900 feet vertically below the level of the surrounding country."[1]

Independent evidence will be quoted in Section 6 to show that the depth of the sheet of magma is unlikely to have been more than 600 feet, or at the very most 800 feet, hence the hypothesis that the cavity of the Prospect mass was formed by floating up a block of shales appears unlikely.

Our conclusions as to the solid form of the Prospect mass may be taken as summarised by fig. 3, if this section be regarded as crossing the mass along its shorter axis, *i.e.*, E.N.E. and W.S.W. (magnetic). On account of the oval shape of the mass a section through its major axis would be longer, and the dip of the sheet less. In form the mass is not unlike a shallow oval funnel, if we assume a central supply pipe; and if we suppose the funnel made of enamelled

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[1] Let x be the depth of the top of the sheet below the undisturbed ground level, then $x + 150$ is the thickness of the upraised block, and, assuming the fissures to be filled to the ground surface, we have:

$$\frac{x + 150}{x} = \frac{2·9}{2·6} \text{ and } x = 937·5$$

The value of x would be diminished if the specific gravity of the liquid magma were taken higher and that of the shale lower, but the maximum and minimum figures respectively have been used which appear to us conceivable for these specific gravities. Very probable figures are 2·55 and 2·8 for the shale and magma respectively, which give x = 1,530 feet. Our knowledge of the specific gravities of magmas, that is, of the volume change on fusion, and with rise of temperature, is still too uncertain (Harker, Nat. Hist. Igneous Rocks, pp. 158-9) to admit of more accurate calculation.

iron, the iron may represent the coarse rock, and the enamel the compact outer envelope or pallium. An appropriate name for a form of intrusion so unusual is by no means obvious. It is not a thick sill, as it does not follow the bedding planes; it can hardly be called a laccolite without considerably stretching the definition of that term, though in its mode of formation it does bear a considerable affinity to intrusions of that class; and probably it is not nearly thick enough to be called a boss. Hence none of the recognised names are applicable. It is not usual to include the supply pipe in the conception of the form of a mass; and the likeness of the form of the Prospect mass to a round-bottomed oval dish may perhaps justify its being termed a dish-shaped sheet.

As has been stated already, the magma lifted a block of shale with a bottom convex downwards,[1] but the reason for this peculiarity of shape has not yet been approached. Two explanations may be suggested. Professor T. W. E. David has explained to us in conversation that he regards a shallow cone as a very likely shape for a fissure caused by a magma rising very rapidly—almost with explosive violence. He quotes in illustration of this view the fact that when a heavy piece of roofing slate is smartly struck near the centre by a blunt iron point an obtusely conical flake of slate is pushed out on the other side. The magma, rising from the Hawkesbury Sandstone with sudden violence, might quite conceivably strike the overlying shale with such force as to weaken it along the surface of a shallow cone, which would then naturally provide the easiest path along which the magma could spread. The oval shape of the cone could be explained by assuming that the magma rose from a widened fissure.

[1] See above and the section in figs. 1 and 2, also Plate XXXIV.

A somewhat more elaborate explanation is ventured by us, though merely as an hypothesis. Since the intrusion is most probably of Tertiary age, as will be shown later, it may be assumed that the drainage of this portion of the country was practically the same as it is now, even in detail, where undisturbed by local causes. It is possible, then, that the magma in making its way upward through a pipe or fissure, happened to issue from the sandstone beneath a minor, or tributary, valley. Now the hydrostatic pressure exerted by the magma would suffice to lift a given weight per square foot, and thus a given vertical thickness of shale, but no more. The magma would start to lift the shales immediately over the pipe, and would then begin to spread out. It could not, however, spread horizontally; for, as the surface of the ground rose on either side, that would involve lifting a greater thickness of shale than was possible. It would be able to spread only along a surface always at uniform depth below the surface of the ground. Thus the under surface of the block of shale lifted would conform exactly to its upper surface. Were this so, we should expect the shape of the mass not to be that of a dish with a rim of uniform height all round, but to show two depressions in its rim where it was crossed by the overlying valley bottom. Some such depressions do indeed exist—one to the south running into Booth's Quarry, the other to the north, occupied by the existing valley which drains the central area of the hill (See Plate XXXIV). That this latter was a real depression in the ridge of the intrusive mass, and has not merely been eroded, appears from the trend of the layer of pallio-essexite, and by the disposition of the shale, which was almost certainly continuous through this valley in geologically very recent times. The other irregularities of the surface of the igneous mass, to the N.W. of Booth's Quarry, are not easily explained, though they might represent minor channels or drainings to the Prospect Creek. The striking conformity of the modern ground surface to the upper surface of the eruptive rock is probably due to hardening of the shales.

A study of the drainage of the neighbourhood of Prospect Hill has convinced us that the intrusion reversed the slope of the creek now flowing through it. The latter finds its way northwards into the Parramatta River, whilst the larger creek to the S.W. of the mass, named Prospect Creek, flows into the George's River. Inspection of the map (Plate XXXIV) shows that Prospect Hill encroaches on the basin of the Prospect Creek right up to the banks of that stream itself. It is probable that originally the northern watershed of this basin in this neighbourhood lay just south of the main Western Road, and that a creek flowed from somewhere near here southwards, more or less along the floor of the present valley, but somewhere to the east of the existing creek, over the line where the inlier of shale now reaches its lowest level. The old creek must have crossed Booth's Quarry towards its east end; and it may not be extravagant to regard the well-marked gully which runs S.S.E. from this quarry as an actual remnant of the creek. At least 500 or 600 feet depth of shale must have been removed since the reversal of the drainage, as will be explained in a later section, but there is no reason to suppose that denudation need involve any lateral shifting of stream beds where we are not dealing with strike streams. The whole theory of superimposed drainage as usually stated, involves the assumption of comparatively little lateral shifting over long ages. The watershed of the valley to the east of Prospect Hill has probably also been shifted a mile or so southwards.

The reversal of drainage is no argument for or against either Prof. David's or our own hypothesis. The former applies whether there were an overlying valley or not; the latter requires only that there be a valley, its direction of dip being immaterial. In either case the tilt of the upraised block necessary for the reversal of drainage would result from the sheet of magma becoming only some 50 or 60 feet thicker at the south end than in the north central part, where the creek leaves the mass; and this thickening of the sheet might possibly be accounted for by the feeding fissure being somewhat wider, and thus providing a faster flow of magma, at the south than the north.

It may be noted that acceptance of the hypothesis we venture to offer carried to its logical conclusion would account for the formation of the cavity of the intrusion by the folding of the strata around its edge, if we assume that the valleys were somewhat more steep-sided at that time than now, owing to the then probably greater elevation of the land surface above sea level. It may be granted, we think, that the magma, when it began to spread out, can have had only sufficient upward pressure to produce a small elastic deformation of the shales, whilst lifting them. It overcame their cohesion, and fractured or bent them, only in detail, as it broke across the bedding; but had not sufficient force to break or bend the whole thickness of superincumbent strata. The shales would be in a condition of elastic strain only over a broad marginal zone of the advancing sheet, and not over its whole surface, the strain being at each spot relieved successively by the bending of shale further on. Thus the sheet would be thin and of uniform thickness over most of its area, but wedge-shaped around the edge, as in the case of any ordinary sill. On penetrating outwards and passing beyond the divides, the magma would cease to find its horizontal progress along the bedding planes checked by an increasing weight to be lifted, and it would now begin to spread out horizontally. As the surface of the ground was now sloping down towards the still advancing edge, the thickness of overlying shale was diminished; and the pressure of the magma could, therefore, cause it to undergo an increased elastic deformation, which allowed the sheet to become thicker. Still further advance would cause the bending pressure to be beyond the elastic limit of the now thinner covering of shale. The shale would fracture or shear in innumerable places, producing a monoclinal fold; and the magma would then advance no further horizontally, but begin to lift the whole covering of shales by thickening the sheet. If the pressure of the magma was not sufficiently relieved by the folding of the shales, they probably continued to rise by the formation of a clean fracture, or fault, producing the structure shown diagrammatically in fig. 3. The point of this explanation is that the folding of the shales which was shown above to be the most probable explanation of the peculiar form of the intrusion, is accounted for by the magma passing outwards on two sides at least beyond the divides of neighbouring valleys. The ridges of the intrusive mass would thus lie nearly under these divides; and the main watershed between the Parramatta and George's Rivers may have passed under Clump Hill. The south side would be the only one on which the surface of the ground had not a rising, but a falling, gradient immediately the magma sheet began to expand from its centre; hence in this direction the magma would travel horizontally along the bedding planes of the shales, and reach the depth shallow enough for it to fold the shales sooner than in other directions. It would thus tend to swell up here before the folding was produced in other parts, and give the overlying shale at this point an inward dip. This view affords an explanation of two important facts: that the covering of shale is observed to have an inward dip of 10° at Booth's quarry (the probable point where the old valley crossed the edge of the intrusion), whilst at the Reservoir Quarry and all other points the shale abuts horizontally on the intrusive; and secondly that the southern portion is the most massive and elevated part of the intrusion.

6. Age of the Intruded Mass.

The Prospect essexite consolidated in Upper Triassic strata, hence all that can be said with confidence of its age is that it is Post-Triassic. By comparison with igneous rocks whose age can be determined with more certainty, however, there is ground for supposing that the intrusion took place in early Tertiary time.

Examination of the Post-Triassic igneous rocks within and around the edge of the Triassic basin of New South Wales reveals a remarkable consanguinity, all of them belonging to the alkaline series. The acid and intermediate rocks are obviously alkaline, being ægirine-trachytes, nepheline-syenites, etc., whilst recent researches of Messrs. Card and Mingaye have shown clearly that all the basalts of the Blue Mountains, and the numerous basalt-dykes and necks nearer Sydney, so far as examined, have a distinct alkaline character.[1] There is reason to believe that all these eruptive masses owe their origin to the same period of igneous activity, probably connected with the upheaval of the Eastern Cordillera. It is necessary to consider, however, whether there may not be evidence that there was more than one period of activity.

Mr. E. C. Andrews, in his papers treating of the Tertiary history of the New England Plateau (N.S.W.), finds that the great basalt outpourings in that district fall into two periods. He also mentions the probability of two periods of basaltic eruptions in the Blue Mountain district, separated by a considerable interval of denudation.[3]

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[1] Rec. Geol. Surv. N.S.W., VII, pt. 3, pp. 226 and 236.

[2] Rec. Geol. Surv. N.S.W., VII, pt. 3, (1903) p. 197, and pt. 4 (1904) p. 293.

[3] *Loc. cit.*, p. 216.

The Post-Triassic acid and intermediate flows and intrusions on the periphery of the Triassic basin may perhaps be hypothetically assigned to some part of the same period of activity; and the same may be said with more confidence of the basic intrusions of the centre of the basin. The basaltic rock composing the dykes and necks between Sydney and the Blue Mountains, and also the compact outer envelope of the Prospect Mass, resemble the basalts of the Blue Mountain and Moss Vale districts so closely that they are frequently quite indistinguishable one from another in thin sections under the microscope. The color, habit and proportions of the minerals, and the rock-fabric, are exactly the same, hence there seems to be little doubt that the intrusion of the Prospect essexite may be referred to the same period as the extrusion of the great lava flows to the W. and S.W.

The age of the great basalt outpourings is fortunately determined approximately by the old river gravels and clays which they covered. In the deep leads of Gulgong, near Mudgee, and beneath the basic flows of Wingello near Moss Vale, have been found deposits containing leaves of *Cinnamomum* and other plants of Upper Tertiary character. The vast basalt flows of New England are assigned by Mr. Andrews to the Middle Tertiary.[1] We shall probably then not be far wrong in assigning to the Prospect intrusions a Tertiary Age.

7. Depth of the Intrusion.

The grainsize of the Prospect essexite, and the thickness of the compact and fine-grained envelope, as well as the nearly idiomorphic shape of the felspars, all point to the hypabyssal character of the intrusion. It is possible, however, to obtain some more definite idea of the depth beneath the then existing surface at which the mass consolidated.

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[1] *Loc. cit.*, p. 197.

In the previous section the contemporaneity of the intrusion of the Prospect mass with the volcanic outbursts of similar rock in the surrounding region was shown to be very probable. Some twelve or more volcanic necks are known within a radius of 40 miles from Sydney. Most of them are filled with agglomerate consisting of decomposed basalt and fragments of sedimentary rocks, chiefly Hawkesbury Sandstone, but four contain solid plugs of basalt in addition to agglomerate.[1]

In the Blue Mountain region, as in New England, a moderate uplift, of about 400 feet in the Blue Mountains, was succeeded by a long period of quiescence (Mr. Andrews' "Plateau Cycle"); and the great volcanic outburst of basalt appears to have coincided with the earlier part of the slow, but nearly continuous, great uplift of 3,100 feet.[2] It is reasonable to suppose that the warping of the Triassic basin took place coincidently with these uplifts; hence the Triassic strata were probably slightly flexed before the intrusion of the Prospect mass, but considerably more so afterwards. The greatest depth which has been proved in the Wianamatta shales is 800 feet found in a bore at Penrith.

If we assume that at the time of intrusion the base of the Wianamatta shales was 100 feet lower at Penrith than at Prospect,[3] and that the previous cycle of erosion had produced a fairly level surface between the Blue Mountains and Sydney, not much more undulating than we find at the present day, then there must have been about 100 feet less

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[1] M. Morrison, Dykes and Necks of the Sydney District, Rec. Geol. Surv. N.S.W., VII, pt. 4, p. 273.

[2] Andrews, Proc. Linn. Soc. N.S.W., 1903, pp. 803-6.

[3] This difference of level corresponding proportionally to the uplift of the Blue Mountains before and after the great volcanic outburst. We assume the shale to have been horizontal before Andrews' first uplift (Plateau Cycle).

of Wianamatta shale at Prospect than at Penrith. An estimate of the thickness of shale removed in the neighbourhood of Penrith since the intrusion is now necessary to give us the thickness of shale at Prospect. Penrith lies nearly over the synclinal axis of the elongated basin, and the ground in that district must have been gradually sinking, or at least have remained stationary, whilst the country to the east and west was rising. It is very unlikely, therefore, that denudation of the shales had been rapid here since the time of the intrusion, and the removal of the 200 feet of shale seems to be the utmost that can be allowed. If this be granted, the thickness of the shale at the time of the intrusion cannot have been more than 1,000 feet at Penrith and 900 feet at Prospect.

If we next assume that the Wianamatta shales are now only 200 feet thick at Prospect—a very moderate estimate—and allow 100 feet for the height which the top of the intrusion must have stood above what is now the surface of the surrounding shales, we have remaining 600 feet as the depth at which the top of the intrusion must have lain below the surface level of the surrounding country. Taking the thickness of the intrusive sheet, as 300 feet as was before seen to be probable, and remembering that the shales must have been lifted to this amount over the sheet, we have the figure 900 feet as probably the approximate thickness of the shales which covered the intrusion.

It is more satisfactory to try and fix limits to the depth of the original shale-covering than to advance a single figure. It will be noticed that the assumption of greater denudation at Penrith increases the figure, whilst the assumption of more warping before the intrusion reduces it. To obtain the maximum, assume that 300 feet of shale have been removed at Penrith, which is hardly conceivable, and that there was no warping at all prior to the intrusion, and we obtain 800 feet as the greatest possible depth below the surface of the surrounding country, and 1,100 feet as the corresponding covering of shale. The minimum may be found by assuming only 50 feet denudation at Penrith, and 200 feet of previous warping, giving 350 and 650 feet below the general surface level of the country, and for the thickness of the covering respectively. On the whole perhaps some such figures as 500 and 800 are the most probable, for it is extremely probable that warping of more than 100 feet had taken place prior to the intrusion, whilst the existence of a large flood plain of the Nepean Hawkesbury River at Penrith shows that denudation there has been slow.

II. Petrography of the Main Mass and some Differentiation Products.

By H. I. Jensen and H. S. Jevons.

8. General Petrology of the Mass.

A brief account of the constitution of the main rock of the Prospect mass has already been given. This part of the paper will be devoted to a detailed description of several typical specimens, to an account of the characters of the minerals composing the rock, and to a description of the variations in composition of the rock in different parts of the mass. The more important of these variations are found to be a greater richness of olivine in the quickly cooled envelope, with a corresponding difference in chemical composition, and an increased proportion of ilmenite in the lower part of the main mass, so far as exposed, and also to some extent in the neighbourhood of the large aplitic veins. The evidence of assimilation of the country rock, and the decomposition products, including the origin of the analcite will also be discussed.

The main rock is phanerocrystalline and medium-grained the average grainsize being between 1 and 5 mm. In the heart of the mass the grainsize is in many places as much as 5 mm.; but the pallio-essexite is aphanitic, though still holocrystalline, and wears the aspect of an ordinary fine-grained basalt. The colour of the main mass of rock varies somewhat from point to point; for instance, above the uppermost of the large aplitic veins (Plate XXXV) in the Reservoir Quarry the rock is much darker in colour than below. This difference in colour is probably due to degree of kind of decomposition. In places the compact pallio-essexite has been denuded away, allowing water to filter into the more coarsely grained rock underlying it. This coarser rock is much decomposed because it is permeable to water through the minute contraction crevices separating the crystals, and the water obtains ready access along the many joints which divide it. On the other hand, the rock underlying the aplitic veins is much less jointed, and is accordingly less decomposed. The pallio-essexite near the junction with the shale is very fresh, not having undergone much jointing, and being also protected by its own compactness, and by the band of chert into which it has altered the overlying shales.

The specimens of which systematic descriptions will here be given were chosen with great care from such localities that their examination might be instructive as regards changes in composition in different parts or the mass, and yet that they might be taken from the freshest rock available. It has seemed convenient to divide the specimens into three series according as they were taken:—I, from the Reservoir Quarry, II, from the Emu Quarry, III, from various other points on the mass. In each of the first two series certain typical specimens will be taken in order from the edge inwards according to distance from the nearest junction, and will receive a full description, and other specimens will be compared with them. The proportions of the mineral constituents of the rocks have been determined, not only by calculation from the analysis[1] in all cases where one was available, but also by measurement according to Rosiwal's method. In one column are given the proportions of the minerals by weight after restoration of the original minerals from the decomposition products as far as possible.[2] This restoration naturally involves a certain amount of hypothesis as to the course of decomposition, but the figures so obtained give a much better idea of the original constitution of the rock than any which include the decomposition products. The minerals are always placed in the order of decreasing abundance. In another column in smaller type are stated the figures from which the restorations are made; namely, the proportions by volume of the primary and secondary constituents, as obtained directly from the figures of the measurements, multiplied by their respective specific gravities, and reduced to percentages.

Series I. Reservoir Quarry.

Specimen B.

Locality: S.E. end of Reservoir Quarry, 30 cm. (12 inches) below junction with shale.

Megascopic Description. Colour dark bluish-grey, with typical basaltic appearance; light reddish-brown on decomposed joint surfaces. Fracture subconchoidal.

Microscopic Description. Texture: Crystallinity holocrystalline; grainsize, porphyritic in olivine (phenocrysts 0·15 to 2 mm. long), base very fine and even grained (about 0·12 mm.); fabric pilotaxitic.[3]

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[1] The method of calculation is fully explained in Appendix I.

[2] For the method adopted in restoring the original constituents of the rocks see Appendix II.

[3] The term *pilotaxitic* is used throughout this paper in a sense perhaps rather more extended than the original definition of Rosenbusch. It is applied to any rock of whatever grainsize in which idiomorphic prisms or tables of felspar lie in all directions, the interstices being filled up with grains of ferro-magnesian minerals, both idiomorphic and not, having no parallel optic orientation.

Minerals present. Stated in order of decreasing abundance, the minerals present, and their proportions by weight after allowance for decomposition, are as follows:—

Calculated from Analysis.		Rosiwal Method. By weight as measured.		Rosiwal Method. Corrected for decomposition.
Plagioclase	38·1	Felspar	29·2	32·8
Orthoclase	1·1	Augite	32·0	31·4
Augite	30·4	Olivine	11·5	17·4
Olivine	14·2	Serpentine	8·6	...
Biotite	11·5	Biotite	12·0	11·8
Ilmenite	3·2	Iron ores	6·6	6·5
Magnetite	·5	Shales	0·1	0·1
Apatite	1·0			
			100·0	100·0
	100·0			

The augite is purplish brown in colour, and includes much magnetite in minute octahedra.

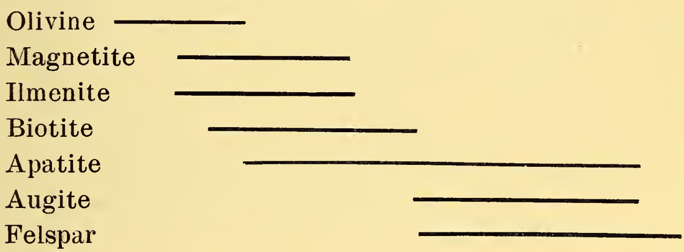
The labradorite occurs in tabular habit, giving mainly lath-shaped sections. It is zoned, but all of it appears to have a refractive index (R. I) well above that of balsam.

The olivine phenocrysts are numerous, and are nearly idiomorphic. They are free from inclusions of iron ores or apatite except on the edges, and they are decomposed to an olive-green serpentine mostly only along cracks.

The analcite is very rare in some parts of the slide, and its presence does not seem in any way dependent on decomposition, as it is often abundant in roughly rectangular patches in parts where chloritisation and serpentinisation are not to be seen.

A certain amount of carbonate of lime is present in the rock, as was proved by testing it with hydrochloric acid under the microscope. Strong effervescence was observed particularly in the vicinity of hematite, leucoxene, and visible patches of analcite. Staining with eosin, the gelatinous silica produced by the action of the acid showed that analcite and zeolites are most abundant in the same patches, though undetected by optical tests alone.

Order of Consolidation. The conclusions regarding the order of consolidation of the minerals obtained by a careful study of the slide are best exhibited in the form of a simple diagram, in which the periods of crystallisation of the several minerals are indicated by horizontal lines opposite their names, showing by their length and position the duration and the order of beginning and ending of the periods. Time is represented by horizontal distance from left to right.



Chemical Composition. By kind permission of Mr. E. F. Pittman, Government Geologist of N.S.W., three analyses were made for us by Mr. J. C. H. Mingaye, Analyst to the Department of Mines, and his assistants. The first of these to be quoted was made from the greater part of the same specimen from which the slide here described was cut. The analysis will be found stated in full in a later section ; it is sufficient here to give the proportions of the essential constituents, they are as follows :—

SiO_2	46·26	CaO	9·18
Al_2O_3	13·36	Na_2O	2·27
Fe_2O_3	2·34	K_2O	1·23
FeO	10·53	Total H_2O	2·23
MgO	8·87	TiO_2	1·78

Compared with analyses of ordinary olivine basalts this rock is seen to be rather poor in alumina and lime, and somewhat rich in soda and ferrous iron. In many respects it agrees more closely with analyses of nepheline basanites, and in some degree resembles those of monchiquites.

Specimen A.

This specimen was taken from the same locality as Specimen B. just described, but only 15 cm. (6 inches) from the junction with the shales instead of 30 cm. (12 inches). The rock is so similar to rock B that there is no reason for describing it in full. It differs from B in having rather less olivine and rather more labradorite. Well rounded fragments of shale are more abundant, and the biotite seems in this slide to be rather more abundant where shale has been absorbed. A complete zone of ferro-magnesian minerals—biotite, augite, and hematite—often surrounds much absorbed pieces of shale. The shale fragments appear under the microscope to be of very fine granular texture and in colour a cloudy grey; between crossed nicols they are opaque.

Locality: Reservoir Quarry, about centre of main face, a few feet below and to the right of the detached mass of shale (see Plate XXXV). Obtained from 4½ metres (15 feet) below the junction with the shales.

Megascopic Description. Colour dark greenish-grey, like the rest of the rock from this zone in the quarry. Minerals—Augite and plagioclase are distinguishable in the hand-specimen, and flakes of biotite are also recognisable.

Microscopic Description. Texture: Crystallinity, holocrystalline. Grainsize variable, from about 0·3 mm. to 1·0 mm., average 0·6 mm.; fabric pilotaxitic, inclining towards ophitic.

Minerals Present.

Corrected for decomposition.		By weight as measured.	
Felspar	44·8	Felspar	35·1
Augite	34·2	Augite	34·2
Olivine	8·2	Serpentine	12·4
Biotite	7·1	Biotite	7·4
Iron Ores	5·6	Iron Ores	5·8
Apatite	0·1	Analcite	4·9
		Chlorite	0·1
	100·0	Apatite	0·1
			100·0

Specimen C.

As the composition of this rock appeared very constant throughout, only a small number of crystal measurements (about 150) were made. Careful microscopic examination shows that a little chlorite and chloritoid are mixed with the serpentine, hence in correcting for decomposition the chlorite has been taken as 0·8 and the serpentine as 11·7.

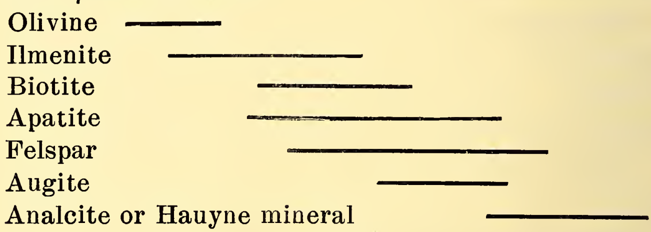
The augite is pinkish-brown in colour, hence titaniferous, and sections vary in outline from idiomorphic to hypidiomorphic. Both augite and felspar contain inclusions of apatite and biotite, and sometimes of ilmenite.

The plagioclase varies from oligoclase to basic labradorite. Many of the larger crystals show zoning, the extinction angle varying from the outside inwards. The felspar is a good deal decomposed, being penetrated by strands of chlorite, and in the more acid parts by broader veins of analcite.

The analcite contains inclusions of apatite (see Plate XXXIX, fig. 3), and occurs both where decomposition has been great and where it has been slight. In some cases it is undoubtedly secondary after felspar, in other cases there is no evidence to prove its secondary origin. In the latter cases augite, serpentine pseudomorphs and felspar present idiomorphic outlines towards patches of analcite which are fairly regular in shape. Even in these cases we find numerous needles of apatite included in the analcite proving that it must have been either secondary after felspar or some other mineral, or an original product of crystallisation of the magma or of the magmatic waters, and not a later decomposition leached out and lodged in steam cavities. Analcite of this kind is shown in a photomicrograph (Plate XXXIX, fig. 3). It is the proportion roughly estimated of analcite in this latter more regular form which is included in the above statement of the proportions of minerals in the restored rock.

The decomposition products are serpentine after olivine chlorite and chloritoid in small hexagonal scales of bluish colour and part at least of the analcite; hematite and calcite in small quantities, and a zeolite, probably stilbite (heulandite), possibly secondary after analcite.

Order of Consolidation.



Specimens D, E, F, G, H.

Specimens D and E are very similar to C, but contain considerably more ilmenite. Biotite and pseudomorphs of serpentine are still plentiful. Specimens F and G were obtained just below the upper aplitic vein in the S.E. end of the quarry. They contain much more ilmenite than either D or E, and rather less biotite. All of these rocks are too decomposed for measurement by the Rosiwal method.

Examination of sections of these specimens brings out the fact that biotite and pseudomorphs of olivine decrease in abundance as we proceed downwards from the outer compact envelope, whereas ilmenite is on the increase.

The maximum percentage of ilmenite is found in certain bands near the upper aplitic vein.

Specimen H was obtained beneath the aplitic vein, where it thickens near the middle of the quarry face (see fig. 4). It is similar in most respects to specimen C, but biotite is very rare. Apatite, on the other hand, is much more abundant—a feature which seems to be a general rule in the vicinity of the aplitic veins. The rock is rather decomposed and contains a good deal of analcite, which appears to be all secondary after plagioclase.

Specimen I (J and K *idem.*)

Locality. A little below the lower aplitic vein a few metres to the left of where this begins to rise. The specimen is typical of the greater portion of the rock underlying the aplitic vein in this quarry, and came from about 18 m. (60 feet) below the junction.

Megascopic Description. Colour grey. Grainsize fairly coarse. Minerals: augite, plagioclase, ilmenite and analcite, are easily recognised with a pocket lens. The rock is fairly fresh—the least decomposed sample of the coarse rock which has been found.

Microscopic Description. Texture: Crystallinity, holocrystalline; grainsize average 1 to 5 mm.; fabric, hypidiomorphic-granular, approaching pilotaxitic.

Minerals Present.

	I. Calculated from analysis.		II. Calculated.	III. Measured and corrected.
Augite	38·2	Augite	38·2	40·5
Plagioclase	35·7	Felspars	38·0	37·2
Orthoclase	2·3	Iron Ores	16·0	16·6
Ilmenite	8·4	Olivine	5·7	4·9
Magnetite	7·6	Biotite	1·7	0·1
Olivine	5·7	Apatite	0·4	0·7
Biotite	1·7			
Apatite	0·4		100·0	100·0
	100·0			

IV.

As measured by Rosiwal's method, and uncorrected.

Augite	34·2
Felspar	31·7
Iron Ores	17·2
Serpentine	7·1
Chloritoid and chlorite	5·0
Analcite	4·0
Biotite	0·1
Apatite	0·7
	100·0

The relative proportions of the minerals present in the rock have been determined by two methods: by calculation from the bulk analysis of the rock[1] (column I), and by measurement according to Rosival's method. The existing composition of the rock, including the quantities of secondary minerals, as determined by the latter method is given above in column IV; and the original composition as deduced from this by making corrections for the decomposition is found to agree very closely with the composition as calculated from the analysis, as may be seen by comparing columns II and III. The method of correcting for decomposition is fully explained, with this specimen as an example, in Appendix II.

Inspection of the slides of this specimen seemed to show that the lines measured had been unlucky in missing biotite crystals. Probably there is nearly two per cent. present; hence for the purpose of calculation 1·7 per cent. was the quantity assumed.

The augite is titaniferous and shows hour-glass structure faintly. After separation from the rock the augite of this specimen was sent to Mr. Mingaye and kindly analysed by

[1] For details of method see Appendix I.

him. In order to separate the augite a part of the rock was powdered and sifted, and the heavier portions (comprising augite and ilmenite) were separated from the lighter (felspar, analcite, chlorite etc.) by the specific gravity method, Klein's solution (cadmium borotungstate) being used. The ilmenite was found to be easily attracted by a common bar magnet, whereas the augite was not; accordingly these were afterwards separated by a hand magnet.

About 10·85 grams of augite-ilmenite were treated, and 6·9 grams of augite was obtained, leaving 3·95 grams; that is 63·6% was augite and 36·4% ilmenite. The ilmenite was not quite pure, however, for any augite grains to which ilmenite adhered, or which included ilmenite, were attracted. The augite obtained was pure.

By the Rosiwal method the proportion of augite uncorrected for decomposition in this rock (Specimen I) was 33·9% and of ilmenite 17·1%. Thus of the total augite and ilmenite 66·5% was augite and 33·5% was ilmenite. This closeness of the relative proportions of augite and ilmenite by the two methods of estimation and consideration of the fact that error crept into the former method, firstly in the sifting, secondly by the augite including or partly embracing ilmenite fragments and thus being attracted by the magnet, gives confirmation of the reliability of the Rosiwal method.

The following was the result of analysis of the augite:—

SiO_2	49·66	H_2O	0·10
Al_2O_3	5·77	TiO_2	0·10
Fe_2O_3	5·00	P_2O_5	0·04
FeO	7·10	MnO	0·01
MgO	13·03	SrO	trace
CaO	20·78	V_2O_5	0·06
Na_2O	0·55	CuO	0·01
K_2O	0·11		

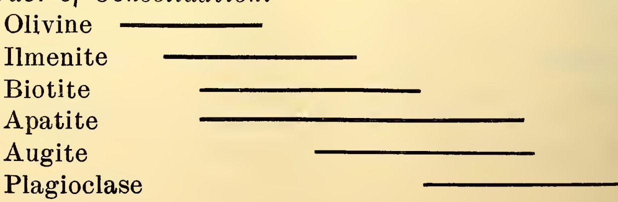
ZrO_2, Cr_2O_3, NiO, CoO, BaO, and Li_2O tried for and proved absent.

The plagioclase possesses the extinction angles of labradorite. The mean refractive index of most of the felspar is 1·558, but there is some as low as 1·540, and some that is intermediate between these figures. Probably we have mainly labradorite surrounded by andesine and a small amount of oligoclase, which in places approaches albite. The felspar does not gelatinise with acid (HCl). It is largely decomposed and replaced by chlorite, sericite, kaolin, analcite, and zeolites.

The ilmenite is idiomorphic, presenting hexagonal and lath-shaped sections. As noted above it is attracted by a magnetite intergrown with it. This is also confirmed by the result of the bulk-analysis of the rock which shows a comparatively small amount of TiO_2.

Of the decomposition products augite has given rise to chloritoid, some of which is closely allied to ottrelite and to chlorite, probably chlinochlore. Most of the serpentine is after olivine, but some of it seems to replace augite—if it was not derived from it. The analcite occurs chiefly in large irregularly rounded masses enclosing crystals of the ferro-magnesian minerals and apatite. It also occurs in angular interstitial masses, some of which do not contain apatite. This is easily accounted for however on the supposition of secondary derivation from felspar, by the fact that much of the felspar does not contain apatite. It is significant that the comparison of a number of specimens shows that the quantity of analcite in both of these forms increases *pari passu* with the state of decomposition of the rock.

Order of Consolidation.



Chemical Composition. The following is a bulk analysis of a part of this specimen kindly made for us by Mr. Mingaye; and we set beside it for comparison the analysis of the essexite of Brandberget, Gran, published by Brögger in his paper on the Basic Eruptive Rocks of Gran :—

	I.	II.
SiO_2	41·05	43·65
Al_2O_3	12·27	11·48
Fe_2O_3	6·39	6·32
FeO	11·07	8·00
MgO	6·38	7·92
CaO	10·96	14·00
Na_2O	2·43	2·28
K_2O	0·53	1·51
H_2O	4·02	1·00
TiO_2	4·39	4·00

I. Essexite of Prospect (Specimen I). II. Essexite of Brandberget, see Q.J.G.S., vol. 50 (1894) p. 19.

The two analyses closely resemble one another, but of the two the Prospect rock is evidently much the more decomposed. In the part of the mass from which this specimen came it also contains more ilmenite and less biotite than the rock of Brandberget. Compared with normal essexites, the Prospect rock is poor in alkalies, and richer in lime and magnesia. It is also poor in silica and alumina, and rich in ferrous oxide. These latter differences are easily accounted for by its much higher content of ilmenite and magnetite. The analysis also agrees closely with those of olivine-gabbros and olivine-dolerites, allowing for a deficiency of labradorite in the Prospect rock, and of its ilmenite.

Specimen T (Univ. of Sydney Coll., No. 2154)

Locality. About 40 yards from the N.W. end of the Reservoir Quarry, that is, a few yards beyond the left end of the section. As the thick aplitic veins curve up rapidly, the specimen comes from a point 70 or 80 feet from the nearest point on the lower vein. The rock here resembles specimen I very closely, the only difference of importance being that the quantity of ilmenite and magnetite is much less, and that there is little apatite, and practically no biotite. This supports the view that ilmenite and apatite are most plentiful in the main rock near the aplitic veins.

Series II. Specimens from the Emu Quarry.

Specimen L.

Locality. S.E. corner of Emu Quarry, within 5 cm. (two inches) of the junction with the shale. Megascopically very similar to specimen B previously described.

Microscopic Description. Texture: Crystallinity, holocrystalline; grainsize, porphyritic in olivine—phenocrysts average 1 mm. in length; base 0·1 mm. Fabric, pilotaxitic approaching panidiomorphic, as the augite and felspar crystals are mostly nearly idiomorphic.

Minerals Present.

Corrected for decomposition.		By weight as measured.	
Felspar	37·6	Felspar	37·0
Augite	33·6	Augite	33·7
Olivine	21·1	Olivine	20·1
Iron Ores	7·4	Iron Ores	7·4
Biotite	0·5	Serpentine	1·0
Apatite	0·1	Biotite	0·5
		Analcite	0·2
	100·0	Apatite	0·1
			100·0

The minerals have the same characters as those described for the previous specimens. The olivine is little decomposed. The analcite occurs in two forms, interstitially and in minute cracks in the felspar generally clear and colorless; and in well rounded masses of from $\frac{1}{2}$ to 2 mm. in diameter, having a cloudy yellowish appearance under the microscope. The former kind was reckoned as felspar in the determination of the proportions of the minerals. Some of the rounded masses have small aggregates of augite and ilmenite surrounding them. There is little doubt they are small spherical vesicles with an infilling of analcite, and that the small crystals of augite and ilmenite adhered to the bubbles at an early stage of the crystallisation of the magma owing to surface tension. In this slide there occurs a fragment of quartz measuring $3\frac{1}{2}$ by 2 mm. as represented in fig. 1, Plate XXXIX. It is probably derived from the shale, and is surrounded by a zone of alteration products, apparently partly actinolite.

The order of consolidation is practically the same as that of specimen B from the Reservoir Quarry.

Specimen M.

Locality. S.E. corner of Emu Quarry, a few metres west of specimen L, at the junction, actually in contact with the shale.

Megascopically bluish-grey in colour with angular black inclusions. The rock effervesces strongly with acid in every part.

Microscopic examination shows that this rock is a peculiar product of alteration, containing so much calcite that it occupies an intermediate position between a basalt and a magnesian limestone.

The constituent minerals in order of decreasing abundance are now as follows:—calcite and dolerite, felspar (andesine), chlorite, and a little serpentine. The rock was probably originally very similar to specimen L above described, though, since the felspar possesses low extinction angles and appears to be andesine, we may conclude that the magma in this case assimilated more of the shale than did that of specimen L. No biotite is present, and this is evidence that it is not a product of chemical interaction but an original constituent of the whole magma. The calcite, with probably some dolomite, is most abundant, and occurs both in veins and throughout the rock, replacing different minerals, but notably olivine. The replacement of olivine by calcite or dolomite is common in decomposed basalts of the Sydney district (*e.g.* those of Hornsby and Guildford), and is no doubt due to decomposition of the rock by percolating water, probably charged with calcium carbonate from the adjoining somewhat calcareous shale. Whether any of the calcite in specimen M was derived from the shale prior to consolidation, and either remained as unabsorbed grains or was in small quantity dissolved in the watery magma at great pressure and then crystallised out, is a question which it is impossible to answer, owing to the undoubted secondary replacement having effaced the necessary criteria.

Specimen P.

Locality. Taken from the ledge separating the shallower from the deeper part of the Emu Quarry, a few metres from the eastern wall of the quarry. The rock immediately over it has been removed, but, assuming that the junction with the shale extended horizontally from the nearest point where it now exists, specimen P must have lain about seven metres (23 feet) below the surface of the ground, and nearly five metres (16 feet) below the junction with the shale. Below the compact pallio-essexite is a layer of dark fine grained essexite $3\frac{1}{2}$ metres (nearly 12 feet) thick, and below this a band about 20 cm. (8 ins.) thick, richer in biotite and ilmenite, from which specimen P was taken. Underlying this band, whose characters are now to be described, is an aplitic sheet 5 cm. (2 ins.) thick of the kind to be described in the third part of this paper.

Underneath this again is a layer 45 cm. (18 ins.) thick of fairly dark coarse grained rock rich in augite, containing near the aplitic rock much biotite; and beneath this is a layer 30 cm. (1 ft.) thick of a coarse light-coloured essexite rich in felspar and analcite, and containing patches of a greenish decomposition product, and this graduates downwards into the main mass of coarse essexite. Exposed on the same wall as specimen P, a few feet to the S.W., is a lenticular mass of very coarse or "pegmatitic" rock, at about 4·25 metres (14 feet) below the junction level.

Megascopic Description. Dark, moderately fine grained doleritic rock in which the constituent minerals are visible to the unaided eye.

Microscopic Description. Texture: Crystallinity, holocrystalline; grainsize, medium, about 1 to 3 mm.; fabric, hypidiomorphic granular to sub-ophitic.

Minerals Present:

Corrected for decomposition.		By weight as measured.	
Felspar	50%	Felspar	44%
Augite	28	Augite	18
Iron Ores	14	Iron Ores	15
Olivine	4	Serpentine	6
Biotite	2	Chlorites	6
Apatite	2	Analcite	4
	——	Stilbite and calcite	3
	100	Biotite	2
		Apatite	2
			——
			100

In making the correction for decomposition the stilbite and calcite have been assumed to have been formed from augite, and they have been taken as present in equal quantity.

The felspar is of two kinds, the more abundant being plagioclase, the less abundant an alkali felspar—orthoclase, anorthoclase, or microperthite. The plagioclase is nearly idiomorphic, is of thick tabular habit extended parallel to 010, is irregularly twinned on the carlsbad and albite laws, and is zonal in composition. The centre part for about one third of a diameter consists of an acid labradorite, as shown by a maximum symmetrical extinction of rather less than 30°, and by its R.I. being decidedly above that of balsam. Outwards it alters at first slowly in composition, the remainder of the crystals being mainly andesine; but in crystals whose growth continued until the end of the period of consolidation we find that near the outside the felspar becomes rapidly more acid in composition, until the periphery is an alkali felspar with R.I. distinctly less than balsam. The narrower series of albite twin lamellæ thin out towards the periphery, leaving the alkaline outer band untwinned, except for some patchy secondary twinning.

The other felspar referred to above, occurs in slightly smaller individuals, tending also to euhedrism but more nearly isometric in habit, and thus giving mainly short rectangular sections. In many crystals there is no evidence of primary twinning, but some are twinned on the carlsbad law. Wherever edges of undecomposed portions of the crystals are in contact with balsam the R.I. is found to be distinctly lower than that of balsam; and, if we may judge by the strength of Becke's bright line in comparison with the lines to which we are accustomed from pure albite and orthoclase, the strength of this line would appear to be intermediate between them, indicating for this felspar a mean R.I. of about 1·530. Between crossed nicols under a low power the crystals present a patchy appearance. Under a high power the brighter patches, which have slightly higher D.R., are seen to be finely twinned parallel to the longer axis of the crystal section, and therefore presumably on the albite law; whilst the less bright surrounding patches are perfectly clear and free from twinning.

These features are those characteristic of secondary microperthite, the albite having in course of time separated from a soda orthoclase. That this interpretation is correct in this case is confirmed by the fact that the patches showing albite twinning are often bounded by cleavage cracks, which are well marked as the section is thin. The only other interpretation would be that the orthoclase had turned in patches into microcline not albite, perhaps during the process of grinding the section, but the fact that there is no trace of a cross twinning is against this view. Both the secondary twinning and the R.I. of the untwinned felspar favour the conclusion that the mineral was originally an orthoclase rich in soda. A careful search has failed to reveal any primary microperthite, appearances which at first sight resembled it being always more satisfactorily explained on closer examination as of secondary origin. The sharp separation into alternate sinuous layers which characterises primary microperthite is nowhere to be seen even with a high power. At the same time this does not preclude the possibility that the originally apparently homogeneous soda orthoclase is a cryptoperthite.[1] The alkaline outermost zone of the plagioclase crystals is identical in every property with the soda orthoclase individuals, and is almost certainly of the same composition.

The decomposition products of the two felspars are different, and render them easily distinguishable in ordinary light. The alkali felspar decomposes chiefly to kaolin, and thus has the brownish cloudy appearance so familiar in the granites. It has also decomposed to analcite, sometimes here and there in patches, but often completely, so that a large patch of analcite may be recognised by the dusty kaolin and cleavage cracks to be a complete pseudomorph of a felspar crystal. The plagioclase crystals, on the other

[1] Rosenbusch, Mikr. Phys. 3rd edition (1892) Vol. I, p. 678.

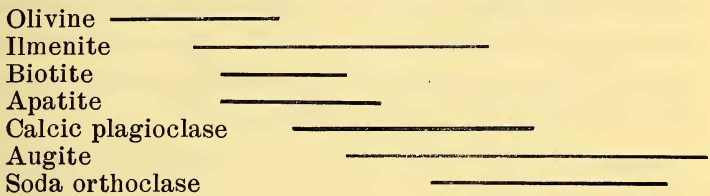
hand, in the portions composed of labradorite and andesine are glass-clear, like sanidine, except in patches or "strings" (widened cracks) filled with decomposition products. Of these the most abundant is analcite, generally clear; there is also a colourless mineral, in small flakes and granules, showing usually one good cleavage and straight extinction whose mean R.I. is about 1·55 or 1·56, and whose D.R. is about 0·025, which is doubtless a scapolite, for the R.I. is distinctly too low for it to be prehnite; there is serpentine in radial patches and tufts derived from neighbouring olivine and chlorite forming a mosaic of minute radial bundles.

The relative proportions which the rock contains respectively of calcic plagioclase and soda orthoclase, including in the latter the alkaline mantles of the plagioclase crystals, is not easy to determine. It was impossible, owing to the advanced state of decomposition, to separate them in the Rosiwal measurement, but as a rough estimate we would distinguish as alkali felspar from a quarter to one-third of the total felspar, *i.e.* from 12 to 17 per cent. of the whole rock.

In addition to the decomposition products already mentioned above, there is only one other of importance, a zeolite in radial spherulitic aggregates approaching $\frac{1}{2}$ mm. in diameter. Its fibres have a low extinction angle, its R.I. is 1·50 and its D.R. about ·008, which properties suggest stilbite. The serpentine in cracks and cavities is a light olive green in colour; where it replaces olivine, which has entirely disappeared, its colour is deep reddish-brown.

Apatite is abundant and occurs in large needles, sometimes 2 mm. in length, penetrating augite and felspar crystals, but only the edges of the olivine pseudomorphs, and very small in the centres of the ilmenite crystals. All the iron ore has the form and colour of ilmenite, but may be magnetiferous and is unaltered.

Order of Consolidation. The most difficult, but most interesting, point in the sequence of consolidation is the relation of the periods of crystallisation of the felspars to one another and to augite. Each mineral of this group occurs frequently in idiomorphic crystals enclosed by another member of the group, and the soda orthoclase and augite both play an interstitial role. Hence we conclude that the periods of the two latter minerals were largely coincident, and that the calcic plagioclase, whilst overlapping somewhat, both began and ended before them.



Specimens N, O, and Q.

Five other specimens from the Emu Quarry have been examined in detail, and three of these deserve notice. Their localities horizontally are all close to those of specimens L and P, and their vertical relations to these latter specimens, as well as their general characters, are shown in the following table:—

Specimen.	Depth below Junction.		Characters.
	Metres.	Inches.	
L	0 05	2	Described above.
		Feet.	
N	0·30	1	Similar to L, but biotite (about 3%) and olivine (roughly 23%) somewhat more abundant. The iron ore is partly magnetite.
O	1·5	5	Similar to L, but augite has no tendency to idiomorphism, and both olivine and biotite are much more abundant, chiefly at the expense of labradorite. The rock is crowded with olivine phenocrysts, and the proportions are probably roughly: total olivine 25%, biotite 7%.
P	4·85	16	Described above.
Q	5·15	17	Similar to P, but grainsize less, and biotite more abundant.
		20	Similar to J (Reservoir Quarry) but grainsize coarser (5 to 10 mm). Unfortunately much decomposed.

Series III. Specimens from Various Parts of the Mass.

Six specimens taken from exposures on various parts of the mass other than the two principal quarries have been examined in detail, and they prove that both the pallio-essexite and the various types of the main mass of essexite present everywhere the same features as those specimens from the quarries already described. The following points of difference are perhaps worth noting, though none of them appear to be of great importance.

Specimen Y. A pallio-essexite from Cactus Hill, north of Emu Quarry, is very similar to specimen B, but poorer in biotite, and a little richer in apatite.

Specimen X. From the middle of the stone wall, south of Greystanes. Differs from S (rather C, J, P) in that (1) the augite is more titaniferous, having occasionally quite a copper colour, and is the most abundant constituent; (2) ilmenite occurs in large hexagonal tables, with much leucoxene; (3) apatite in long acicular crystals probably forms 5% of the rock; (4) the felspar so far as preserved is plagioclase, from labradorite to oligoclase, mainly the latter, but large interstitial patches of analcite occur in the rock. Another specimen of the same variety from the north end of the stone wall is coarser, and has augite crystals 10 mm. long.

10. Characters of the Original Minerals.

The foregoing detailed descriptions are intended to give precise ideas of the varieties of the rock found in different parts of the mass. The features of interest in the minerals composing the rock require separate treatment, the characters of the felspars and of their decomposition products, being especially noteworthy. The original minerals will be treated in this section, and those of secondary formation in the next.

The following is a complete list of the original minerals which we have discovered in the mass divided into two classes:—

(A) Those forming 10% or upwards of the rock in any part of the mass. (B) Those not forming anywhere as much as 10% of the rock.

(A)	(B)
Plagioclase (from labradorite to albite)	Aegyrine-augite
Orthoclase (and soda-orthoclase)	Apatite
Augite (titaniferous)	Quartz (derived)
Diopside	Magnetite
Olivine	Pyrite
Biotite	
Ilmenite	

The Felspars.

In the main mass of rock the felspar is nearly every where entirely plagioclase. The crystals are idiomorphic in general form, but uneven on their surfaces of contact with other crystals. Their habit is tabular, parallel to the face 010; and the sections are thus mostly lath-shaped. Twinning on the carlsbad and albite laws affects every crystal, but not very regularly, and traces of pericline twinning are rarely seen. The composition of the plagioclase cannot be stated with accuracy because the crystals are strongly zoned. The average composition of the plagioclase is shown by calculation from an analysis (see Appendix), to be that of an acid labradorite with the formula Ab_4An_3. A large central area of each crystal section is seen to consist of labradorite whose composition is probably about Ab_3An_4 and this labradorite probably composes nearly half the volume of each crystal.[1] Outwards the crystals then

[1] The composition of the cores of the plagioclase crystals as stated above is arrived at in the following rough and ready manner. Since the more basic core is seen in most crystals to occupy distinctly more than half the area of the section it is assumed that it forms about half the

become gradually more acid, the outermost zone in crystals whose growth was not much interfered with being an oliogoclase (approximately Ab_6An_1). At occasional points on the periphery of crystals where the final mother liquor consolidated, the outermost zone seems to be nearly pure albite. The decomposition of the crystals renders their zoning evident in ordinary light. The most abundant product of their alteration is undoubtedly analcite, but where this has not been formed, the outer zone, chiefly of oliogoclase, and perhaps often andesine, is marked out by the familiar dusty deposit of kaolin, whilst the kernels of labradorite are clear and glassy. Large patches of the crystals are replaced by analcite; and the crystals, both inner and outer zones, are traversed by many irregular widened cracks, filled sometimes with serpentine and sometimes with chlorite, but most often with analcite.

Whilst the felspar of the great mass of the rock has the composition and characters just described, there occur in segregation veins and in the rock bordering upon them, alkali felspars of two kinds. In the aplitic veins (consisting of essexo-aplite) occurs pure albite in idiomorphic crystals, tabular on 010, twinned on the carlsbad and albite laws, and much altered to kaolin, but not at all to analcite. The other alkali felspar is a soda-orthoclase. It occurs in the aplite, side by side with the albite crystals, and often enveloping them, and also in the rock lying on either side

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volume. The outer half of each crystal varies continuously from the composition of the core to pure albite, and its average composition is taken to be roughly the arithmetic mean in molecular proportions between the compositions of these two extremes. Then if Ab_xAn_y be the composition of the core, the composition of the outer part will be $Ab_{(x+y)}$ + Ab_xAn_y or $Ab_{(2x+y)}\ An_y$. Assuming that there are approximately equal numbers of molecules in equal volumes, the composition of the whole crystal would be $Ab_{(2x+y)}\ An_y \pm 2(Ab_x\ An_y)$ and this is equal to the known average composition $Ab_4\ An_3$, whence we have the equations $\begin{matrix} 4x + y = 4 \\ 3y = 3 \end{matrix}$, or $\begin{matrix} x = \frac{3}{4} \\ y = 1 \end{matrix}$, or $\begin{matrix} x = \\ y = 4. \end{matrix}$

of aplitic and pegmatitic veins which passes gradually into the normal rock of the mass. It is found both in large crystals of irregular outline, and playing the part of an interstitial material between the crystals of pyroxene and of both felspars, in optical continuity with either of the latter. In the pegmatites all three kinds of felspar are combined in each crystal. The core is labradorite and becomes gradually more acid outwards as in the felspar of the main rock until perhaps a basic andesine is reached; then there is a sudden change to alkali felspar, first apparently a narrow zone of albite and then microperthite, which at least in one or two cases, seems to have a rough radial arrangement and would therefore be primary.

PYROXENES.

In the main rock the dominant ferro-magnesian mineral is a titaniferous augite of the usual violet-brown colour, and pleochroic. The content of titanium-oxide shown by the analysis is, however, less than might have been expected from its colour. The "hour-glass" structure is well shown. Occasionally (as in specimen X) it is copper colored, and therefore presumably more titaniferous. The augite never plays a wholly interstitial role, most of the crystals having a tendency to idiomorphism. Sometimes, and apparently in the neighbourhood of segregation veins, is is completely idiomorphic.

In the segregation veins, both aplitic and pegmatitic, the pyroxene is mainly a pale green augite not pleochroic. Its composition as calculated from the bulk analysis of the coarser aplitic rock will be found in the appendix. There is also aegyrine-augite occurring into it, and as separate small crystals frequently idiomorphic. It has a duller and rather more olive-green colour than pure aegyrine, and its pleochroism is not so strong.

Other Minerals.

The olivine occurs usually in large nearly idiomorphic individuals, but in the outer envelope (pallio-essexite) there is a second generation. It alters to a serpentine which is always deeply coloured, sometimes olive-green, sometimes brown. In the pallio-essexite the olivine is sometimes practically unaltered (*e.g.* east end of the Reservoir Quarry). This suggests that it is a highly ferriferous variety, a fact which is confirmed both by the composition it was found necessary to assign it in calculating the modes of the rocks in which it occurs, and by its high D.R. (see appendix). Its average composition is found to be approximately as follows

$$SiO_2\ 35\% \quad FeO\ 41\% \quad MgO\ 24\%$$

Examination between crossed nicols shews that it is not homogeneous in composition. In the main mass it is much decomposed, but in the pallio-essexite the phenocrysts are seen to have an outer border showing higher colours than the interior of the crystal, which is fairly uniform in colour. This outer zone and the small crystals of the second generation therefore approach nearer to fayalite in composition.

The biotite is intensely pleochroic, 𝔞 a very pale straw yellow, 𝔟 and 𝔠 very deep reddish-brown. The composition assumed for it for purposes of calculation will be found in the appendix. The ilmenite occurs mostly in hexagonal tables and occasionally in triangular skeletons. Between the two great segregation veins in the Reservoir Quarry (Plate XXXV) the rock is remarkably rich in ilmenite, which has the form of hexagonal lamellæ, often 20 or 30 mm. in diameter, though no more than 1 mm. thick. As calculation of the mode shows that magnetite is present in addition to ilmenite in every case, though not distinguishable microscopically, it must usually be intergrown with the ilmenite.

11. Characters of the Secondary Minerals.

The following is a complete list of the alteration products which we have recognised in the Prospect essexite:—

Derived from felspar:—analcite, kaolin, scapolite, stilbite.

Derived mainly from ferric minerals:—serpentine, chlorite, chloritoid, calcite, dolomite (or ankerite).

Pyrite is also present, and some of it at least is probably secondary; possibly all of it is secondary, and its inclusion in the list of primary minerals is hypothetical.

The origin of the analcite will be discussed in the next section; the kaolin occurring in the alkali felspars, oligoclase and perhaps andesine, calls for no remark, and we may therefore pass to the scapolite. This mineral was identified in thin sections, and it occurs widely in the mass as a granular filling of widened cracks in the labradorite. It is the second product to appear in the alteration of the rock, analcite being the first, but the scapolite is itself decomposed as alteration proceeds, whilst the analcite persists.

The stilbite does not appear until alteratiou has progressed so far that there is a good deal of analcite formed, and the olivine is almost wholly changed to serpentine; and, as several altered specimens are without it, it is apparently not always formed. When present it occurs as sheaf or fan-like masses of long fibres. Each mass has but one centre of radiation, and replaces a felspar crystal, pseudomorphing its faces often on one side only.

The serpentine and chloritoid are both products of the alteration of the augite. The former is of dull bluish colour and shows the familiar grey to inky blue polarisation tints. The latter occurs in masses of radially arranged bundles of fibres resembling secondary spherulites. It is grass-green in colour, and strongly pleochroic from yellow (𝔠) to olive-green and deep bluish-green. Its D.R. is approximately 0·020. Both chlorite and chloritoid occur replacing augite, the former more abundantly, and also filling veins and small pockets in the decomposing felspars. The formation of these minerals does not take place until the augite decomposes, which does not begin until the olivines have completely gone and the felspars have been very largely altered.

Cavities in the rock and opened joint cracks often contain masses of a homogeneous dark green chloritic material. It is amorphous to the naked eye, and a broken surface has something of a waxy lustre. Mr. J. W. Hogarth very kindly analysed one of these masses for us at the Sydney Technical College, with the result stated in column I. of the following table :—

	I.	II.	III.
SiO_2	14·9	30·5	33·5
Al_2O_3	4·7	10·0	11·0
Fe_2O_3	6·1	12·5	14·0
MgO	10·6	22·0	24·2
CaO	29·7	2·0	2·2
K_2O	0·3	0·5	0·6
H_2O at 100°	11·0	22·5	14·5
CO_2	22·6	...	...
MnO	trace	...	...
	99·9	100·0	100·0

The analysis is only an approximate one which was carried out solely for the purpose of gaining a rough idea of the composition of this mineral. There is obviously much calcite in it, and if to the 22·6 per cent. of CO_2 we allot 28·7 parts of CaO we find that about 51 per cent. of the chloritic mass is calcite. Subtracting this we find the remainder has the percentage composition shown in Column II. This is too high in water for any of the chloritic or chloritoid minerals, and it is very probable that, as the material was dried at 100° only, much uncombined moisture was included in the estimation. Deducting therefore 8 per cent. of the water (as a rough guess), and bringing the remainder to 100 again, we have the composition shown in Column III. This corresponds fairly closely with some analyses of chlorites.

Calcite and dolomite are present wherever the rock is much decomposed. The crystals of spar occasionally show twinning, but usually do not, so that whilst both calcite and dolomite are probably present it is impossible to say in what proportion. Indeed the crystals may sometimes be magnesite or ankerite.

12. Origin of the Analcite.

The question, as to whether the whole of the analcite found in the essexite under description was of secondary origin, would not have been raised but for the controversy which has arisen as to the existence of evidence of analcite occurring as an original constituent of igneous rocks, and for the fact that this mineral does occur in the Prospect rock in forms very suggestive of idiomorphism.

Much of the analcite is undoubtedly secondary for various stages of decomposition of a felspar crystal to analcite have been noticed. One part of a felspar may be completely altered, another part of the same crystal unaltered. The alteration begins both from the inter-crystal spaces and along cracks in the crystals, (see Plate XXXIX, fig. 5) both in labradorite and in alkali falspar, and quite as much in the former as the latter. This secondary analcite after felspar is penetrated by apatite needles in the same way as the original felspar (see Plate XXXIX, fig. 3), and it sometimes shows the cleavage and kaolinisation of the felspar, as in specimen P.

On the other hand there are certain appearances which at first sight suggest that some of the analcite is primary. In many sections analcite crystals are found mostly free from apatite inclusions and presenting idiomorphic outlines to masses of stilbite or chlorite (see Plate XXXIX, fig. 4). Closer inspection shows, however, that crystal faces are commonly absent on one side; and there is no doubt that these crystals are a late product of alteration, being deposited in cavities which were subsequently filled up by another mineral. This view is supported by the fact that beautiful hand specimens of analcite in eikositetrahedra may be obtained from geodes in parts of the Prospect rock which are much decomposed. Whether the cavities are miarolitic (*i.e.* irregular steamholes), or whether they have been formed by the complete removal of olivine, felspar, or augite, by the percolating waters, leaving a space which was subsequently filled, there is no means of certainly deciding. We see nothing to preclude the latter mode of formation, but cannot prove its actual operation.

In one instance, observed in slide T, (Specimen 2154 Sydney University Collection), analcite was noticed which presented apparently idiomorphic outlines to perfectly fresh felspar and augite; it contains inclusions of apatite, and hence was not formed in a cavity. This case is probably to be explained as a phenomenon due to the accidental conjunction of faces of augite and felspar in such a way as to give a section of the analcite crystal with false faces inclined to one another at about the same angle as the faces would give in a section of the eikositetrahedron. In the pallio-essexite are occasionally found rounded masses of analcite as described in specimen L. These could perhaps be interpreted as phenocrysts of analcite partially resorbed; but their want of uniformity in size is against this view, and they are easily explained as spherical vesicles filled with secondary analcite.

Frequently allotriomorphic masses of analcite include perfectly fresh felspar as well as apatite and fresh augite, and are surrounded by apparently fresh rock. These analcite masses often exhibit the weak anomalous double refraction which has been noted in other rocks by various authors, and which is no doubt due to the unequal strain set up by local changes of volume in the surrounding minerals as they continue to decompose. In some areas of analcite there may also be seen a patch colored a deep dirty brown by transmitted light which shades off into the surrounding analcite without a sharp boundary. Similar patches have been noted by Mr. G. W. Card in the analcite bearing basalts of the Sydney district, and he suggests that they may be caused by alteration of the analcite.[1] Examination with a high power shows clearly that they consist of analcite closely packed with inclusions; but the nature of the latter we were unable to determine. The frequent occurrence of these patches in the centre of an analcite mass does not lend support to the view that they are formed by its alteration; and we are not able to offer any opinion as to their origin. In other places the analcite appears to play mainly an interstitial role.

There can be no doubt whatever that the greater part of the analcite is secondary; and it appears to us, after careful consideration, that all the many forms in which the mineral occurs at Prospect are capable of explanation on the hypothesis that it is a product of decomposition. If the analcite, which occurs in rounded or nearly idiomorphic masses were original, we should be forced to conclude that it crystallised before the felspar, in part at least. Cross and Pirsson, however, consider analcite the last substance to crystallise in the supposed analcite-bearing igneous rocks.[2] On the other hand, were there any analcite

[1] Records of the Geological Survey of N.S.W., Vol. VII, (pt. 2) p. 93.

[2] The Monchiquites or Analcite-bearing Igneous Rocks, by L. V. Pirsson, Journ. of Geol., Vol. IV, (1896) No. 5.

which was the last product to crystallise in the Prospect rock, it would be strange if there were not the slightest distinction in structure or inclusions to be found between the primary and the undoubtedly secondary analcite. We therefore conclude that there is no proof of original analcite occurring in the Prospect essexite or any of the rocks associated with it.

The hypothesis that whilst most of the analcite is formed from felspar some may have resulted from the decomposition of a lenad, *e.g.* nepheline, which occurs in some of the closely related basalts of the district, is not easy either to prove or disprove. A careful search with the microscope has revealed no trace of nepheline. It is true that the calculation of the mode shows a small deficiency of silica from that making albite with all the soda and alumina; but, if regarded as original, this deficiency would require the presence of less than two per cent. of nepheline. Without microscopic proof of the presence of nepheline, it seems better to conclude that the deficiency of silica is due to decomposition, a little silica being wholly removed (perhaps with lime) in the formation of analcite. That sodalite was originally present would be an hypothesis hard to prove or disprove; there can hardly be any remaining, if we may judge by the insignificance of the quantity of chlorine found in the analyses, all of which is probably contained in the apatite. Taking everything into consideration we do not believe that any lenad was present.

Our conclusion, reached in the foregoing discussion, may seem that we have relied solely upon the internal evidence afforded by our specimens of the Prospect essexite. It remains to be seen whether experience gained from similar rocks elsewhere supports our conclusion. Mr. G. W. Card has noted the occurrence of analcite in many of the basalt dykes and necks of the Sydney district, and concludes that it is primary.[1] These rocks are so closely related to the Prospect essexite in mineralogical and chemical composition (see analysis of analcite-basalt of Bondi, Analysis No. II) that were their analcite proved to be primary it would be strong prima facie evidence for a like origin at Prospect. Mr. Card's proof that the isotropic mineral is indeed analcite is incontrovertible; but his only grounds for believing in its primary origin are contained in the sentence: "The manner of occurrence of the analcite, and the freshness of the rocks as a whole, quite preclude the possibility of a secondary origin." With this conclusion we are unable to agree. The manner of occurrence is interstitial, except for occasional irregular patches. An interstitial disposition is exactly what we should expect in a very fine-grained rock where the analcite was secondary after felspar, and the few irregular patches would occur where alteration had proceeded further. Our experience at Prospect, too, is that analcite, undoubtedly secondary, is one of the very first products of decomposition, and may occur in a rock where the other minerals are very little altered.

13. Consideration of the Analyses.

By the kind permission of the Government Geologist of New South Wales, Mr. E. F. Pittman, two complete analyses of the Prospect rock were specially made for our investigation by Mr. J. C. H. Mingaye, Analyst to the Deparment of Mines, in the Government Laboratory. The samples submitted were parts of specimens I (essexite) and B (pallio-essexite), and the analyses of these are stated in columns I and III respectively of the following table. In column II is quoted an analysis of the Prospect rock previously made by Mr. Mingaye from a chemical study of the basic rocks of the Sydney district. The specimen, of which no part has been preserved, probably came from the Emu

[1] Rec. Geol. Surv. N.S.W., Vol. vii, (pt. 2), p. 93.

Quarry; and it was therefore taken from a zone higher up, *i.e.* nearer the periphery of the mass, than specimen I, but probably not so near the contact as specimen B. We reach this conclusion both from a brief note by Mr. G. W. Card which accompanies the analysis in which he describes the specimen as megascopically "holocrystalline, black, even-grained and somewhat compact," which accords well with the character of the main mass of the rock exposed in the Emu Quarry, and from a comparison of the analysis with those of our specimens. Both the low specific gravity and content of TiO_2 show that the sample contained less ilmenite than specimen I, which mineral, as we point out later, decreases in abundance from the great segregation veins upwards; and also it is intermediate between specimens I and B in the percentages of silica, lime and the alkalies. If, as we believe, the same vertical distribution of the constituents may be assumed for the locality of the Emu Quarry as is observed in the Reservoir Quarry, the internal evidence is also in favour of the supposition that the specimen came from the main mass of the Emu Quarry. In column IV is stated an analysis of the aplite occurring in the great veins of the Reservoir Quarry. It will be discussed in the third part of the paper, but is stated here for convenience in bringing all the complete analyses together.

	I.	II.	III.	IV.
SiO_2	41·05	43·06	46·26	58·82
Al_2O_3	12·27	16·31	13·36	16·91
Fe_2O_3	6·39	5·40	2·34	2·40
FeO	11·07	7·61	10·53	4·59
MgO	6·38	5·49	8·87	0·88
CaO	10·96	9·37	9·18	2·42
Na_2O	2·43	3·12	3·27	6·74
K_2O	0·53	1·07	1·23	2·96
H_2O (100° C)	0·44	1·16	0·15	0·56

	I.	II.	III.	IV.
H_2O (100° C.+)	3·58	2·93	2·08	1·98
CO_2	0·03	1·36	0·06	0·54
TiO_2	4·39	2·46	1·78	1·14
ZrO_2	abs.	...	abs.	...
P_2O_5	0·19	0·32	0·42	0·34
SO_3	...*	...	0·13	...
Cl	trace	0·02	0·01	0·01
S(FeS_2) FeS	0·35	0·26	abs.	...
Cr_2O_3	trace*	...	0·02	...
NiO, CoO	0·02	0·06	0·01	...
MnO	0·17	0·23	0·12	0·13
BaO	abs.	0·02	0·05	...
SrO	†trace*	trace	trace*	...
Li_2O	abs.	trace	abs.	...
V_2O_3	0·06	0·05	0·03	...
CuO	trace	...	trace*	...
	100·31	100·30	99·90	100·42
Specific gravity	3·058	2·814	2·947	2·665

* Less than 0·01%. † Spectroscope. ‡ Flame Reactions only.

No. 3465, *Pyrites was observed in this sample. On heating some of the finely powdered rock with sulphuric acid and hydrofluoric acid fine pyrites was left. No pyrites in No.* 3464.—*J. C. H. Mingaye.*

I. Essexite, Specimen I towards north end of Reservoir Quarry. J. C. H. Mingaye's analysis.

II. Essexite, probably from Emu Quarry (see text). J. C. H. Mingaye's analysis. Quoted from Rec. Geol. Surv. N.S.W., Vol. VII, part iii (1903) *p.* 230.

III. Pallio-essexite, Specimen B, south end of Reservoir Quarry, J. C. H. Mingaye's analysis.

IV. Essexo-aplite, coarser-grained variety, Reservoir Quarry. H. P. White's analysis.

The significance of the above analyses in relation to the quantitative distribution of minerals throughout the mass will be considered in a subsequent section, and a discussion of the bearing of the analyses upon the nomenclature of the rock may be postponed to the next section, which is devoted to that subject. It will be sufficient here to make a comparison in regard to the composition of the essexite of Prospect and its varieties with rocks of other well known occurrences. With this object there are exhibited in the usual manner in Tables I and III analyses of the Prospect rocks, and of a number of rocks similar in chemical composition.

The great difficulty which the eye experiences in grasping rapidly a sufficient number of figures renders comparisons from analyses presented in this form tedious and uncertain, hence the attempts of several authors to introduce some style of graphic representation of the chemical composition of rocks. We have endeavoured here to facilitate comparison without cumbrous diagrams by simply using numerals consisting only of the essential digits. The principle on which the method is based is that errors of less than about five per cent. of the stated quantity of the constituent are negligible, for variations greater than this between specimens are commonly found from points in one mass less than a metre apart. If this margin of error be adopted, it is unnecessary to use fractions at all in stating quantities making over 10 per cent. of the rock, for the number 10 may be taken as representing all quantities from 9·50 to 10·49, and the maximum possible error 0·5, becomes less than 5 per cent. as the quantity increases above 10. Similarly, quantities between 5 and 10 are sufficiently represented by the use of a fraction no smaller than a half. The eye is assisted if a sign less complex than either ·5 or $\frac{1}{2}$ be used to represent one-half, and we have found a simple hyphen convenient. In Tables II and IV the same analyses are repeated in the fashion of presentment we propose. In stating silica percentages the quantity is given to the nearest unit, no fractions being used. We might have written the figures for alumina in the same way without exceeding the 5 per cent. limit, and would have done so had the quantities been somewhat larger; but, as they range down to about 13 per cent., it has seemed better to group them with the figures for ferrous oxide, magnesia and lime, in statement to the nearest half-unit. The remaining constituents, which generally form less than 5 per cent. of the whole rock, we state correctly to the first decimal place. We have found that the use of the full point in its normal position, as is frequently done for decimals in America, and not raised by turning, as is general in English practice, saves the eye from some distraction, and enables more rapid apprehension of the numbers. The analyses have also been rendered strictly comparable by the estimation of water and carbon dioxide, which are practically wholly the result of decomposition and by subsequent calculation to 100.

The composition of the Prospect rocks is such that they stand on the borders separating a number of groups. They are very closely related to the normal olivine-gabbro magma as it appears in hypabyssal intrusions, as will be seen by referring to analyses Nos. I, II, and III. All of them are dolerites (diabases). The first, from Scourie, Sutherlandshire, (G 3·105) consists of plagioclase giving lath-shaped sections, a pale chocolate-brown augite, "titaniferous magnetic iron-ore," which from the plate would appear to be ilmenite, perhaps with magnetite intergrown, and apatite. There is no olivine or biotite. The second is from the Upper Ruhrthal, in Westphalia. The third is from a massive dyke in the Berwyn Hills, North Wales, which has been examined in detail by one of us (H.S.J.), though the description is not yet published. It is composed of plagioclase (53%), namely labradorite zoned nearly to albite on the periphery, of titaniferous augite (20%), olivine (15%), magnetite, ilmenite, and a little biotite, and in fact differs only from the Prospect rock in having more felspar and olivine and much less augite, and in having no aplite of alkaline character associated with it. It also exhibits to perfection secondary analcite in enlarged cracks in the labradorite crystals.

On the other hand, though distinctly less alkaline than the normal essexites, the Prospect rock is closely related to that group, for in composition it is almost identical with the Norwegian essexites described by Brögger—those of Sölvsberg, Brandberg, and Tofteholmen—which occur in an alkaline comagmatic region, and are well recognised as subalkaline members of the essexite family. The analysis of the essexite of Tofteholmen (see column VI) may be compared with the analyses of the main rock of Prospect (Nos. IV and V). The constituents of the Sölvsberg essexite are a violet titaniferous augite (26%), labradorite and a little orthoclase (together 46%), olivine (12½%), biotite (9½%), iron ores (5%), and its chemical composition is shown in column VII.

The Prospect essexite resembles the foregoing rocks in mineralogical as well as chemical composition; but it compares closely in the latter though not in the former respect with the subalkaline (alkali-calcic) members of the alkaline lamprophyres. As examples we may mention the camptonites of Kjöse-Aklungen, of the La Plata Mountains, Colorado, and of Mount Ascutney, Vermont, U.S.A.; and the monchiquite of the Rio do Ouro, Sierra de Tingua, Brazil. Analyses of the two latter rocks are quoted here (Nos. VIII and IX respectively in Tables III and IV), and it may be noticed that they compare somewhat better with the pallio-essexite (No. XII) than with the Prospect essexites. In them the augite is to a large extent replaced by a somewhat alkaline hornblende.

Another group of rocks to which the Prospect pallio-essexite is closely related in chemical and mineral composition is the subalkaline basalts—those which, though themselves containing little or no lenad mineral, occur in districts where basic lavas containing lenads are common. In this group must be placed the basaltic rocks of the dykes and necks of the Sydney district in which Prospect lies, as a few of them contain nepheline,[1] and the analyses of two of them here quoted (No. X from Bondi and No. XII from Camden Park) agree very closely with that of the Prospect pallio-essexite (No. XI) and essexites (Nos. V and VI). This similarity of composition may be accepted as an indication of their origin from a common magma. In thin section under the microscope these basalts are practically indistinguishable from the Prospect pallio-essexite. Analyses of two other rocks of this class are quoted in columns XIII and XIV. The former is a basalt from near Olot in the north-east of Spain forming part of the Western Mediterranean comagmatic region recently described by Dr. Washington, which includes many nepheline-basalts. It consists of labradorite, a colorless augite, olivine, titaniferous magetite and a little orthoclase. Hornblende and biotite are absent. The latter (No. XIV) is a basalt from Uvalde County, Texas, a district where basanites and nepheline- and melilite-basalts are found. It contains labradorite, a very little alkali-felspar (?), augite, olivine, biotite, magnetite, and apatite.

In concluding this brief account of other rocks to which the Prospect essexite closely approximates in composition,

[1] G. W. Card, Rec. Geol. Surv. N.S.W., Vol. VII, part 2, p. 236.

it may be of interest to compare quantitatively the mineral compositions (modes) of the rocks of which the analyses have been quoted above, in cases where these have been calculated. The percentage of the mineral compositions by weight will be found in the subjoined table. The letter *c* (circa) preceding a figure for any mineral means that it is to be taken as only approximate. It is interesting to note that the minerals, which are of the same character in all the rocks, vary very considerably in their relative proportions in spite of the uniformity of chemical composition.

	III.	V. (Prospect)	XII.	VII.
Plagioclase	53	36	38	45
Orthoclase	3	2	1	1
Augite	20	38	30½	26
Olivine	15	6	14	12½
Biotite	1	2	11½	9½
Iron ores and apatite ...	8	16	5	6

14. Nomenclature of the Rocks.

The names which should be used to denote the rocks already described in this paper must now be considered. The appropriate naming of rocks in the segregation veins will be discussed later. The comparison of the Prospect with other rocks, undertaken in the last section, shows that it is impossible to assign unhesitatingly to the former any single name from amongst those in common use. Amongst New South Wales geologists the main mass of the Prospect rock has always been called a *dolerite* in the sense of Teall, Hatch, and others, and not in the German sense, or a *diabase* in Harker's sense, or perhaps by some in Bonney's or the German sense of an altered or old fine-grained basic rock, as the stone is green with chloritization. The compact dark bluish rock of the outer envelope has always been spoken of as *basalt*. For precision the prefix *olivine-* was occasionally used. At first sight there appears to be every justification for the continued use of these terms, for the rock undoubtedly has essentially the mineral composition and the habit of a dolerite (diabase), and also the chemical composition, as was shown in the foregoing section. But when account is taken of the presence of biotite, and of the occurrence in the mass of segregation veins containing as much as 18 per cent. of orthoclase, and a little ægyrine-augite, the similarity to normal dolerites is felt to be less marked. In addition to this there is the fact that, as explained in the first part of this paper, the Prospect rock appears to be genetically associated with indubitably alkaline rocks. Where it has cooled rapidly it is indistinguishable under the microscope from basalts of the district, which pass by almost imperceptible gradations into nepheline basalts, such as those of Lue and Burragorang. It would seem that the Prospect rock and the various basalts must be regarded as the hypabyssal and superficial representatives of the basic magma which resulted from deepseated differentiation of a primordial alkaline magma. The more acid products of this differentiation were intruded at the same time as the basalts, possibly in early Tertiary time, but for some unknown reason, have only appeared at the present surface around the periphery of the great Sydney basin, as at Jamberoo,[1] Cambewarra and Mittagong in the south and south-west, at Barrigan and Orange in the west, and the Nandewars in the north. If, then, we are right in regarding the magma of the Prospect rock as the basic differentiation product of an alkali mother magma, there is good reason to apply to it the name usually applied to the non-lenadic intrusive rocks of such magma, namely essexite.

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[1] Rec. Geol. Surv. N,S.W., Vol. VIII, p. 1.

That this course would not be opposed to existing practice is, we think, clear from the close correspondence of the Prospect rock, both in mineral and chemical composition, with the intrusive rocks of Sölvsberg and Brandberg in the Christiania region. These were named by Brögger olivine-diabases,[1] but were soon after associated with the essexites by Rosenbusch,[2] and this name for them has since been very generally accepted. We prefer, therefore, to call the main mass of the Prospect rock *essexite*, and its compact envelope, as already explained, pallio-essexite; but at the same time there is no doubt that it is in accordance with the usage of many authors at the present time to call the main mass an *olivine-dolerite*, or *diabase*, and its envelope an *olivine-basalt*.

The nomenclature of the Prospect rock, according to the quantitative system of Cross, Iddings, Pirsson and Washington, has been found by ascertaining the norms of those specimens which have been analysed. The calculated norms are displayed in the following table, and they place each of the rocks in the subrang *camptonose*. Specimen L a fine-grained pallio-essexite from Emu Quarry (No. I) and the specimen, probably from the Emu Quarry, which furnished the analysis previously published, fall near auvergnose (No. II), and should properly be called auvergnose-camptonose. The pallio-essexite (No. III of the subjoined table), however, falls well within the boundaries of camptonose. The mode and texture of the rocks may be indicated according to the rules laid down by the authors. The main mass is a *grano-augite-camptonose*, and the compact outer envelope is a *pitaxi-biaugi-camptonose*, using the contraction *pitaxi-* to signify pilotaxitic.

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[1] Quart. Journ. Geol. Soc., Lond. (1894) p. 18.

[2] Mikr. Phys. II, (1896) p. 250.

Table of Norms.

	I. (Specimen L)	II.	III. (Specimen B)
Orthoclase	3.34	6.12	7.23
Albite	17.29	22.53	20.44
Anorthite	20.85	27.52	18.07
Nepheline	1.89	2.00	3.98
Diopside	26.51	13.87	20.15
Olivine	7.66	8.95	19.50
Magnetite	9.28	7.89	3.48
Ilmenite	8.36	4.71	3.34
Apatite	0.34	0.67	1.01

15. Variations of Composition in the Main Mass.

A feature of considerable interest in the Prospect mass is the changes in the relative proportions of the mineral constituents from point to point, because they are evidence of difference in situation whilst the magma was cooling. The probable nature of the processes of differentiation which operated will be discussed in the last part of this paper, and in this section we confine ourselves to a statement of the facts. The quantitative distribution of the minerals was ascertained both by comparison of a number of specimens, whose mineral compositions were determined by calculation from analyses and by measurement, and by microscopic study of sections of several other specimens which did not seem sufficiently individual in character to require measurement. The evidence of the former kind is contained in the following table, in which are assembled the mineral compositions of all the specimens which have been determined quantitatively. It will be noticed that one specimen is here included (see column V) which has not been in our hands for description, and of which the precise locality is unfortunately unknown. Its mineral composition was calculated from the analysis published by the Geological

Survey of New South Wales, the quantity of biotite stated as present being an assumption, though Mr. Card's description mentions biotite as "fairly abundant," and the working of the analysis seemed to give about two and seven per cent. as the extreme limits possible for it. This specimen, which we may call the "Survey specimen," would not have been included except for its interest as a highly felspathic variety.

	I.	II.	III.	IV.	V.	VI.	VII.
	5 cm. L. Emu Quarry.	30 cm. B. Reservoir Quarry.	450 cm. C. Centre Reservoir Quarry.	500 cm. P Emu Quarry.	400 cm. 900 cm. Survey Specimen Emu Quarry.	1500 cm. Coarse Aplite Reservoir Quarry.	1800 cm. I. N.W. of Reservoir Quarry
Felspar ...	37–	39–	45	50	56–	78–	38
Augite ...	33–	30–	34–	28	20–	16	38–
Olivine ...	21	14	8	4	7	nil	5–
Iron ores ...	7–	4	3–	14	11–	5	16
Biotite ...	0–	11–	7	2	3–	nil	1–
Apatite ...	.1	1.0	.1	2.0	.7	.7	.4
(Orthoclase)	n.d.	1	n.d.	*c* 15	5	18	2–

In the table the specimens have been set from left to right in the order of their distance from the overlying junction of the intrusive rock with the shales, that distance being always measured in the nearest direction, and, for convenience of comparison, uniformly stated in centimetres. In the case of the Survey specimen only the limits can with any certainty be given, conditioned by the facts that the rock is not aphanitic, and that the maximum depth of the Emu Quarry below the junction is nine metres; but it seems probable that it came from the lower part of the quarry, which would bring it over seven metres below the junction. The specimens do not unfortunately form a continuous series taken in a vertical direction under one point, the inaccessibility of the quarry faces and the irregularities of weathering rendering this practically impossible. That they come from widely separated parts of the mass does not seem to be important, as our observations all tend to show that essentially the same changes in composition take place in a vertical direction in all parts of the mass which are exposed. Whilst in the figures quoted in the table for felspar orthoclase has been included, it has seemed desirable to repeat the orthoclase separately for those specimens which have been analysed, and in which its quantity can therefore be determined with some certainty.

Directing attention first to the rocks of the rapidly cooled envelope (columns I and II), we notice that they are similar in composition except for the proportion of biotite, which in specimen L is practically absent, but in specimen B is present to the extent of nearly 12 per cent. Examination of other specimens shows that biotite is usually abundant in the pallio-essexite; and its absence in one of these specimens is an excellent instance of the irregularity of its distribution, which is seen to be very marked when many specimens from all parts of the mass are compared. On the whole, biotite tends to be most abundant in a zone within 5 m. of the junction with the shales, its percentage there being generally from 6 to 12, whilst in the interior of the mass its proportion usualy lies between one and five per cent. Yet from any part of the mass a specimen may chance to be taken which contains very little biotite. In other respects specimens of the pallio-essexite all agree; olivine is very abundant, the iron ores moderately so, whilst augite and felspar usually appear in about the same proportion, as in specimens L and B (columns I and II).

On passing downwards into the mass a striking change in composition is apparent. Felspar continually increases in proportion, whilst olivine and biotite fall off in a very marked degree. It is true that 5 cm. from the junction biotite is almost absent; but this may fairly be regarded as irregular, being probably due to reaction with quartz absorbed from the shale. As regards the felspar and olivine, the continuous change becomes apparent at a distance of only 30 cm. from the contact (compare columns II and I), but in this case it may be illusory, and due to the great horizontal distance separating the specimens, or to some other cause, and may not be connected with the general change shown by succeeding specimens. Felspar, which at the periphery composes about 38 per cent. of the rock, forms 45 per cent. at $4\frac{1}{2}$ m. from the junction, rapidly increasing to 50 per cent. at 5 metres from the contact, and reaching 56 per cent. a metre or so further down.

Though in this section we are treating properly only of massive varieties, it is necessary to say a few words here regarding the aplitic veins which are found traversing the mass, and which will be described in detail later. All the larger of these veins, or more correctly sheets, have a horizontal disposition. The uppermost is met in both quarries at about 5 m. (16 feet) below the junction, that is just below the level of specimen P. At depths respectively of about 13 and 17 metres are seen in the Reservoir Quarry two much thicker segregation veins. An analysis of a specimen of the coarse aplite from one of these was made, and its mineral composition, which probably represents fairly accurately the composition of all the aplitic veins, has been calculated from this, and is added to the above table (column VI). Evidently the aplitic rock is the climax of the progressive changes of composition just described; the felspar has risen to 78 per cent., orthoclase which has risen from 1 to 5 per cent. now counting 18 per cent.; olivine and biotite have disappeared altogether; and augite has continued its slow but continuous diminution.

All the changes so far described take place within five metres of the contact. Continuing downwards, the rock remains of a felspathic character, having probably a composition generally closely similar to that of specimen P (column IV), though we have not determined quantatively any specimen from this zone. Above, between, and below the two massive aplitic veins of the Reservoir Quarry, the rock is decidedly felspathic in character, probably similar in composition to the Survey specimen (column V) though with less olivine and biotite, but after passing little more than a metre below the lowest aplitic vein we find that the rock has very rapidly become much less felspathic again, as shown by the composition of specimen I (column VII) which was taken fully 18 metres below the junction. This specimen is the richest of any in augite and iron ores; it has about the same proportion of felspar as the pallio-essexite, though rather more of the anorthite molecule, a moderate percentage of olivine, and very little biotite. The main rock underlying the lowest aplitic vein seems everywhere to be comparatively uniform in composition. It is only at the north-west end of the Reservoir Quarry that the rock is exposed to any depth below the aplitic veins: here the latter turn upwards parallel to the upper contact surface (see Plate XXXV) because the section line of the quarry runs into the raised outer rim of the mass referred to above; and, thus, though we get to no absolutely deeper level, we do, at this end of the quarry, get specimens from a greater depth below the top of the igneous mass than is possible anywhere else. Unfortunately it is also here that the rock is most decomposed, because denudation has removed the protecting cover of pallio-essexite; but so far as we have been able to observe the rock at this locality, it does not appear to present any of the rapid changes in composition which are to be found in the overlying 20 metres (65 feet) or so of rock. Hence we may assume specimen I to be typical of the main rock everywhere throughout the mass at depths lying between 20 and 40 metres (65 and 130 feet) below the upper contact surface.

As to what the composition of the rock may be at greater depths we have no hint.

The distribution of the iron ores is peculiar and calls for a few special words. In considering the iron ore contents of the pallio-essexite, however, account must be taken of the possibility of error in the ferrous and ferric iron determination of the analysis of specimen B referred to in Appendix I. By calculation from analysis the percentage of iron ores in that specimen is only 3·7, but as obtained by measurement on the Rosiwal method, and after correction for decomposition, it is 6·5. Repeated experience has shown that the Rosiwal method is very fairly accurate, and the slight tendency to exaggerate the colored constituents could not account for this discrepancy. Calculation gives ilmenite 3·2 and magnetite only 0·5, whereas in all the other Prospect rocks for which analyses are available these two minerals are present in nearly equal proportions; and it is precisely the quantity of magnetite which would be affected by an underestimation of ferric iron. Hence it seemed preferable to rely upon the Rosiwal method for the estimation of total iron ores, and to obtain the magnetite by difference between this and the quantity of ilmenite. In the following table are shown the percentages of iron ores in the same specimens as are represented in the last table, and also the ratio of iron ores to augite in the same specimens.

	I.	II.	III.	IV.	V.	VI.	VII.
	L. 5 cm.	B. 30 cm.	C. 450 cm.	P. 500 cm.	Survey Specimen >400 cm. <900 cm.	Coarse Aplite 1500 cm.	I. 1800 cm.
Ilmenite ...	...	3.2	...	...	4.8	2.2	8.4
Magnetite ...	...	3.3	...	...	6.8	2.8	7.6
Total ores ...	7.4	6.5	5.6	14.0	11.6	5.0	16.0
Ratio $\frac{\text{ores}}{\text{augite}}$	.22	.20	.16	.50	.56	.31	.42

Reference to the foregoing table shows that the pallio-essexite contains from $5\frac{1}{2}$ to $7\frac{1}{2}$ per cent. of iron ores (see columns I, II, and III) the quantity diminishing somewhat away from the contact. Going downwards, the iron ores then increase considerably, fall off again in the highly felspathic varieties, (Survey specimen and aplite), and then increase to their maximum in the main rock below the segregation veins. This rather complex arrangement might perhaps be accounted for by supposing that the average proportion of iron ore, which in the pallio-essexite is about 7 per cent., would normally have increased downwards rather rapidly to the 16 per cent. found in the main rock below; but that continuous increase downwards was prevented by the concentration of the felspars in the level between 5 and 17 metres below the junction, the dilution by felspar of course reducing the percentage of all the other minerals. If augite be taken as a standard of reference, because it diminishes with increase of the felspar, we find that the ratio of total iron ores to augite is variable, but that in passing from specimen P to the Survey specimen, when the felspar changes from 50 to $56\frac{1}{2}$ per cent., the ratio of ores to augite is nearly constant, thus perhaps pointing to the dilution theory as acting between these two specimens.

Changes in the proportion of the iron ores are not found only in a vertical direction, or from the exterior of the mass inwards, but also in an apparently irregular manner. The best example of this is to be found in the Reservoir Quarry, a little to the south-east of the middle of the face. In the immediate neighbourhood of the great segregation veins, and particularly in their pegmatitic portions, the ilmenite crystals attain great size and generally lie nearly horizontally. They form a striking feature in the hand-specimens, appearing as very thin hexagonal tables or leaves with almost the lustre of biotite and often nearly 3 cm. (1 inch) in diameter. Other bands or patches rich in ilmenite have been found in other parts of the mass.

Little can be said with certainty as to the distribution of apatite, because it is almost impossible to estimate its quantity with any approach to the truth by the Rosiwal method unless unusually abundant. The impression gained from all the slides made, however, is that there is a tendency for apatite to be more abundant in the immediate neighbourhood of segregation veins, whilst there is undoubtedly a good deal of it in those veins themselves. Of the specimens represented in the table, P comes from close beside an aplitic vein, the Survey specimen (column V) probably comes from near one, and column VI is the aplite, and all have more apatite than specimen I; but so has a specimen of the pallio-essexite also (column II).

The main features of the distribution of the minerals as described above may be summarised thus: (1) the pallio-essexite is richer in olivine and biotite than the main rock, and its plagioclase is a little more acid; (2) a concentration of felspar occurs in a layer extending horizontally probably throughout the mass, and reaching downwards from a depth of 4 or 5 metres below the junction with the shales to 17 metres, and always parallel with the junction; (3) the irregular distribution of the iron ores, which tend, however, to be much more abundant in the main rock than in the pallio-essexite, especially than in the inner zone of the latter (as represented by specimen C); and (4) the uniformity in composition of the main rock below the segregation veins so far down as it is anywhere visible. The principal changes in composition have been found to be in a vertical direction; as to whether there is any change horizontally on a large scale in the mass as a whole, the exposures do not warrant any certain conclusion. Probably the pallio-essexite on the sides of the mass has the same composition as on the top, and if so there must be horizontally the same change on going inwards to the main rock as was found in going vertically downwards; but there is nowhere any indication of further horizontal change.

16. Metamorphism and Assimilation of the Country Rock.

The only kind of country rock abutting on the intrusive rock at the present surface of the ground is the Wianamatta shales, which varies little in composition, except that occasional bands are more sandy and others more calcareous than the average. In no place is more than the very slightest alteration apparent. The shales have been considerably hardened, enabling them better to resist weathering, but in the hand-specimen no other change but the different fracture due to this hardening is visible. In thin section under the microscope, specimens of shale taken from close to the junction appear precisely the same as unaltered shale, so that the alteration which has taken place must be extremely slight, and be confined probably to a recrystallisation on an extremely minute scale. Optical investigation having given this negative result, the matter did not seem worth pursuing by chemical analysis.

Melting up and assimilation of the country rock has undoubtedly occurred to some extent, though probably not on a large scale. Direct evidence is afforded by the occurrence in a number of slides of the pallio-essexite of circular or oval patches which are nearly opaque or dark grey in colour, having a minutely granulated appearance; do not depolarise except weakly as a very fine mosaic under the high power; and whose edges are not defined, but shade away gradually into the surrounding fine-grained ground mass. These are unquestionably partially absorbed fragments of shale, which they closely resemble in every way under the microscope; but no special minerals are seen around them, nor any unusual abundance of the ordinary minerals of the essexite. Hence we may assume that the portions of shale assimilated merely augmented the felspars of the magma and perhaps to some extent the augite, by supplying hypersthene molecules produced by the interaction of quartz with olivine. A few rounded crystals of quartz have been found in the pallio-essexite, which are undoubtedly grains of sand derived from arenaceous bands in the shales. One of these which occurs in a section of specimen L is reproduced in fig. 1, Plate XXXIX. The quartz is all one crystal, but it has been much cracked, and chlorite has forced its way into the cracks. It is surrounded by a reaction rim of a very pale green or colorless fibrous mineral disposed in an irregularly radial manner, which may be either actinolite or simply a non-titaniferous augite. It is evidently formed by reaction of the quartz with the olivine molecules still in the magma, with the inclusion perhaps of some anorthite and wollastonite molecules. The amphibole or pyroxene of this reaction rim is now a good deal chloritized.

Indirect evidence of assimilation of the shales is perhaps to be found in the more acid character of the plagioclase of the outer envelope as compared with the rock of the main mass. Microscopic evidence alone suggested this comparative acidity, as the maximum extinction angles in symmetrical sections of the plagioclase crystals were found to be lower in specimens coming from near the contact than in the specimens from the main mass. Subsequent calculation from analyses of the average compositions of the plagioclase of the typical specimens amply confirmed this view. In specimen B of the pallio-essexite the average compositions of the plagioclase was Ab_7An_3, in specimen I of the main rock it was Ab_4An_3. That the more acid character of the felspars of the outer envelope is due to assimilation, and not to some kind of differentiation cannot be absolutely affirmed; indeed it may be only partly due to assimilation and largely to the fact that the process of differentiation which produced the great segregation veins containing nearly pure albite, to be discussed in the succeeding part of this paper, impoverished the main rock near these veins (which is all that is accessible) in regard to the albite component; so that the average composition of the plagioclase of the pallio-essexite would be only a little more acid than that of the original magma before intrusion, and that of the main rock distinctly more basic. Hence we may say that there is evidence of slight assimilation, but no more.

Analyses of Prospect and other rocks.

Table I.

	I.	II.	III.	IV. (Prospect)	V.	VI.	VII.
SiO_2	47·45	46·92	45·41	43·06	41·05	47·90	47·00
Al_2O_3	14·83	18·05	16·85	16·31	12·27	16·55	15·20
Fe_2O_3	2·47	3·61	4·14	5·40	6·39	5·67	5·69
FeO*	14·71	6·73	8·86	7·90	11·26	8·10	6·85
MgO	5·00	7·43	7·27	5·49	6·38	4·44	8·76
CaO	8·87	9·11	9·43	9·37	10·96	9·35	12·60
Na_2O	2·97	2·99	3·38	3·12	2·43	3·23	1·45
K_2O	0·99	1·24	0·64	1·07	0·53	2·08	0·66
H_2O	1·00	2·58	2·63	4·09	4·02	0·2	0·30
CO_2	0·36	0·10	0·09	1·36	0·03	...	...
TiO_2	1·47	0·94	1·41	2·46	4·39	1·91	2·30
P_2O_5	...	0·19	0·18	0·32	0·19	0·32	trace
	100·12	99·98	100·29	100·30	100·31	99·75	100·81

Table II.

	I.	II.	III.	IV.	V.	VI.	VII
SiO_2	48	48	46	46	43	48	47
Al_2O_3	15	18–	17–	17–	13	17	15
Fe_2O_3	2·5	3·7	4·3	5·5	6·7	5·7	5·7
FeO*	15	7	9	8–	12	8	7
MgO	5	7–	7–	6	6–	4–	9
CaO	9	9–	10	10	11–	9–	12–
Na_3O	3·0	3·1	3·5	3·3	2·5	3·3	1·5
K_2O	1·0	1·3	·7	1·1	·5	2·1	·7
TiO_2	1·5	1·0	1·5	2·6	4·5	1·9	2·3
P_2O_5	...	·2	·2	·3	·2	·3	trace

* To the FeO are added MnO, NiO, and CoO.

I. DOLERITE; Scourie, Sutherlandshire, Scotland. J. J. H. Teall, anal., J. J. H. Teall, Q.J.G.S., XLI, (1885) p. 135.

II. DOLERITE (Diabase); Bochtenbeck, between Niedersfeld and Wiemeringhausen, Oberes Ruhrthal, Westfalen.

III. DOLERITE; Nant Llwyngwern, Berwyn Hills, North Wales. M. Dittrich, anal. Not previously published.

IV. ESSEXITE; Prospect, probably Emu Quarry. J. C. H. Mingaye, anal. G. W. Card, desc., Records Geol. Surv. N.S.W., Vol. VII, part 3 (1903) p. 229. In addition 0·02 Cl, 0·26 S, 0·02 BaO, 0·05 V_2O_5.

V. ESSEXITE; Prospect, Specimen I, towards north end of Reservoir Quarry. J. C. H. Mingaye, anal. In addition 0·35 S, 0·06 V_2O_5.

VI. ESSEXITE; Tofteholmen, Christiania Fiord, Norway. V. Schmelck, anal. W. C. Brögger, Erup.-gest. des Kristianiageb., Vol. III, p. 83.

VII. ESSEXITE; Solvsberg, Gran, near Christiania. Särnstr and Schmelck anal. W. C. Brögger, Q.J.G.S., L. (1894) p. 19.

Table III.

	VIII.	IX.	X.	XI. (Prospect.)	XII.	XIII.	XIV.
SiO_2	48·22	43·74	43·39	46·26	46·51	47·66	45·11
Al_2O_3	14·27	14·82	16·67	13·36	15·27	14·36	12·44
Fe_2O_3	2·43	2·40	3·47	2·34	2·50	2·83	2·67
FeO*	9·23	7·52	8·99	10·66	9·00	8·44	9·62
MgO	6·24	6·98	7·30	8·87	8·40	8·19	11·56
CaO	8·45	10·81	8·79	9·18	9·12	9·36	10·61
Na_2O	2·90	3·08	3·30	3·27	3·12	3·51	3·05
K_2O	1·93	2·90	2·17	1·23	1·17	1·54	1·01
H_2O	1·94	2·94	2·96	2·23	1·43	0·37	0·94
CO_2	0·15	1·50	0·39	0·06	0·61	...	...
TiO_2	2·79	2·80	2·20	1·78	2·20	3·83	2·34
P_2O_5	0·64	0·64	0·41	0·42	0·33	0·45	0·51
	99·80	100·23	100·28	99·90	99·90	100·54	100·02

Table IV.

	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
SiO_3	49	46	45	48	48	48	46
Al_2O_3	14–	15–	17–	14	15–	14–	12–
Fe_2O_3	2·5	2·5	3·6	2·4	2·5	2·8	2·7
FeO*	9–	8	9–	11	9	8–	10
MgO	6–	7–	7–	9	8–	8	11–
CaO	8–	11–	9	9–	9–	9–	11
Na_2O	3·0	3·3	3·4	3·4	3·2	3·5	3·1
K_3O	2·0	3·0	2·3	1·3	1·8	1·5	1·0
TiO_2	2·9	2·9	2·3	1·8	2·3	3·8	2·4
P_2O_5	·7	·7	·4	·4	·3	·4	·5

* To the FeO are added MnO, NiO, and CoO.

VIII. Camptonite; Mount Ascutney, Vermont, U.S.A. W. F. Hildebrand, anal. R. A. Daly, B.U.S.G.S., 148, p. 70. In addition 0·04 BaO, 0·01 Cl, 0·05 F, 0·36 FeS_2.

IX. Monchiquite; Rio do Ouro, Serra do Tingua, Brazil. P. Jannasch, anal. Hunter and Rosenbusch, Tscher. Min. Pet. Mit., xi (1890) p. 464. In addition S 0·10.

X. Basalt, containing analcite; Bondi, Sydney, N. S. Wales. J. C. H. Mingaye, anal. G. W. Card, J. C. H. Mingaye, and H. P. White, Rec. Geol. Surv. N.S.W., Vol. vii, pt. 2, (1902), p. 97. In addition V_2O_5 0·01, SO_3 0·19, Cl 0·02, BaO 0·02.

XI. Pallio-essexite; Prospect, specimen B, south end of Reservoir Quarry. J. C. H. Mingaye, anal. In addition SO_3 0·13, Cl 0·01, Cr_2O_3 0·02, BaO 0·05, V_2O_3 0·03.

XII. Basalt; Camden Park, near Sydney, N.S.W. J. C. H. Mingaye, anal. Mingaye and White, Rec. Geol. Surv., N.S.W., Vol. vii, pt. 3, (1903), p. 230. In addition V_2O_5 0·03, SO_3 0·11, Cl 0·04, Cr_2O_3 0·02, BaO 0·04.

XIII. Basalt (Camptonose); Castelfullit, near Olot, Catalonia, Spain. H, S. Washington, anal. and desc., Q.J.G.S., Vol. lxiii, (1907), p. 74.

XIV. Basalt; Pinto Mountain, Uvalde County, Texas. W. F. Hildebrand, anal. W. Cross, B.V.S.G.S., 168, p. 61. In addition Cl 0·11, S 0·01, V_2O_3 0·04.

III. The Segregation Veins.

By C. A. Süssmilch and H. Stanley Jevons.

17. Distribution of the Segregation Veins in the Mass.

In petrological literature the term segregation vein has a generally understood but not very precise signification. It will be used here to mean all those rock masses which are distinct in composition from the main rock of the intrusion, tending to be more acid, and which in their origin are intimately connected with the later stages of cooling and crystallisation of the magma, whether occurring in sheets or irregular shapes, within or without the main mass. The term denotes the rocks commonly known as aplites and pegmatites, the former finer-grained, the latter coarser-grained than the main rock; but we extend it to rocks of this character in the widest sense—whether their grainsize differ much or little from that of the main mass, and whatever the composition of the latter.

In the segregation veins at Prospect there occur both aplitic and pegmatitic rocks, and these only according to our definitions which will be explained later; but these distinct rocks are not generally confined to different veins, but are closely intermingled or associated in the same vein. In tracing the distribution of the segregation veins through the mass, therefore, no account need be taken of the rocks composing them. The only general feature we have observed regarding the distribution of the different types of rock is that the smaller veins (those up to about 10 cm. in thickness) appear to be more frequently composed of the aplite only, than of either the pegmatite only, or both rocks mixed. Both constituents of the segregation veins appear at a distance lighter in color than the main rock, whether fresh or weathered, the aplite rather more so than the pegmatite, and there is thus little difficulty in finding and following them over any available area of rock. The veins vary much in thickness, from 1 to 120 cm.

The best exposure in which to study the segregation veins is undoubtedly the Reservoir Quarry. Here may be seen at a glance the two great segregation veins already mentioned above (see Plates XXXV. and XXXVI.). They lie about 4 m. (13 ft.) apart; and they run parallel in a remarkable degree with the junction surface of the pallio-essexite and with the shales, following even minor undulations of the junction, the uppermost at a depth of 13 m. (45 ft.) below it. Where the junction turns sharply upwards and vanishes in the present ground surface, near the north-western end of the quarry, the great veins follow and also are lost by denudation; so that in the middle of the quarry the outcrops of these two veins upon the face are roughly horizontal, whilst in the north-western part of the quarry they dip to the south-east at 30° (see Plate XXXV). The true dip of these great segregation sheets in the southern half of the quarry may be ascertained by standing near the face of quarry and looking to the south east. On the southern wall of the quarry, although the rock is much decomposed, the segregation sheets are clearly seen, dipping at about 35° inwards, towards the face of the quarry (see Plate XXXVI). Their dip here is nearly east-north-east, that is, directly towards the centre of the southern part of the intrusion, as may be seen on consulting the plan. The reason why the outcrops of the veins on the face turn upwards and disappear in the northern half of the quarry, is that these sheets no longer dip at right angles to the face, but due east (magnetic). The sheets have in the southern pavement of the intrusion, a quaquaversal dip towards a centre of the intrusion. Bearing in mind the close conformity of the outcrops of the sheets upon the face with the overlying junction, it seems probable that the sheets were everywhere parallel to the junction, hence the upper surface of the intrusion near its periphery must have had a quaquaversal inward dip of about 35°; which is evidence of the existence of the peculiar rim to the oval dish-shaped sheet already mentioned in the first part of this paper.

In the northern part of the Reservoir Quarry, the main rock is exposed well below the great segregation veins, and it is found to be comparatively free from segregation veins of any kind. A few thin veins are to be seen, generally not exceeding 10 cm. in thickness, two or three of which are parallel with the two great veins, whilst most of them have no special orientation. There is no trace of any other great segregation veins comparable with the two just described. They would be easily seen even on the most weathered rock if they existed.

Between the great segregation veins there are a few thin veins connecting them, running nearly at right angles to them or more obliquely; and these cross veins sometimes swell into irregular masses of aplitic and pegmatitic material. Above the great veins there are also numerous smaller veins running in various directions. One of these, averaging from 20 to 30 cm. in thickness, is larger than the rest; it branches off the upper great vein near the middle of the quarry face, runs upwards a little, and then continues parallel with the junction of the shale, at a depth of 5 m. (16 ft.) below it. This vein finds its counterpart in a somewhat similar vein lying at the same depth in the Emu Quarry. The smaller veins are some of them parallel with the junction, and the rest run very roughly at right angles to it. It is worthy of note that the segregation veins never penetrate into the most compact part of the pallio-essexite, that is, within 2 m. (6 ft.) of the junction with the shale, and the few which are found in the sub-pallium to 4 m. from the junction are always thin.

The thickness of the two great segregation veins is variable; indeed they are not regular sheets like the very thin veins, but from point to point are everywhere alternately swelling and thinning out again in an irregular manner. In the thinnest parts they are sometimes reduced to as little as 15 cm. in thickness, where largest they reach a width of 120 cm. Their average thickness is perhaps about 60 cm. In places, however, the veins swell up into oval or irregular shaped masses, from which one or more subsidiary veins often branch off. The largest of these (Fig. 4) is shown on Plate XXXV., near the letter H, and is described and figured in the next section. It is nearly 3 m. thick, and more than twice as long.

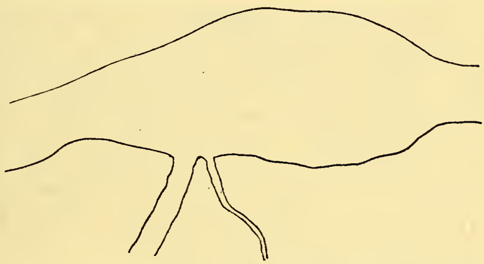

Fig. 4.—*Sketch of part of one of the large Segregation Veins.*

In the Emu Quarry segregation veins are common in much the same degree as in the upper levels of rock exposed in the Reservoir Quarry, and the upper of the two great veins is exposed in the deeper part of the quarry at its north end, so there is evidence that they have a wide extension. Exposures in other parts of the mass (*e.g.* Booth's Quarry) show that segregation veins, chiefly aplitic, are widespread in the mass at a level immediately below the most compact pallio-essexite. Neither pegmatitic nor aplitic veins have been found penetrating and intruding the shales anywhere at Prospect.

18. Megascopic Characters and Relations of the Rocks Composing the Veins.

The rocks filling the segregation veins vary both in composition and texture. As already stated they may be classed in two distinct groups: the pegmatitic which is coarser than the normal rock, and the aplitic which is of equal or finer grainsize. There are two kinds of pegmatites, and three kinds of aplites, distinguished from one another by their grainsize. All grade into one another, but the types named are the most abundant. The finer pegmatite has a variable grainsize, approximately 2·5 mm. and is thus but little coarser than the main rock. The coarser varies considerably in its grainsize, roughly from 5 to 10 mm., but individual crystals more than 30 mm. in length are not uncommon. Towards the southern end of the Reservoir Quarry the pegmatite of the great segregation veins contains abundant ilmenite in exceptionally large crystals. They are thin hexagonal flakes, sometimes skeleton-like, a deep rich brown in colour, with almost the splendent lustre of biotite, and commonly 3 or 4 cms. in diameter, though in one place they reach 10 cm. in greatest diameter. It is curious that they seem to stand roughly perpendicular to the edge of the vein.

The finest-grained aplite is almost compact in appearance, its grainsize varying from 0·1 to 0·15 mm. In the medium variety the grainsize varies from 0·25 to 0·75 mm., and in the coarse aplite from 1 to 2 mm. In different patches of the same kind of aplite, or from part to part of one patch, the grainsize may vary between the limits stated (which do not pretend to great accuracy); but the boundaries between aplites of different grainsize are always extremely sharp. The coarse aplite often has the same grainsize as the main rock of the intrusion, but is quite distinct both from it and from the fine-grained pegmatite in texture and composition.

The most interesting feature of the segregation veins is the mutual relations of these different varieties of aplite and pegmatite when they occur side by side in the same vein. When the two are present in the same vein the aplite always occurs in the middle of the vein with the pegmatite on either side. There are, of course, many small veins containing aplite only, and a few containing pegmatite only; but where the two are together there is always pegmatite on either side of the aplite, though there may be very much more on one side than the other. The pegmatite not infrequently appears to shade off gradually into the main rock, and it is never separated from it by a quite sharply defined boundary, but its junction with the aplite it encloses is generally quite sharp.

The relations of the pegmatite to the aplite, and of the different varieties of these rocks to one another, are never suggestive of the intrusion of a consolidated rock by a wholly or partly liquid magma. There are no broken fragments of one rock in another, there is never the slightest trace of a rapidly closed selvage, and there is no fluxion structure. The bounding surfaces of these rocks are always rounded, not angular, though where patches are of lenticular shape they may be drawn off to points at either end. No better simile could be found for the relations of these various rocks than the intermixing of the different colours in the plainer kinds of "marbled" paper used by bookbinders. There are the same flowing curves, sharp points and streaks, and the same sharp edges to the varieties of rock as to the different colours.

It is impossible in words to convey a correct idea of the relations of the kinds of rock in the segregation veins, and we have therefore reproduced here sketches and photographs of such parts of the veins, easily accessible in the lower part of the Reservoir Quarry, as seemed to exhibit specially well in a small area structures which are common throughout the great veins and occur also in others. In Plate XXXVII is recorded part of the upper great segregation vein near the middle of the Reservoir Quarry. It shows the relations of the medium and fine aplites, and the fine and coarse grained pegmatites, the aplites as usual lying in the middle of the vein in wavy streaks. Fig. 4 is a sketch of the large irregularly oval segregation mass in the upper great vein in the Reservoir Quarry, already referred to, which is located near letter H in Plate XXXV. It is an arched lenticular swelling of the vein, both the pegmatite and aplite becoming thicker. Two veins consisting of varieties of aplite branch off from the middle downwards. The following is a measured section across the thickest part of the vein at this point:—

Pegmatite grading imperceptibly into normal essexite	12	inches
Pegmatite with veins of aplite ...	24	,,
Aplite medium to coarse	26	,,
Pegmatite	24	,,
Pegmatite grading into normal essexite	24	,,
Total	110	,,

It has been possible to take a few photographs of the segregation veins, and two of them are reproduced in the plates to be found at the end of this paper. In Plate XXXVII we see a portion of the upper great aplitic vein taken near the middle of the Reservoir Quarry. On either side lie coarse and fine pegmatite and in the middle medium and fine aplite. A little study of the photograph shows that the arrangement of the different varieties of rock, though somewhat irregular, is not devoid or order. The medium aplite occurs only as a strip of varying width in the middle of the vein; it is bordered by fine aplite, and the pegmatite occupies the rest of the vein above and below. The coarse aplite here occurs mostly in the shape of bulging pockets. The dimensions of the vein measured across the middle of the picture from top to bottom are these:—

Coarse pegmatite	...	15	cms.	6	inches.
Fine pegmatite ...	...	2·5	,,	1	,,
Fine and medium aplite...	...	7·5	,,	3	,,
Fine pegmatite ...	...	2	,,	$0\frac{3}{4}$	,,
Coarse pegmatite	...	35	,,	$13\frac{1}{2}$	,,
Approximate total width		62	,,	24	,,

A photograph of the lower great vein only a few metres from the part just described is reproduced in Plate XXXVIII. Measuring across the vein it is composed as follows:—

Pegmatite	...	7	inches.
Medium aplite	...	2	,,
Coarse aplite	$\frac{1}{3}$ to	$\frac{1}{4}$	,,
Medium aplite	...	$2\frac{1}{2}$	,,
Pegmatite	...	3	,,
Total...	...	$14\frac{3}{4}$	,,

The specimen shows the full width of the whole vein at this point. As usual the aplite occupies the middle of the vein. A vein containing aplite only will be seen branching downwards at the left of the photograph. This vein contains medium aplite and is about $1\frac{1}{2}$ to 2 inches in thickness.

A specimen of fine-grained aplite, with a vein of coarse-grained aplite traversing it is, reproduced in Plate XL. The aplite is light greyish-green in colour, the individual crystals of felspar are just visible with the naked eye, and the fracture is rather rough. In general appearance it reminds one rather of a solvsbergite, but the green colour is not so bright, being chloritic. The vein of coarse-grained aplite has sharply defined and irregular boundaries. Opposite edges do not fit into one another, either on this side or on the reverse, hence the vein is probably not a small dyke or injection into a fissure. If it were so, the fissure must have been formed in some most unusual manner. The tabular crystals of albite can be clearly seen, and some black crystals of augite. Some dull patches are crystals of secondary dolomite showing curved faces and absence of lamellar twinning under the microscope. In this, as also in the fine-grained aplite, the tabular felspar crystals lie in all directions, there being no trace of fluxional parallelism.

There remains one feature worthy of close attention. The fine-grained aplite appears to be associated with the medium or coarse-grained aplite in two ways; it often occurs in blobs or rounded masses which look as if they had been suspended in the coarser aplite, but also occurs as a definite band or "selvage" on either side of the coarser aplites, *i.e.*, between the coarse aplite and the pegmatite. The following section measured from the upper vein near the south end of the quarry illustrates this:—

	Thickness.
Pegmatite	6 inches
Fine aplite ...	1½ to 2 ,,
Medium to coarse aplite	10 ,,
Fine aplite	1½ ,,
Pegmatite ...	12 ,,
Total ...	31 ,,

19. Petrological description of the Pegmatites and Aplites.

The aplites and pegmatites differ little from point to point except as regards grainsize. It appears unnecessary therefore, to describe a number of individual specimens, and we give a generalized description, first of the pegmatites and then of the aplites, in tabular form.

Pegmatites.

Megascopic Description.—Colour: At a distance, dark greenish-grey; near at hand, speckled white, dark green and black. Grainsize: Coarse, varies in different specimens from 2 mm. to 10 mm., and occasionally more. Commonest grainsize 2·5 to 3 mm. (denoted fine-grained, limits 2 to 5 mm) and 5 to 10 mm. (coarse-grained, limits 5 to 10 mm.). Minerals visible: Felspars, white or chloritic green. Long rectangular crystals are often seen beautifully zoned, the centre clear and glassy, and thus appearing rather dark, the outer zone opaque white owing to kaolinisation. The boundary between the zones is sharp, and is marked in a few crystals by a thin dark line of chlorite, which makes a perfect rectangle. Black prisms of augite are common, and needles of apatite may be seen with a lens. There are also abundant white patches of analcite, and dark green masses of chlorite.

Microscopic Description. Texture: Holocrystalline, hypidiomorphic-granular. Grainsize, see above.

Minerals present:—

		Corrected.	As measured
Original—	Labradorite	50	49·0
	Albite	33½	31·4
	Pyroxene (augite, diopside and ægyrine-augite)	11	8·2
	Ilmenite	5	5·1
	Apatite	0½	0·5
Secondary—	Analcite	...	3·8
	Chloritoid and chlorite	...	2·0
		100·0	100·0

The measurement was made by about 350 separate lengths on each of two slides. In the correction the analcite has been divided nearly equally between the albite and labradorite because there is much difficulty in deciding what it replaces when it occurs in patches, and a small allowance has been made for the tendency to overestimate the colored constituents. The measurement should only be taken as affording a very rough idea of the composition of the pegmatites.

Felspars.

The plagioclase is mostly idiomorphic and thick tabular in habit, all the larger crystals being zoned. Under the microscope the interior is usually seen to be fairly clear and glassy, and is proved by the R.I. being markedly higher than balsam, and by the extinction angles in symmetrical sections ranging up to 24°, to be an acid labradorite. These labradorite centres must be nearly uniform in composition throughout, for they show shadowy extinction only very slightly. Perhaps at their edge they may be acid enough to be called andesine. Then there is a sudden transition to practically pure albite which has a mean R.I. very slightly, though distinctly below that of balsam. These outer zones of albite are turbid and brownish in colour from kaolinisation, and twinning on the carlsbad and albite laws is continued in them from the labradorite centres. Pericline twinning occurs, though rarely. On measuring the diameters across some of the short lath-shaped sections, we found that the albite occupies about a quarter of the diameter, the figures on three well formed crystals being respectively 30, 25 and 27 per cent. Remembering that the alkaline felspar forms the outer shell of the crystal, calculation shows that at this ratio of diameter, each completely formed crystal must consist of 60 per cent. of alkali felspar, and 40 per cent. of the acid labradorite. This proportion appears somewhat startling in comparison with the results of the Rosiwal measurement, but the discrepancy is easily accounted for by the fact that the crystals never are perfectly developed, more than half the space of the albite zone being occupied by interfering crystals.

The alteration of labradorite to analcite along cracks and cleavage planes, producing veins and small patches of the mineral, is common in the pegmatites as in the main mass. A photograph of one of the large plagioclase crystals between crossed nicols is shown in Plate XXXIX, Fig. 5, which shows the analcite plainly. There is also seen the carlsbad twin-plane in the upper part of the picture, and in the lower part faintly the kaolinised outer zone of alkali felspar. The analcite veins are very clearly seen by ordinary light if the condenser be sufficiently stopped down.

Pyroxenes.

There are three varieties of pyroxene present in the pegmatites :—

(1) A pale green non-pleochroic diopside in nearly idiomorphic stout prisms, some, but not all, having an outer zone of ægyrine-augite.

(2) A light purplish-brown feebly pleochroic augite with hour-glass structure, chiefly in large prisms reaching occasionally 3 cm. in length, but partly also interstitial to felspar, and generally similar to the augite of the main rock. It is never bounded by ægyrine-augite.

(3) Ægyrine-augite, pleochroic from dark grass-green and olive-green to yellow, irregularly distributed as small imperfect prisms and as a narrow outer zone to the diopside crystals.

One instance only was observed of intergrowth of the brown augite and the diopside, the latter occurring as an irregular outer zone. In relative abundance the brown augite is predominant, and the ægyrine-augite quite subordinate, forming less than one per cent. of the rock.

Other Minerals.

The other minerals are all similar to those occurring in the main rock. The biotite is of the usual strongly pleochroic brown variety, the crystals averaging about 1 mm. in diameter. The ilmenite presents a triangular skeleton structure very perfectly in places, and is variable in quantity, ranging from 3 to 8 per cent. in different parts of the normal pegmatite, whilst basic patches occur here and there much richer in ilmenite. Apatite is abundant and its prisms frequently surpass 3 mm. in length.

Aplites.

Megascopic Description.—Colour: White, grey or pale green. Grainsize: (*a*) the fine-grained type 0·1 to 0·15 mm.; (*b*) the medium-grained type 0·25 to 0·75 mm.; (*c*) the coarse-grained type 1 to 2 mm. Minerals visible: felspar, sometimes pyroxene, rarely biotite. Miarolitic structure is not uncommon, particularly in the coarser types.

Microscopic Description.—Texture: Holocrystalline, almost panidiomorphic-granular. Grainsize, see above.

Minerals present:—

Original—Albite
Orthoclase (? anorthoclase)
Pyroxene (diopside, augite, and ægyrine-augite)
Biotite (rarely)
Ilmenite
Apatite

Secondary—Analcite
Chloritoid and chlorite
Calcite

The Felspars.

These, which consist of albite and orthoclase (? anorthoclase), make up from 70% to 85% of the rock. They are always idiomorphic and thick-tabular in habit. Under the microscope they are seen to be much kaolinised, while some crystals show alteration into analcite. The chloritoid decomposition products are frequently present, sometimes marginally arranged. The albite crystals have a R.I. distinctly lower than that of the canada balsam, and in sections symmetrical to the albite lamellae, give extinction angles up to 16°. Pericline twinning is occasionally seen. The orthoclase exhibits carlsbad twinning, but is too decomposed for an accurate determination as to whether it is anorthoclase or not.

Pyroxene.

This mineral is present in relatively small quantity and usually occurs as small idiomorphic crystals, wholly or partly enclosed in the felspars. It is usually a pale green, non-pleochroic diopside, with in some of the larger crystals an inner zone of purplish-brown feebly-pleochroic augite. A thin outer zone of ægyrine-augite is occasionally present. In one slide only, numerous small idiomorphic crystals of ægyrine-augite occurred, associated with much biotite. The pyroxenes are much less altered than the felspars, producing chloritoid decomposition products. Some crystals have been partly replaced by calcite.

Other Minerals.

These are all similar to those described as occurring in the pegmatite veins, but are, for the most part present in less quantity.

The following is an analysis of the aplite by J. C. H. Mingaye with the norm calculated from it:—

Analysis, coarse Aplite.		Molecular ratio.	Norm.	%
SiO_2	58·82	980	Quartz	1·92
Al_2O_3	16·91	166	Orthoclase	17·79
Fe_2O_3	2·40	015	Albite	56·59
FeO	4·59	064	Anorthite	6·95
MgO	0·88	022	Corundum	0·10
CaO	2·42	043	Hypersthene	6·82
Na_2O	6·74	109	Magnetite	3·48
K_2O	2·96	032	Ilmenite	2·13
H_2O 100 C.	0·56	141	Apatite	0·62
H_2O 100 C. +	1·98		Calcite	1·20
CO_2	0·54	012	HO_2 and Cl	2·55
TiO_2	1·14	014		
P_2O_5	0·34	002	Total	100·15
Cl	0·01	...		
MnO	0·13	001		
Total	100·42			

Class—Dosalane. Order—Germanare.
Rang—Monzonase.
Subrang—Akerose (Magmatic Name).

In view of the decomposition which this rock has undergone, as evidenced by the presence of calcite, chlorite, and other decomposition products, it is necessarily difficult to form a satisfactory estimate of the "mode," and it is still more difficult to satisfactorily calculate the mode of the unaltered rock. The calculation is given in Appendix I with the following result:—

Ilmenite	2·2
Orthoclase	18·2
Albite...	56·3
Anorthite	4·0
Magnetite	2·8
Pyroxene	15·8
Apatite	0·7
	100·0

The amount of pyroxene shown is somewhat larger than the examination of a number of slides led one to expect.

Appendix I.

Determination of the Mode.

The calculation of the mode, or actual mineral composition, of a rock is possible, as pointed out by Cross, Iddings, Pirsson and Washington,[1] only when it contains not more than one ferric or alferric mineral, unless the compositions of any such minerals present be known.

If there be more than one alferric mineral present, it is necessary to know, not only the composition of each, but also the quantity present of all but one. Hence the calculation of the mode entails, if it is to be done accurately,

[1] Quantitative Classification, p. 210.

not only the separation and analyses of all the ferric and alferric minerals present, but also the measurement of the rock by the Rosiwal method. When all the necessary data are not available it is possible to calculate the mineral composition approximately by making reasonable assumptions as to the composition of one or two minerals, or their quantity. This is the course we have followed with regard to the Prospect rocks. The composition of the augite we know by analysis. We assumed a composition for the biotite agreeing closely with a number of analyses of biotite from igneous rocks and left the composition of the olivine to be determined by the remainder. A check was obtained, however, by the necessity of assuming the olivine to have the same composition in both specimens. This led to a slight re-adjustment of the proportion of FeO and MgO molecules in the biotite; and a closely approximate solution of the compositions of the rocks was finally obtained with the assumption of the following compositions for biotite and olivine:—

	Biotite.		Olivine.	
	Molecular.	By Weight.	Molecular.	By weight.
SiO_2	40	37·2	33·4	35·2
Al_2O_3	11	17·3	...	...
Fe_2O_3	4	9·9		
FeO	10	11·1	32·4	40·1
MgO	20	12·4	34·2	24·0
K_2O	6	8·7		
H_2O	8	2·2		
TiO_2	1	1·2		
	100	100·0	100·0	100·0

It will be seen that, whilst the biotite has quite a normal composition, the olivine is unusually rich in iron, and is a hyalosiderite, approaching fayalite. Its composition as here found is not dependent on the composition assumed for the biotite, but is conditioned by the remainders of FeO and MgO after allotting for the augite and magnetite in specimen I, which contains an insignificant quantity of biotite as will be seen on referring to the table of molecular proportions for that specimen. Confirmation of the high iron content of the olivine is to be found in the deep colour of the serpentine, whether brown or green, resulting from its alteration. Further verification of its ferriferous nature seemed desirable, however, and the only readily available means appeared to be the determination of the strength of double refraction, for according to the figures of Levy and Lacroix[1] that of olivine is ·036, that of natural fayalite ·049 and of artificial fayalite ·043. Sections of specimens B and Y in which the olivine is abundant and little altered were searched, and the section giving the highest colour examined in convergent light, with the result that a section was found in Y very nearly parallel to the optic axes, in B one not so nearly parallel, but sufficiently so to be worth examining further. The highest colour shown by any of the labradorite crystals in the vicinity of the olivine crystal chosen was then found. In both cases it lay in the first order yellow to red, and was accurately determined by addition and subtraction with a quarter-wave plate.

The olivine crystals were found to be heterogeneous in composition. Most of the crystals have an outer zone distinctly stronger in double refraction than the interior of the crystal section, the strength of D.R. increasing gradually but rapidly on nearing the edge of the section. In one or two cases, however, the zone of stronger D.R. was wrapped round an irregular centre of weaker D.R., the boundary between the two being perfectly sharp. The readings, and the results obtained by us of Michael Levy's chart are shown in the following table.

---

[1] See Mineraux des Roches, pp. 248-9.

Specim.	Colour of Olivine between crossed nicols.		Maximum phase difference (eX) of labradorite.	Thickness of slice in neighbourhood of olivine crystal.	∴ Minimum Possible D.R.	
	Interior.	Outer Zone.			Interior.	Outer Zone.
Y	Green IV Ord.	Red IV Ord.	450 $\mu\mu$	·050 mm.	·038	·042
B	Red IV Ord.	Green V Ord.	505 ,,	·058 ,,	·037	·041

The chief element of uncertainty was found to be the D.R. of labradorite, which is here taken as ·009. Levy and Lacroix give ·008 for both albite and labradorite, and ·013 for anorthite, but their determination for labradorite is admittedly accurate only to within ·002. If ·008 is correct for albite, and this seems to be in accordance with general experience,[1] the probability would seem to be that the D.R. of labradorite is ·009 at least, assuming that the progressive change in properties with composition holds good for D.R. as with all the other optical properties. The results in the two slides agree very closely when allowance is made for the section in B not being quite parallel to the optic axes. If the D.R. of labradorite be assumed to be ·0085 the D.R. of the olivine must be reduced in each case by ·002.

The figures obtained certainly agree with the hypothesis that the olivine is more than usually ferriferous. There can be no question as regards the difference of D.R. by ·004 between the interior of crystals and the outer zone, so that, even if the interior of the crystals be olivine of normal composition, nearly one-third of the volume of the phenocrysts, and the whole of the not very numerous small crystals of the groundmass, must be unusually rich in iron.

In the two specimens in which the composition of the augite was known, it was found that the silica was deficient for producing albite with all the soda. At first thought the presence of nepheline would be inferred from this, but there is no microscopic evidence whatever of the original

[1] *Cf.* the determination of the D.R. of the andesine of Baskerville as ·0081 by Offret (Bull. Soc. Min., France, 1890, XIII, p. 648.)

presence of any lenad—not the slightest suggestion of it. A deficiency of silica is not uncommonly found in calculating modes from chemical analysis, and it is most probable that in this, as in other cases, the deficiency is due to the decomposed state of the rock. A slight under-estimation of ferric iron would have the same effect by producing an underassignment of magnetite; and it is just possible, considering the difficulties of ferrous iron determinations, that a small part of the deficiency may be due to this cause in specinen B, in which the ferric iron is particularly low and the dcficiency of silica rather high.

The removal of silica during decomposition is undoubtedly the main cause of the deficiency of silica, as shown by the presence of much secondary analcite; and in calculating the modes, silica has therefore been added sufficient to form polysilicates of the whole alkalies excluded from the alferric minerals.

Mode of Specimen I.

The quantity of biotite present was assumed to be a little less than 2 per cent., in conformity with the microscopic evidence, and the number of molecules of oxides in the proper proportion necessary to make this quantity was calculated. Allotment then proceeded as in the following table, equations involving lime-alumina ratios being used to determine the augite and anorthite:—

	Composition by Weight.	Composition by Molecules.	Apatite	Ilmenite	Biotite	Orthoclase	Albite	Augite	Anorthite	Magnetite	Olivine	Sums	Differences
SiO_2	41·05	684	...	...	10	24	222	307	110	...	32	705	−21
Al_2O_3	12·27	121	...	...	3	4	37	21	55	...	...	120	+1
Fe_2O_3	6·39	40	...	...	1	...	...	7	...	32	31	40	...
FeO, MnO	11·26	157	...	54	3	...	..	37	...	32	33	157	...
MgO	6·38	159	...	...	5	...	...	121	..	...	...	159	...
CaO	10·96	196	3	...	...	...	...	138	55	...	...	196	...
Na_2O	2·43	40	...	...	...	...	37	3	...	...	...	40	...
K_2O	0·53	6	...	...	2	4	...	...	...	...	...	6	...
TiO_2	4·39	55	...	54	...	...	...	1	...	...	...	55	...
P_2O_5	0·19	1	1	...	...	...	...	...	...	...	...	1	...
H_2O	...	...	...	...	2	...	...	...	...	...	...	...	...
	95·85												

Mineral.		Mols. × Molec. weight.		Weight.	Percentage wt.
Orthoclase		·004 × 556		2·22	2·3
Albite		·037 × 524		19·39	20·0
Anorthite		·055 × 278		15·29	15·7
Biotite	SiO_2	·010 × 60	= ·600	1·70	1·7
	Al_2O_3	·003 × 102	= ·306		
	Fe_2O_3	·001 × 160	= ·160		
	FeO	·003 × 72	= ·216		
	MgO	·005 × 40	= ·200		
	K_2O	·002 × 94	= ·188		
	H_2O	·002 × 18	= ·036		
			1·702		
Augite	SiO_2	·307 × 60	18·420	37·18	38·2
	Al_2O_3	·021 × 102	2·142		
	Fe_2O_3	·007 × 160	1·120		
	FeO	·037 × 72	2·664		
	MgO	·121 × 40	4·840		
	CaO	·138 × 56	7·730		
	Na_2O	·003 × 62	0·186		
	TiO_2	·001 × 80	0·080		
			37·182		
Olivine	SiO_2	1·032 × 60	1·920	5·47	5·7
	FeO	·031 × 72	2·232		
	MgO	·033 × 40	1·320		
			5·472		
Ilmenite		·054 × 152		8·31	8·4
Magnetite		·032 × 232		7·42	7·6
Apatite		·001 × 336		·34	·4
				97·22	100·0

Sum of principal components in analysis: 95·85 + 0·36 H_2O + 1·26 deficient SiO_2. 97·47 deficit 0·25. Composition of plagioclase: $Ab_{74}An_{55} = Ab_4An_3$.

Mode of Specimen B.

In this specimen the quantity of biotite was determined by the Rosiwal method, which gave 12·0 per cent. It is found generally that the proportion of coloured constituents is liable to slight exaggeration by that method, owing to portions of the coloured mineral which overlap a colourless mineral at an oblique junction being counted as if belonging wholly to the former. For the purpose of calculating the mode we have therefore assumed the quantity of biotite present to be 11·5 per cent., and have then proceeded as in the case of the previous specimen (I). It is unnecessary to exhibit the reduction of the mineral composition from molecular proportions to weight percentage as the method followed was exactly the same as in the example just given (Spec. I.).

	Composition by Weight.	Composition by Molecules.	Apatite	Ilmenite	Biotite	Orthoclase	Albite	Anorthite	Augite	Magnetite	Olivine	Sums	Difference
SiO_2	46·26	771	...	.	71	12	300	84	249	...	82	798	− 27
Al_2O_3	13·36	131	...	...	20	2	50	42	17	...	...	131	...
Fe_2O_3	2·34	15	...	...	7	...	...	...	6	2	..	15	...
FeO MnO	10·53 0 13	148	...	21	17	...	...	...	30	2	78	148	...
MgO	8·87	222	...	...	37	..	...	..	98	...	87	222	...
CaO	9·18	164	10	...	...	...	...	42	112	...	...	164	...
Na_2O	3·27	53	...	...	...	...	50	...	3	...	...	53	...
K_2O	1·23	13	..	...	11	2	...	.	...		...	13	...
H_2O	...	...	...	...	14	...	...	...	...	...	...	14	...
TiO_2	1·78	22	...	21	. .	...	...	...	1		...	22	...
P_2O_5	0·42	3	3	...	...	...	...	..	...		...	3	...
Percentage of composition of the rock by weight			1·0	3·2	11·5	1·1	26·4	11·7	30·4	0·5	14·2	100·	0

Sum of mineral weights 99·32.

Sum of analysis + H_2O + def. SiO_2 99·07. Excess 0·25.

Composition of plagioclase : $Ab_{100}An_{42} = Ab_7An_3$.

MODE OF COARSE APLITIC ROCK (Essexo-aplite).

The problem of calculating the mode of the coarse aplitic rock from its analysis differs from that of the preceding two specimens, for microscopic examination shows that it is devoid of both biotite and olivine, and that the pyroxene present must have a composition different from that of the violet-brown augite of the main rock, as it is colourless to pale-green in colour, and passes in the outermost zone to aegyrine-augite. The quantity of the latter in terms of pure aegyrite (acmite) is quite insignificant, probably much less than one per cent. of the rock. It seemed needless therefore to attempt to determine the quantity of the aegyrite molecule separately, and it was regarded as a component of the augite, which would thus be somewhat richer in soda than that of the main rock. There remained but one ferro-magnesian mineral of which both the quantity and the composition are thus approximately determinable. Quartz and lenads being proved absent microscopically, constituents were first assigned to apatite, ilmenite, and orthoclase. Albite was formed with all the soda except a reasonable amount held for the augite. The anorthite was reduced to the minimum compatible with not giving the augite a very unusually high percentage of alumina, the difficulty being that increasing the anorthite would have left the augite almost impossibly poor in lime. Perhaps the rock has lost some of its lime by decomposition. The anorthite thus determined, the remainder, after a reasonable quantity of iron oxides has been assigned to magnetite, is treated as augite. Its composition has been calculated and is stated in the first column of the following table. It is seen to be very poor in lime and rich in ferrous-oxide and alumina :—

Composition of Augite by Weight.		Composition of Rock by Weight.	Composition of Rock by Molecules	Apatite	Ilmenite	Orthoclase	Albite	Anorthite	Magnetite	Augite
50·3	SiO_2	58·82	980	...	...	193	630	28	...	130
9·8	Al_2O_3	16·91	166	...	...	32	195	14	...	15
3·1	Fe_2O_3	2·40	15	...	...	...	..	...	12	3
21·7	FeO, MnO	4·72	66	...	14	...	...	...	12	40
5·6	MgO	0·88	22	...	...	...	..	...	...	22
7·9	CaO	2·42	43	7	...	...	..	14	...	22
1·6	Na_2O	6·74	109	...	...	...	105	...	...	4
	K_2O	2·96	32	...		32	..	...	...	...
100·0	TiO_2	1·14	14	...	14	...	...	...	...	...
	P_2O_5	0·34	2	2	...		...			
Percentage composition of the rock by weight ...				0·7	2·2	18·2	56·3	4·0	2·8	1·58

Sum of mineral weights 97·78.
Sum of analysis 97·33. Excess 0·45.
Composition of Plagioclase: $Ab_{105}An_7 = Ab_{15}An_1$.

Appendix II.

Restoration of the Original Composition of the Decomposed Rocks.

The secondary constituents of igneous rocks fall into two classes: the products of incipient alteration, and the minerals resulting from advanced decomposition. The former, such as kaolin and scapolite, are without influence on the boundaries of the crystals in which they occur, and in the Rosiwal measurements they count as parts of those crystals and are wholly neglected. Secondary minerals of the latter kind, on the other hand, frequently transgress the original limits of the crystals from which they are formed; so that in measuring a rock there is no option but to reckon them separately, and allow for them afterwards. The most abundant products of advanced alteration in the Prospect rocks are analcite, serpentine, and chlorite, with which we may include the chloritoid, owing both to its similarity in composition, and to the difficulty of separating the two under the microscope. Stilbite and calcite, or dolomite, are comparatively rare as defined masses; but calcite probably forms some proportion, though often a small one, of most of the masses of chlorite. Thus the only secondary minerals which have to be broken up and allotted to original minerals are analcite, serpentine, chlorite and a little calcite, with occasionally some stilbite.

The method here adopted is first to calculate the quantity of augite and olivine which would have been required to form the weights found of chlorite and serpentine respectively. The quantity of felspar lost by decomposition is then determined by reckoning the volume of analcite found as felspar, and by adding to this the weight of felspar which must have been displaced by the net expansion of the augite and olivine as they altered to chlorite and serpentine. There is little doubt that some lime and silica are completely removed from the rock itself by the percolating water, to be deposited in adjacent cracks and cavities, and perhaps a little soda also goes. Calcite and stilbite, where they appear in measurements are allotted to both augite and labradorite. The successive steps in the restoration of the original minerals will now be detailed, the figures obtained in the correction of the measurement of specimen I. being quoted as an example.

The composition by weight of specimen I was found to be as follows:—

Augite	34·2	Analcite	4·0
Felspar	31·7	Biotite	0·1
Iron Ores	17·2	Apatite	0·7
Serpentine	7·1		——
Chlorite	5·0		100·0

To form olivine out of serpentine, deduct approximately 12 per cent of water and then 18 per cent. of silica, for the dehydrated serpentine will contain nearly 50 per cent. of silica, and deducting silica to 18 per cent. of its weight will leave a remainder having about 38 per cent. of silica, which is the proportion in a ferriferous olivine, thus:—

$$7{\cdot}1 \times {\cdot}88 \times {\cdot}82 = 5{\cdot}1 = \text{total olivine.}$$

In forming augite from chlorite regard must be had to the compositions of these minerals as determined by analysis. The principal difference in composition between the two minerals is as regards the water, silica, and lime, the losses or gains of other constituents being comparatively negligible. We may assume that a little calcite is usually mixed with the chlorite, say about 3 per cent., and we must then deduct 16 per cent. for water and carbon dioxide, leaving a remainder which has approximately the composition shown in column I below. Adding to this 55 per cent. of SiO_2 and 34 per cent. of CaO, and reducing to percentages again, we have the composition shown in column II :—

	I.	II.	III.
SiO_2	38·2	49·4	49·7
Al_2O_3	12·8	6·7	5·8
Fe_2O_3 and FeO	16·3	8·6	10·1
MgO	28·0	14·8	13·0
CaO	4·0	20·1	20·8
Na_2O and K_2O	·7	·4	·7
	100·0	100·0	100·0

and this compares fairly closely with the composition of the augite, shown in column III. Thus for the silica and lime together 89 per cent. must be added to the dehydrated chlorite to give us the destroyed augite. Add to this the existing augite, and we have the original total, thus :—

$$5{\cdot}0 \times {\cdot}84 \times 1{\cdot}89 = 7{\cdot}9 + 34{\cdot}2 = 42{\cdot}1 = \text{total augite.}$$

In restoring decomposed felspar the space now occupied by analcite is to be reckoned as filled with felspar, say, on the average an andesine (sp. gr. 2.65), so what has been reckoned as analcite is converted to felspar by multiplying by the ratio of their specific gravities, thus :—

$$4{\cdot}0 \times \frac{2{\cdot}65}{2{\cdot}25} = 4{\cdot}7$$

The quantity of felspar lost and now replaced by serpentine and chlorite is found by calculating the expansion of the olivine in passing to serpentine, and the contraction of the augite in changing to chlorite and counting the balance, which is always one of expansion if there be an appreciable quantity of olivine present, as the volume of felspar replaced by serpentine and chlorite. The several volumes are found thus :—

	Relative Volumes.	Differences.	
Chlorite	$5·0 \div 2·7 = 1·83$	$-\ 0·47$	$+\ 0·85$
Augite destroyed	$7·9 \div 3·4 = 2·32$		
Serpentine	$7·1 \div 2·6 = 2·74$	$+\ 1·32$	
Olivine	$5·1 \div 3·6 = 1·42$		

The net increase of volume (0·85) multiplied by the specific gravity of the felspar (2·65) gives us 2·3 as the weight of felspar replaced by serpentine. Adding to this the existing felspar and that replaced by analcite, we have:—

$$31·7 + 4·7 + 2·3 = 38·7 = \text{total felspar.}$$

The other constituents of the rock are unaltered, so that the corrected relative weights are as in column I below. Their sum is greater than 100 because the original minerals are heavier than the decomposition products, and reducing to percentages we obtain the figures in column II. In column III is placed, for the sake of comparison, the proportions of the constituents as calculated from the analysis, and in column IV the differences.

	I.	II.	III.	IV.
Augite	42·1	40·5	38·2	+ 2·3
Felspar	38·7	37·2	38·0	− 0·8
Iron Ores	17·2	16·6	16·0	+ 0·8
Olivine	5·1	4·9	5·7	− 0·8
Biotite	0·1	0·1	1·7	Assumed
Apatite	0·7	0·7	0·4	+ 0·3
	103·9	100·0	100·0	

It will be seen that the proportions by the two methods are in general agreement, but that by the Rosiwal method the percentages of augite, iron ores, and apatite are greater than by calculation, and the quantities of the other minerals less. The disparity is probably due to two causes: partly to some serpentine having been counted as chlorite, and partly to the tendency of the Rosiwal method to overestimate the coloured constituents of a rock, owing to the fact that where crystals of the latter overlap a colourless constituent the whole width of the overlap, and not only half, is reckoned as part of the coloured constituent. The latter source of error is accentuated by the fact that the slides used are rather thick. The difference of the biotite is assumed from inspection of the slides, as already stated.

Appendix III.

NOTE.—The following paragraph should have appeared at the end of Part III, on page 540, but was accidently omitted.

The question now arises as to the naming of the rocks occurring in the segregation veins. Although they differ, particularly in the case of the aplite, in their mineral and chemical composition from the essexite, they are so essentially a part of the essexite intrusion that any names given should show that connection; we therefore propose the names essexo-pegmatite and essexo-aplite for these two rock types. The names aplite and pegmatite have usually been restricted in their use to the segregation veins occurring in granite; there is, however, no reason why they should not be applied to similar segregation veins occurring in any igneous rocks, the names being modified as above to indicate the parent rock to which they belong.

EXPLANATION OF PLATES.

Figs. 1, 2, 3. Diagrammatic sections of the Prospect intrusion.

Fig. 4. Rough sketch of that part of the upper segregation vein shown at H on Plate XXXV (transfer).

PLATE XXXIV.

Geological map of the Prospect Intrusion, New South Wales, also sketch section on line AB.

Plate XXXV.

The central portion of the main face of the Reservoir Quarry.

Plate XXXVI.

Southern end of the Reservoir Quarry looking south-east, showing the two large segregation veins dipping toward the main face of the quarry.

Plate XXXVII.

Portion of the upper segregation vein.

Plate XXXVIII.

Portion of the lower segregation vein.

Plate XXXIX.

Fig. 1. Micro-Section of pallio-essexite with included grain of quartz.

,, 2. Micro-Section of pallio-essexite showiug a phenocryst of olivine.

,, 3. Micro-Section of essexite. The clear white mineral in the centre of the slide is analcite. The partly decomposed white mineral is plagioclase, and the dark crystals at the left are augite.

,, 4 Micro-Section of essexite much decomposed with idiomorphic crystals of analcite and much chlorite.

,, 5. Crystal of labradorite from essexo-pegmatite, between crossed nicols, showing alteration along cracks and cleavages into isotropic analcite.

,, 6. Micro-Section of essexo-aplite showing idiomorphic felspars. The dark colored material is chlorite.

Plate XL.

Specimen of fine-grained aplite with a vein of coarser aplite. (About natural size.)

NOTE ON THE OCCURRENCE OF *TÆNIOPTERIS* IN THE ROOF OF THE COAL SEAM IN THE SYDNEY HARBOUR COLLIERY.

By W. S. Dun.

[Communicated by permission of the Under Secretary for Mines.]

With Plate XLI.

[*Read before the Royal Society of N. S. Wales, December 6, 1911.*]

THIS brief note serves as a record of an addition to the flora of the shales overlying the coal seam in the Sydney Harbour Colliery already referred to in this Journal[1]—*Cladophlebis* cf. *Roylei*, Arber, *Schizoneura gondwanensis*, and *Rhipidopsis ginkoides*, Schmal.?, var. *Süssmilchi*, Dun.

I am again indebted to Mr. C. A. Süssmilch for the loan of the specimen here referred to as *Tæniopteris*, cf. *McClellandi*, Oldham and Thomas.

As preserved, the portion of the frond is seen to be 24 mm. in width, with a well marked and prominent midrib, the venation slightly inclined, about two to the millimetre, —the furcation is irregular, near the midrib and between that and the margin, and not regularly developed.

For comparison, reference may be made to the works of Feistmantel,[2] Zeiller,[3] and others quoted in Arber's "The Glossopteris Flora."

No exactly similar frond has hitherto come to my notice from Australian beds. It occurs abundantly in the Rajmahal Series of India of the Upper Gondwanas (Lower

[1] This Journal, 1910, XLIV, pt. 4, pp. 615–619, pls. 49–51.

[2] Flora Gondwana System, 1879, I, pt. 4, t. 1, f. 14–16, t, 2, f, 4.

[3] Flore fossile Gites de charbon du Tonkin, 1902, t. 9, f. 3–5.

[4] Brit. Mus. Cat., 1905, p. 126.

Mesozoic ? = Jurassic). The Tonkin deposits are regarded as of Rhætic age, in this latter case it is of some interest to note that the fossil fish of Gosford, which are considered by David to occur in beds either at the base of the Hawkesbury or top of the Narrabeen Stage[1], point to a possible age as based on a correlation with European fish faunas, of which Smith Woodward says[2] "So far as can be determined from the fishes, therefore, the Hawkesbury beds may be regarded as homotaxical with the Keuper of Europe, or at latest, with the Rhætic, and on the whole, the present writer is inclined to adopt the first of these interpretations."

Associated with the leaf is the impression of an insect's wing, a description of which will be submitted later.

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[1] The Fossil Fishes of the Hawkesbury Series at Gosford. M. Geol. Surv. N.S.W., Pal. IV, 1890, p.8. [2] *Ibid.*, p. 55.

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 3, 1911.

The Annual Meeting, being the three hundred and fortieth (340th) General Meeting of the Society, was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 3rd, 1911.

Professor T. W. E. DAVID, President, in the Chair.

Thirty-nine members and twelve visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of candidates for admission as ordinary members were read; one for the second, and one for the first time.

Mr. W. J. CLUNIES ROSS and Mr. GERALD HALLIGAN were appointed Scrutineers, and Mr. W. M. HAMLET deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—

GEORGE ALFRED JULIUS, B.Sc., M.E., Norwich Chambers, Hunter-street, Sydney.

The Annual Report of the Council for the year ending 31st March, 1911, was read as follows and adopted.

ANNUAL REPORT OF THE COUNCIL.

The number of members on the roll on the 30th of April 1910, was 315. During the past year the Society has lost two honorary members, and two ordinary members, by death; twelve ordinary members have been elected and nine have resigned, leaving a total of 316 members on the roll at the end of April 1911. This total does not include the fourteen honorary members. The losses by death were:

Honorary Members:

Sir WILLIAM HUGGINS, Upper Tulse Hill, London.
STANISLAO CANNIZARO, Reale Universîta, Rome.

Ordinary Members:

Dr. WALTER SPENCER, elected 1896.
W. J. MACDONNELL, elected 1868.

Books and periodicals have been purchased at a cost of £41 13s. 7d. A great number of unbound books and periodicals are about to be bound in a cheap style of binding in order to make them accessible to the members.

The number of Institutions on the exchange list is 429, and the publications received in exchange for the Society's Journal and Proceedings during the year comprise 222 volumes, 1815 parts, 161 reports, 282 pamphlets, 20 maps; total 2500.

During the past year the Society held eight meetings, at which thirty-two papers were read, the average attendance of the members being thirty-one, and of the visitors three.

A series of Popular Science Lectures, illustrated by lantern slides or diagrams, was delivered during the year as follows:—

June 16—"*The Velocity of Chemical Changes*," by Professor FAWSITT, D. Sc., Ph.D., illustrated by experiments.

July 21—"*Early Blue Mountain Exploration, Barallier's furthest West*," by R. H. CAMBAGE, L.S., F.L.S.

August 18—"*The Mountains of New South Wales, their Nature and Origin*," by C. A. SÜSSMILCH, F.G.S.

September 15—"*Modern Methods of Recording Earthquakes*," by Rev. E. F. PIGOT, B.A., M.B., S.J.

November 8 and 11—"*The Social View of Capital,*" by R. F. Irvine, M.A.

The Honorary Treasurer's Financial Statement for the year ended 31st March, 1911, was presented to the Society, and on the motion of Mr. Carment seconded by Prof. J. A. Pollock was adopted :—

GENERAL ACCOUNT.

Receipts.		£ s. d.	£ s. d.
Subscriptions	One Guinea	50 8 0	
	,, ,, Arrears	13 13 0	
	Two Guineas	382 4 0	
	,, ,, Arrears	58 16 0	
	,, ,, In Advance ...	6 6 0	
			511 7 0
To Parliamentary Grant on Subscriptions received—			
Vote for 1910-1911			400 0 0
,, Rent			391 14 6
,, Sundries...			26 8 6
,, Exchange added to Country cheques			0 2 0
,, Clarke Memorial Fund—Loan			130 16 1
			1460 8 1
To Balance on 1st April, 1910			1 8 9
			£1461 16 10

Payments.	£ s. d.
By Advertisements	15 2 9
,, Assistant Secretary	272 5 0
,, Books and Periodicals	41 13 7
,, Bookbinding	19 9 5
,, Caretaker	84 12 6
,, Electric Light	28 12 8
,, Freight, Charges, Packing, etc.	8 12 0
,, Gas	6 5 4
,, Insurance	19 15 5
,, Interest on Mortgage	124 0 0
,, Office Boy	31 10 10
,, Petty Cash Expenses...	11 13 6
,, Postage Stamps	29 3 2
,, Printing	33 5 2
,, Printing and Publishing Journal	249 9 11
Carried forward	975 11 3

Payments—*contiuued.*	£ s. d.	£ s. d.
Brought forward		975 11 3
By Rates		64 12 9
„ Repairs		42 10 2
„ Stationery		13 7 6
„ Sundries		37 1 9
„ Conversazione...		63 2 3
„ Clarke Memorial Fund—Repaid Loan General Account	130 16 1	
„ Ditto, ditto, Interest...	1 3 9	
		131 19 10
„ Bank Charges		0 16 8
„ Cash in hand 31st March, 1911		2 1 0
„ Cash in Bank on 31st March, 1911... ...		103 2 8
		£1461 16 10

BUILDING AND INVESTMENT FUND.

Dr.	£ s. d.
To Loan on Mortgage at 4%	3100 0 0
„ Clarke Memorial Fund—Loan	18 15 11
	£3118 15 11

Cr.	£ s. d.
By Deposit in Government Savings Bank, March 31st, 1911	1 8 2
„ Balance of Account, 31st March, 1912	3117 7 9
	£3118 15 11

CLARKE MEMORIAL FUND.

Dr.	£ s. d.
To Amount of Fund, 31st March, 1910	501 11 11
„ Interest to 31st March, 1911	14 10 9
„ General Account Repaid on a/c Loan	130 16 1
„ General Account, Balance	2 3 6
	£649 2 3

Cr.	£ s. d.
By Deposit in Savings Bank of N. S. W., March 31, 1911 ...	285 1 9
„ Deposit in Government Savings Bank, March 31, 1911 ...	214 8 6
„ Repaid on a/c Loan to Building and Investment Fund ...	130 16 1
„ Loan to Building and Investment Fund	18 15 11
	£619 2 3

Audited and found correct, as contained in the Books and Accounts.

W. PERCIVAL MINELL, F.C.P.A., *Auditor.*

D. CARMENT, F.I.A., F.F.A., *Honorary Treasurer.*

Sydney, 26th April, 1911.

On the motion of Mr. Henry Deane, seconded by Mr. Houghton, Mr. W. P. Minell was duly elected auditor for the ensuing year.

On the motion of Mr. J. H. Maiden, seconded by Mr. R. H. Cambage, Mr. W. Botting Hemsley, F.R.S., late of Kew, was unanimously elected an Honorary Member in recognition of his distinguished services in promoting a knowledge of the Australian Flora.

Ninety-six volumes, 169 parts, 15 reports, 7 pamphlets, and 15 maps were laid upon the table.

There being no other nominations, the following gentlemen were declared duly elected Officers and Members of Council of the Royal Society of New South Wales for the ensuing year:—

President:

J. H. MAIDEN, F.L.S.

Vice-Presidents:

W. M. HAMLET, F.I.C., F.C.S.	F. H. QUAIFE, M.A., M.D.
H. D. WALSH, B.A.I., M. Inst. C.E.	Prof. T. W. E. DAVID, C.M.G., B.A., D.Sc.

Hon. Treasurer:

D. CARMENT, F.I.A., F.F.A.

Hon. Secretaries:

F. B. GUTHRIE, F.I.C., F.C.S.	Prof. POLLOCK, D.Sc.

Members of Council:

R. H. CAMBAGE, L.S., F.L.S.	CHARLES HEDLEY, F.L.S.
H. G. CHAPMAN, M.D.	T. H. HOUGHTON, M. Inst. C.E.
J. B. CLELAND, M.D., Ch.M.	HENRY G. SMITH, F.C.S.
HENRY DEANE. M.A., M. Inst. C.E.	Prof. WARREN, M. Inst. C.E., Wh.Sc.
R. GREIG-SMITH, D.Sc.	W. G. WOOLNOUGH, D.Sc., F.G.S.

The President made the following announcement:—that the Geological Section, of which Mr. J. E. Carne, F.G.S., was Chairman, and Mr. C. A. Sussmilch, F.G.S., Honorary Secretary, would meet every second Wednesday in the month, unless members were otherwise notified.

Professor T. W. E. David then delivered his Presidential Address.

In it he referred to the loss which the Society has sustained during the year in the deaths of Dr. WALTER SPENCER and Mr. W. J. MACDONNELL. Dr. SPENCER had not only given to the Society the benefit of his services as a member of the Council, but had of late been prominent as president of the New South Wales branch of the British Science Guild. His efforts to secure larger playgrounds and reserves for the school children had been crowned with success, and his good work would live after him. Mr. MACDONNELL was esteemed as a patient and enthusiastic worker in Astronomy.

Reference was made to the recent Antarctic expeditions under Captain SCOTT and Captain AMUNDSEN and Lieutenant SHIRASE, and a strong appeal was made to the members of the Royal Society to support Dr. DOUGLAS MAWSON in the Australasian expedition which he was now organizing with so much energy.

An outline was given of the preliminary scientific work about to be undertaken in the Northern Territory, on behalf of the Federal Government, by Professors BALDWIN SPENCER and GILRUTH of Melbourne University, Dr. BREINL of the School of Tropical Medicine, and Dr. W. G. WOOLNOUGH as Geologist. This expedition, which starts early in June and which will be away for about eight or ten weeks, is intended to be a prelude to a larger expedition in which every branch of Science bearing on the problems of the Northern Territory will be represented.

The special subject of the address was the geological structure of the Australian Continent, especially in relation of the evolution of its mountains, valleys, plains and plateaus. A large scale relief map of Australia and Tasmania, specially prepared for illustrating these features by Mr. W. K. MCINTYRE of Sydney University, was exhibited. This was based on an accurate map kindly supplied by Mr. H. E. C. ROBINSON.

At the conclusion of the address, a very hearty vote of thanks was given to the retiring President, and Mr. J. H. MAIDEN was installed as President for the ensuing year.

ABSTRACT OF PROCEEDINGS, JUNE 7, 1911.

The three hundred and forty-first (341st) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, June 7th, 1911, at 8 p.m.

Mr. J. H. MAIDEN, President, in the Chair.

Twenty-eight members were present and ten visitors.

The minutes of the preceding meeting were read and confirmed.

The certificates of candidates for admission as ordinary members were read; one for the second, and one for the first time.

Mr. W. J. CLUNIES ROSS and Mr. WILLIAM WELCH were appointed Scrutineers, and His Honor Judge DOCKER deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—

R. D. WATT, M.A., B.Sc., Professor of Agriculture in the University of Sydney.

The President made the following announcements:—

(1) That the Council had decided to open a subscription list in favour of Mr. W. H. WEBB, who had resigned the office of Assistant Secretary, after a service of thirty-four years.

(2) That a series of Popular Science Lectures, illustrated by lantern slides, experiments, or diagrams, would be held during the Session, on the following dates, at 8 p.m.:—

June 15—"*Insects and Disease,*" by W. W. FROGGATT, F.L.S.

July 20—"*The Ancient Italian House, with special reference to Pompeii,*" by Dr. F. A. Todd.

August 17—"*The Reign of Ill-custom in English Spelling,*" by Professor E. R. Holme.

September 21—"*The History of Taxation,*" by B. R. Gelling.

(3) That a meeting to further the objects of Dr. Mawson's Antarctic Expedition would take place in the vestibule of the Town Hall, Sydney, on June 13th, at 4 p.m.

(4) That the Geological Section would not meet this month.

(5) That donations consisting of 22 volumes, 88 parts, 12 reports, 24 pamphlets, and 3 maps, were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "Notes on Transition Curves," by W. Shellshear, M. Inst. C.E. In the absence of the author, the paper was read by Mr. H. Deane.
2. "Notes on the Oxy-acetylene Welding Process," by Prof. S. Henry Barraclough, with a practical demonstration of cutting and welding steel by Mr. George Kennedy.

ABSTRACT OF PROCEEDINGS, JULY 5, 1911.

The three hundred and forty-second (342nd) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, July 5th, 1911, at 8 p.m.

Mr. J. H. Maiden, President, in the Chair.

Twenty-one members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of candidates for admission as ordinary members were read; one for the second, and one for the first time.

Dr. E. STOKES and Dr. COOKSEY were appointed Scrutineers, and Mr. D. CARMENT deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—

CHARLES FRANCIS LASERON, The Technological Museum, Sydney.

The President made the following announcements:—

(1) That the Popular Science Lecture on "The Ancient Italian House, with special reference to Pompeii," by Dr. F. A. TODD, would be delivered in the Society's House on July 20th, 1911.

(2) That a printed announcement referring to a proposed testimonial to Mr. W. H. WEBB has been distributed in the hall for members.

(3) That donations consisting of 13 volumes, 90 parts, 9 reports, 3 pamphlets, and 5 maps were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "Observations on the Corrosion of Steel in Water," by G. J. BURROWS, and C. E. FAWSITT, D. Sc., Ph. D.

Prof. DAVID, Mr. DARNELL-SMITH, Dr. COOKSEY and Dr. STOKES took part in the discussion.

2. "On the application of Fourier's Series to Statistical Data, illustrated by the Analysis of Fluctuations of Annual Period in Rate of Marriage, Temperature, Suicide etc." by G. H. KNIBBS, C.M.G., F.R.A.S., F.S.S., etc., Commonwealth Statistician. Read in abstract by Mr. F. B. GUTHRIE.

3. "*Echinorhynchus pomatostomi*, a subcutaneous parasite of Australian Birds," by T. HARVEY JOHNSTON, M.A., D.Sc. and J. BURTON CLELAND, M.D., Ch.M. Read by Dr. J. B. CLELAND.

EXHIBITS.

(1) Two volumes Eleventh Edition of Encyclopædia Britannica on India Paper, by F. H. QUAIFE, M.A., M.D.

(2) The Digby and Biggs Dionic Water Tester, by Dr. E. STOKES.

ABSTRACT OF PROCEEDINGS, AUGUST 2, 1911.

The three hundred and forty-third (343rd) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, August 2nd, 1911, at 8 p.m.

Mr. J. H. MAIDEN, President, in the Chair.

Twenty-four members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

One new member, Professor R. D. WATT, M.A., B.Sc., enrolled his name and was introduced.

The certificate of a candidate for admission as an ordinary member was read for the second time.

Mr. LAWRENCE HARGRAVE and Mr. CLUNIES ROSS were appointed Scrutineers, and Dr. QUAIFE deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society :—

EDWARD STEVENSON SMITHURST, 7 Bridge-st., Sydney.

The President made the following announcements :—

(1) That the Popular Science Lecture on "The reign of ill-custom in English Spelling," would be delivered by

Professor E. R. HOLME, M.A., in the Society's Hall, on the 17th August, 1911.

(2) That Volume XLIV, of the Society's Journal would be ready for distribution to members in about two weeks.

(3) That donations consisting of 34 volumes, 155 parts, 8 reports, 3 pamphlets, and 5 maps had been laid upon the table.

CORRESPONDENCE.

Letter from Mr. W. BOTTING HEMSLEY, F.R.S., expressing his thanks to the Society on his election as an Honorary Member of the Society.

THE FOLLOWING PAPERS WERE READ:

1. "Erosion and its Significance," by E. C. ANDREWS, B.A., read in abstract by Mr. C. A. SUSSMILCH, in the absence of the author.

2. "Notes on the Geology of West Moreton, Queensland, by W. G. WOOLNOUGH, D.Sc., and R. A. WEARNE, B.A., read in abstract by Mr. C. A. SUSSMILCH in the absence of the authors.

3. "Preliminary Note on the Nepheline-bearing Rocks of Liverpool and Mount Royal Ranges," by W. N. BENSON, B.Sc.

4. "Geology of the Kempsey District," by W. G. WOOLNOUGH, D.Sc., read in abstract by Mr. C. A. SUSSMILCH, in the absence of the author.

5. "The effect of Heating and Antiseptic Treatment on the Solubility of the Fertilising Ingredients in Soils," by H. I. JENSEN, D.Sc., read by Mr. F. B. GUTHRIE, in the absence of the author.

6. "The Origin of the Small Bubbles of Froth," by Prof. J. A. POLLOCK, D.Sc.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 6, 1911.

The three hundred and forty-fourth (344th) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street north, on Wednesday, September 6th, 1911, at 8 p.m.

Mr. J. H. Maiden, President, in the Chair.

Twenty-seven members were present.

The minutes of the preceding meeting were read and confirmed.

One new member, Mr. Edward S. Smithurst enrolled his name and was introduced.

The certificate of one candidate for admission as an ordinary member was read for the first time.

The President made the following announcements:—

(1) That a Popular Science Lecture, entitled "A Brief History of Taxation," by Mr. B. R. Gelling, F.S.S., would be delivered in the Society's Hall, on Thursday evening, September 21st, 1911, at 8 p.m.

(2) That the Geological Section would not meet this month, many of the geologists being away in the country.

(3) That donations consisting of 26 volumes, 135 parts, 9 reports, 10 pamphlets, and 5 maps had been laid on the table.

CORRESPONDENCE.

A letter from His Excellency the Governor General consenting to act as Patron of the Society was read.

The President announced to the meeting the death of Mr. F. W. White, printer to the Society for over half a century, and the meeting resolved to express its sincere condolence to the relatives of Mr. White.

THE FOLLOWING PAPERS WERE READ:

1. "Suicide in Australia, a Statistical Analysis of the facts," by G. H. Knibbs, C.M.G., F.R.A.S., F.S.S. etc.,

Commonwealth Statistician. Read in abstract by Mr. F. B. GUTHRIE.

2. "Notes on the Occurrences of Explosive Reports in the Interior of Australia, with suggestions as to their nature," by J. B. CLELAND, M.D., Ch.M.

EXHIBITS.

Mr. W. M. HAMLET exhibited a new wave length Spectroscope, by Hilger.

Mr. ESDAILE exhibited a Stereo-telemeter by Zeiss.

ABSTRACT OF PROCEEDINGS, OCTOBER 4, 1911.

The three hundred and forty-fifth (345th) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, October 4th, 1911, at 8 p.m.

Mr. J. H. MAIDEN, President, in the Chair.

Twenty-nine members were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of candidates for admission as ordinary members were read; one for the second, and one for the first time.

Mr. W. S. DUN and Mr. C. A. SUSSMILCH were appointed Scrutineers, and Mr. R. H. CAMBAGE deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—

JOHN HENRY MACARTNEY ABBOTT, Author, St. James' Chambers.

Eleven volumes, 108 parts, 7 reports, 118 pamphlets, and 43 maps were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "Note on a new type of aperture in *Conularia*," by CHARLES F. LASERON.
2. "The River Gravels between Penrith and Richmond," by H. I. JENSEN, D.Sc.

A discussion then took place on "Notes on the Occurrences of Explosive Reports in the Interior of Australia, with suggestions as to their Nature," by Dr. J. B. CLELAND, in which Dr. WOOLNOUGH, Messrs. HARGRAVE, CAMBAGE, DUN, Dr. JENSEN, Messrs. SUSSMILCH, BARLING, CLUNIES ROSS, and MATHEWS took part, and the author replied.

EXHIBITS.

(1) A new Miniature Model Brunsviga Calculating Machine; (2) Improved Type Large Model Brunsviga Calculating Machine; (3) Prismatic Compass, with Radium Illumination for use in mining or at night; (4) The Verschoyle Pocket Transit, by Mr. E. ESDAILE.

(5) Belemnites and Fossil Cephalopods from Port Darwin, by Dr. WOOLNOUGH.

ABSTRACT OF PROCEEDINGS, NOVEMBER 1, 1911.

The three hundred and forty-sixth (346th) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, November 1st, 1911.

Mr. J. H. MAIDEN, President, in the Chair.

Thirty-one members were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of one candidate for admission as an ordinary member was read for the second time.

Messrs. D. J. Colley and E. C. Andrews were appointed Scrutineers, and Dr. W. G. Woolnough deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society.

G. F. Longmuir, B.A., Science Master, Technical College, Bathurst.

The President announced that the Geological Section would meet on Wednesday the 8th November, at 8 p.m.

Fifteen Volumes, 121 parts, 14 pamphlets, 4 maps and 4 reports were laid upon the table.

A letter from Mr. G. H. Blakemore *re* frost markings was read.

With reference to the death of Mr. William Sutherland, M.A., D.Sc., of Melbourne, it was proposed by Professor Pollock and seconded by Professor David, that a letter of sympathy be forwarded to Miss Sutherland; and with reference to that of Mr. Norman Selfe, an old member of the Society, it was moved by Mr. Houghton seconded by Prof. David, that a letter of condolence be sent to his family.

THE FOLLOWING PAPERS WERE READ:

1. "An Autographic Air Flow Recorder," by W. R. Hebblewhite, B.E., communicated by Prof. S. H. Barraclough, B.E., M.M.E., etc.
2. "Some New England Eucalypts and their Economics," by R. T. Baker, F.L.S., and H. G. Smith, F.C.S.
3. "On Rock Specimens from Central and Western Australia," (collected by the Elder Scientific Exploring Expedition of 1891-2), by J. Allan Thomson, B.A., B.Sc., F.G.S., communicated by Prof. T. W. E. David, B.A., C.M.G., F.R.S., Hon. D.Sc., Oxon,

EXHIBIT.

Rock from Volcanic Neck, Dundas, by Mr. COTTON.

ABSTRACT OF PROCEEDINGS, DECEMBER 6, 1911.

The three hundred and forty-seventh (347th) General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth-street north, on Wednesday, December 6th, 1911.

Mr. J. H. MAIDEN, President, in the Chair.

Thirty-three members were present and six visitors, including Mr. DAVID LINDSAY, the South Australian Explorer.

The minutes of the preceding meeting were read and confirmed.

The certificate of one candidate for admission as an ordinary member was read for the first time.

Five volumes, 141 parts, 12 reports, 2 pamphlets, and 1 map were laid on the table.

The following letter was received from Miss SUTHERLAND:

4 Highfield Grove, Kew, Melbourne,
November 23rd, 1911.

To the Hon. Secretary of the Royal Society of N.S. Wales.

Dear Sir,—Your letter of the 2nd instant received. Will you kindly convey to the members of the Royal Society of New South Wales, on behalf of the members of the family of the late Mr. WILLIAM SUTHERLAND an expression of appreciation and thanks for their kind letter of sympathy, and tribute to his work. Yours faithfully,

JESSIE SUTHERLAND.

THE FOLLOWING PAPERS WERE READ:

1. "A suggested explanation of Allotropism based on the Theory of Directive Valency, by F. B. GUTHRIE, F.I.C., F.C.S.

2. "The Nature and Origin of Gilgai Country," by H. I. JENSEN, D.Sc.

3. "Some Curious Stones used by the Australian Aborigines," by R. H. Mathews, L.S.

4. "The Geology and Petrography of the Prospect Intrusion," by H. S. Jevons, M.A., B.Sc., F.G.S., H. I. Jensen, D.Sc., T. G. Taylor, B.A., B.Sc., and C. A. Sussmilch, F.G.S.

5. "The value of the Nitrate Figure in determining the fitness of water for drinking purposes," by C. S. Willis, M.D., M.R.C.S.

6. "Notes on the occurrence of *Tœniopteris* in the roof of the Coal-seam at the Sydney Harbour Colliery," by W. S. Dun.

7. "The Geology of the Eruptive and Associated Rocks of Pokolbin, N.S.W." by W. R. Browne, B.Sc., and A. B. Walkom, B.Sc.

8. "The Haematozoa of Australian Birds," No. 2, by J. B. Cleland, M.D., Ch.M., and T. H. Johnston, M.A., D.Sc.

9. "On the Australian Melaleucas and their Essential Oils," by R. T. Baker F.L.S. and H. G. Smith, F.C.S.

GEOLOGICAL SECTION.

ABSTRACT
OF
PROCEEDINGS OF THE GEOLOGICAL SECTION.

Monthly Meeting, 8th March, 1911.

Mr. J. E. Carne in the Chair.

Ten members and two visitors were present.

Mr. W. S. Dun exhibited a specimen of *Glossopteris* with some unusual characters from near Mudgee.

Mr. C. A. Sussmilch exhibited crystals of Rhodonite from Broken Hill.

Mr. W. N. Benson exhibited some photographs from Terrigal, and made remarks on some of the physiographical features of the district surrounding Brisbane Water, which led to an animated discussion on the evidences of a recent small uplift.

On the motion of Mr. R. H. Cambage, seconded by Mr. W. S. Dun, the retiring President, Mr. J. E. Carne, and the retiring Hon. Secretary, Mr. C. A. Sussmilch, were re-elected.

Monthly Meeting, 12th April, 1911.

Mr. J. E. Carne in the Chair.

Thirteen members and three visitors were present.

Mr. W. S. Dun, exhibited the wing of an hemipterous insect embedded in selenite from a copper mine at Mount Elliott, Queensland.

A discussion took place on (*a*) The Geographical Unity of Eastern Australia, by E. C. Andrews, and (*b*) A Study of Marginal Drainage, (Presidential Address to the Linnean Society of N. S. Wales) by C. HEDLEY. The discussion was a very animated one, and was adjourned to the following meeting.

Monthly Meeting, 10th May, 1911.

Mr. J. E. CARNE in the Chair.

Thirteen members and four visitors were present.

Mr. W. S. DUN exhibited a specimen of the fossil coral *Diphyphyllum* from the Molong District, and made some remarks regarding the occurrence of Lower Devonian strata in that region.

The discussion started at the April meeting was continued and concluded. The general principle of the geographical unity of Eastern Australia in late Tertiary time was agreed upon, but there was some difference of opinion as to the nature and cause of the earth movement which closed the Tertiary Period.

Monthly Meeting, 12th July, 1911.

Prof. T. W. E. DAVID in the Chair.

Ten members and five visitors were present.

Mr. W. N. BENSON gave a detailed account of the geology of the Nundle, Manilla, and Bingera districts, and Mr. DUN exhibited fossils of Devonian Age (*Spongophyllum*, *Favosites*, and *Stomatopora*), and Carboniferous (*Lithostrotion*) in connection therewith.

Monthly Meeting, 9th August, 1911.

Mr. R. H. CAMBAGE in the Chair.

Nine members were present.

An informal discussion was held on a paper by T. GRIFFITH TAYLOR, B.Sc., on "The Physiography of Eastern Australia."

Monthly Meeting, 11th October, 1911.

Mr. J. E. Carne in the Chair.

Ten members were present.

Mr. A. B. Walkom exhibited an undescribed Cystiphylloid coral from Derrangullen Creek and a new species of *Favosites* from the same locality.

Dr. W. G. Woolnough exhibited specimens of belemnites, ammonites and other cephalopods from Port Charles, Northern Territory, and a fossil crustacean from the same locality.

A discussion then took place on the age of the alkaline igneous rocks of New South Wales. No definite conclusion was arrived at regarding the alkaline intrusives, except that they were Post-Triassic, but the general opinion regarding the alkaline volcanic rocks was that they were at least as young as Miocene.

Monthly Meeting, 8th November, 1911.

Mr. J. E. Carne in the Chair.

Eleven members and three visitors were present.

The principal business of the evening was a discussion on Professor T. W. E. David's presidential address on "The Chief Tectonic Lines of Australia.

On the motion of Mr. W. S. Dun a vote of thanks was passed to the Secretary for his efforts on behalf of the Section during the year.

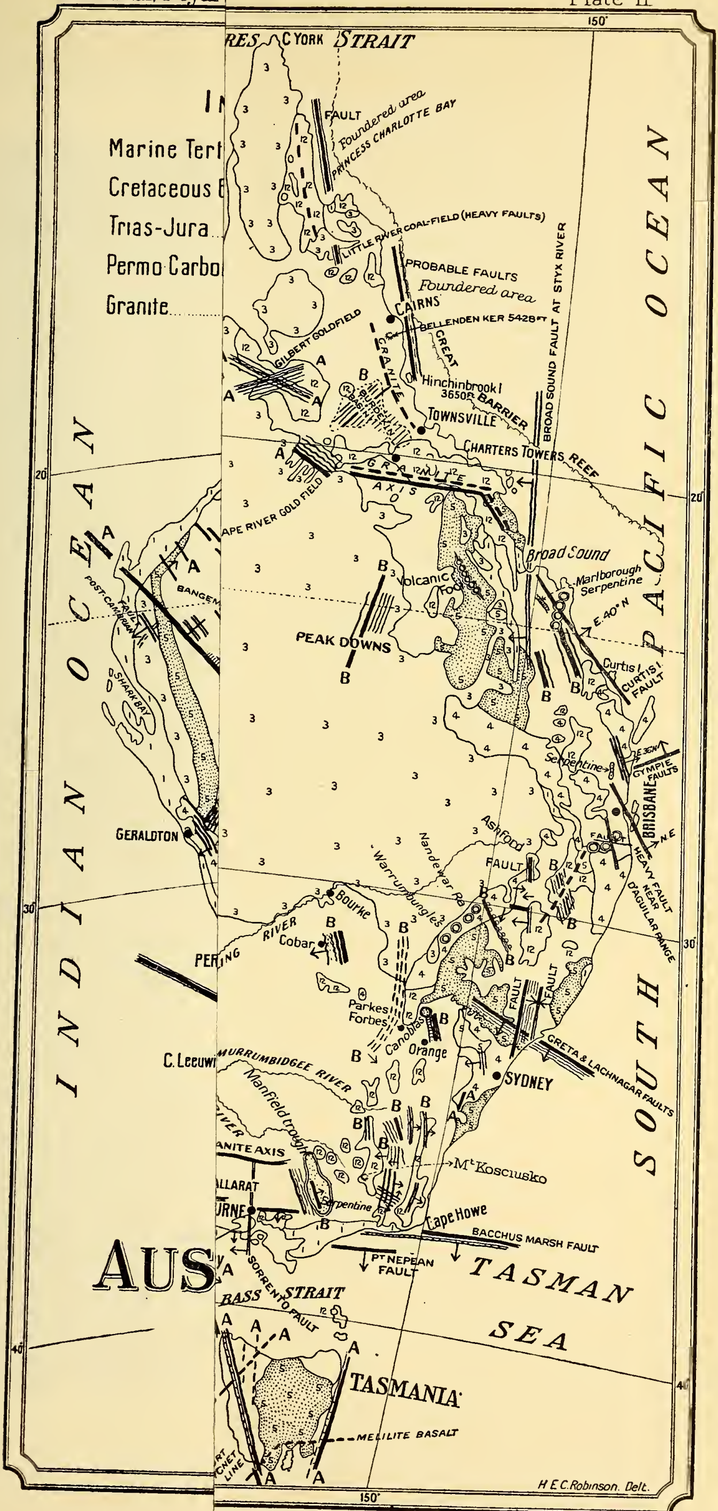
At the close of the meeting the Chairman, on behalf of the members wished *bon voyage* to Messrs. Watson and Hunter, two members of the Mawson Antarctic Expedition.

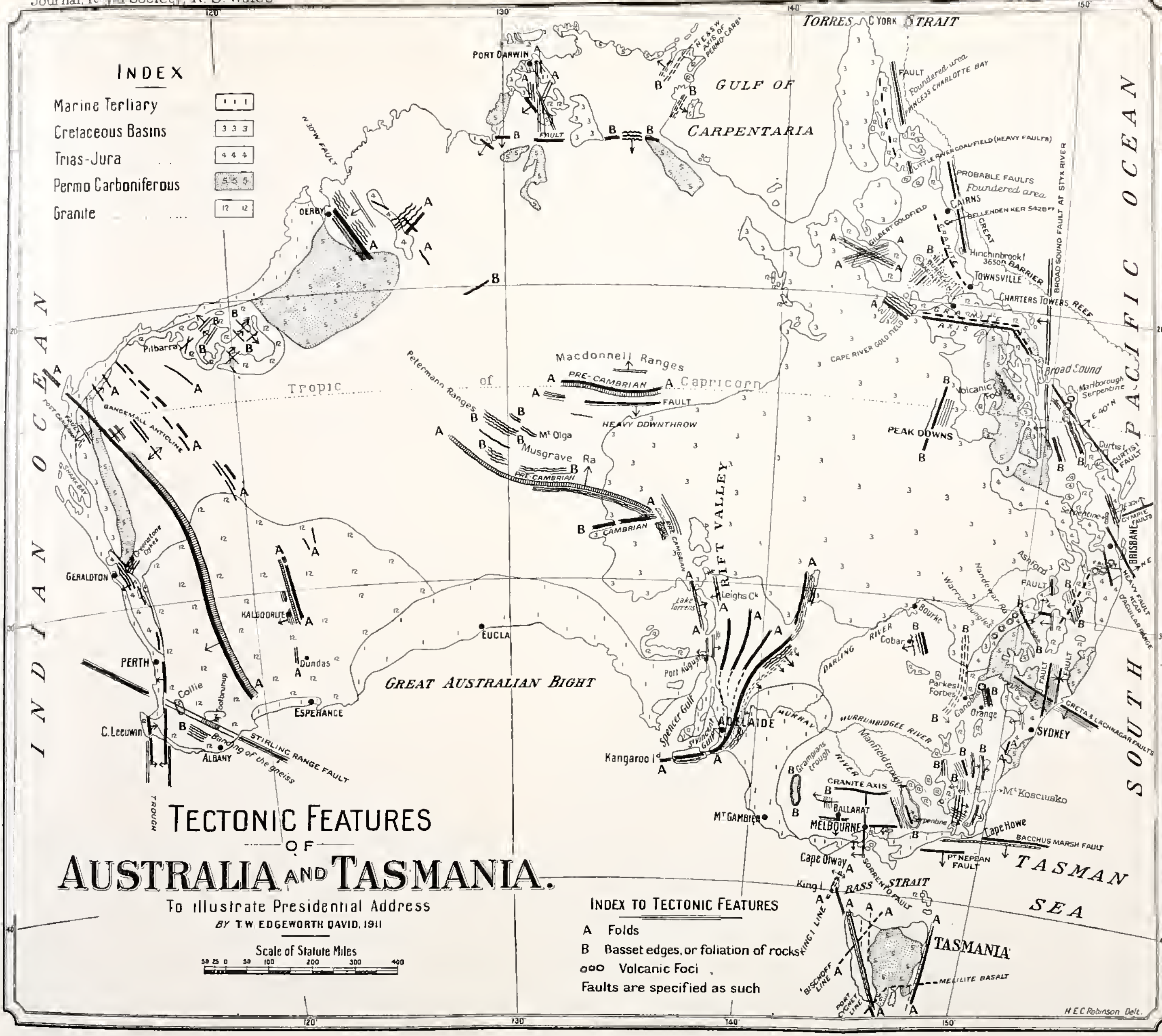
INDEX.

Sydney:
F. W. White, Printer, 344 Kent Street.

1912.


Relief Map of
AUSTRALIA
Shewing Trend Lines.
Constructed by
W.K.M'Intyre.
Based on Maps and Contours
by H.E.C.Robinson.
PACIFIC OCEAN
SOUTHERN OCEAN
INDIAN OCEAN


150°
TORRES STRAIT
C YORK
FAULT
Foundered area
PRINCESS CHARLOTTE BAY
Marine Tert
Cretaceous
Trias-Jura
Permo Carbo
Granite
LITTLE RIVER COAL-FIELD (HEAVY FAULTS)
PROBABLE FAULTS
Foundered area
CAIRNS
BELLENDEN KER 5428 FT
GILBERT GOLDFIELD
GRANITE
GREAT
Hinchinbrook I 3650 FT
BARRIER
BURDEKIN BASIN
TOWNSVILLE
CHARTERS TOWERS
REEF
BROAD SOUND FAULT AT STYX RIVER
GRANITE AXIS
APE RIVER GOLD FIELD
SOUTH PACIFIC OCEAN
INDIAN OCEAN
Broad Sound
Marlborough Serpentine
Volcanic Foci
E. 40° N
PEAK DOWNS
BANGEM
POST-CAMBRIAN FAULT
SHARK BAY
Curtis I
CURTIS I. FAULT
Serpentine
GYMPIE FAULTS
BRISBANE
GERALDTON
Ashford
FAULT
HEAVY FAULT NEAR D'AGUILAR RANGE
Warrumbungles
Nandewar Re
Bourke
RIVER
PERLING
Cobar
Parkes
Forbes
Canoblas
Orange
FAULT
GRETA & LACHNAGAR FAULTS
SYDNEY
C. Leeuwin
MURRUMBIDGEE RIVER
Manfield trough
GRANITE AXIS
BALLARAT
MELBOURNE
Serpentine
Mt Kosciusko
Cape Howe
BACCHUS MARSH FAULT
Pt NEPEAN FAULT
SORRENTO FAULT
BASS STRAIT
AUS
TASMAN SEA
TASMANIA
MELILITE BASALT
H.E.C. Robinson. Delt.


TECTONIC FEATURES OF AUSTRALIA AND TASMANIA.
To illustrate Presidential Address
BY T. W. EDGEWORTH DAVID, 1911
INDEX
Marine Tertiary
Cretaceous Basins
Trias-Jura
Permo Carboniferous
Granite
INDEX TO TECTONIC FEATURES
A Folds
B Basset edges, or foliation of rocks
ooo Volcanic Foci
Faults are specified as such
Scale of Statute Miles
50 25 0 50 100 200 300 400
INDIAN OCEAN
SOUTH PACIFIC OCEAN
TASMAN SEA
GULF OF CARPENTARIA
GREAT AUSTRALIAN BIGHT
TORRES STRAIT
BASS STRAIT
Tropic of Capricorn
PORT DARWIN
DERBY
Pilbarra
GERALDTON
PERTH
Collie
C. Leeuwin
ALBANY
ESPERANCE
KALGOORLIE
Dundas
EUCLA
Macdonnell Ranges
Petermann Ranges
Mt Olga
Musgrave Ra
PRE-CAMBRIAN
CAMBRIAN
HEAVY DOWNTHROW
RIFT VALLEY
Lake Torrens
Leighs Ck
Port Augusta
Spencer Gulf
ADELAIDE
Kangaroo I
Mt GAMBIER
MELBOURNE
BALLARAT
Cape Otway
King I
GRANITE AXIS
Grampians trough
Manfield trough
Mt Kosciusko
Cape Howe
BACCHUS MARSH FAULT
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HEAVY FAULT NEAR D'AGUILAR RANGE
GRETA & LACHNAGAR FAULTS
C YORK
N & S W AXIS OF PERMO-CARB
N 30 W FAULT
BANGEMALL ANTICLINE
STIRLING RANGE FAULT
Banding of the gneiss
Greenstone Dykes
Toolbrunup
TROUGH
FAULT
TASMANIA
KING I LINE
BISCHOFF LINE
PORT CYGNET LINE
MELILITE BASALT
H E C Robinson Delt.

Relief model of Australia and Tasmania by W. K. McIntyre, showing the 'horst' of Tasmania to left of the fault trough of Bass Strait, and Mount Kosciusko at the knotting point of the N. and S. and E. and W. trend lines; one inch to the right of Kosciusko is the Hunter 'Geocol' with the sharp peak of the Warrumbungle Volcanoes behind it, and to the right again the second sharp peak indicates the Nandewar Volcanoes. On the extreme right, is the steep-to coast near Cairns. The Mount Lofty Ranges show up on the near side of St. Vincent's Gulf, with Mount Woodroffe in the middle distance beyond. On the left, in far distance, are the Stirling Ranges.

Fig. 1.

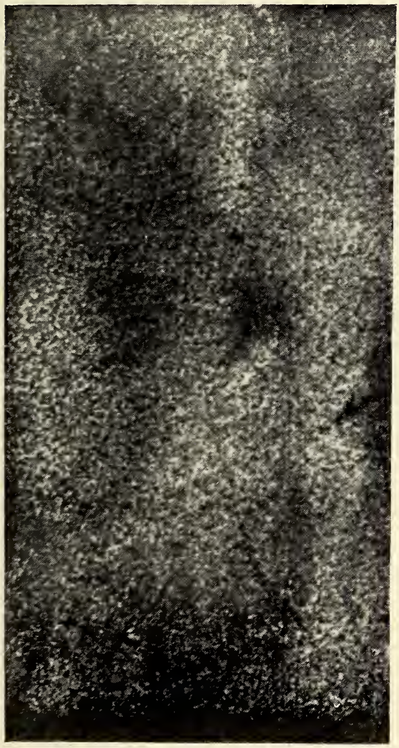
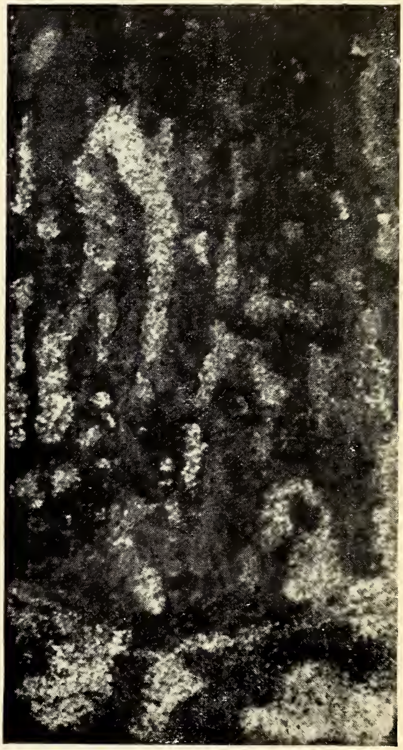
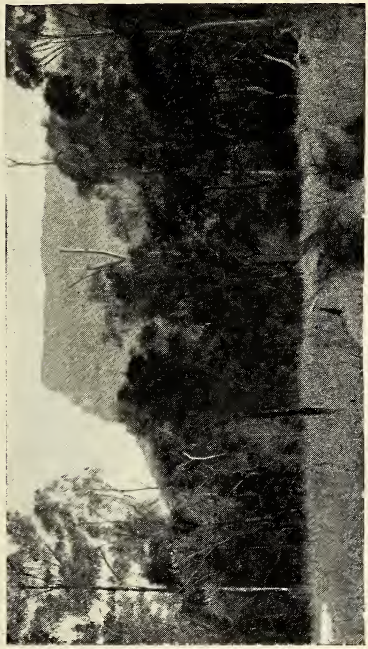


Fig. 2.



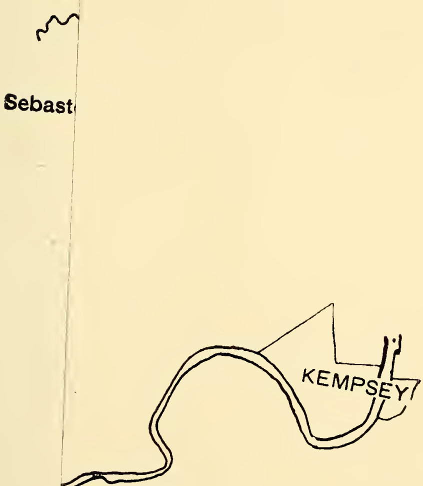


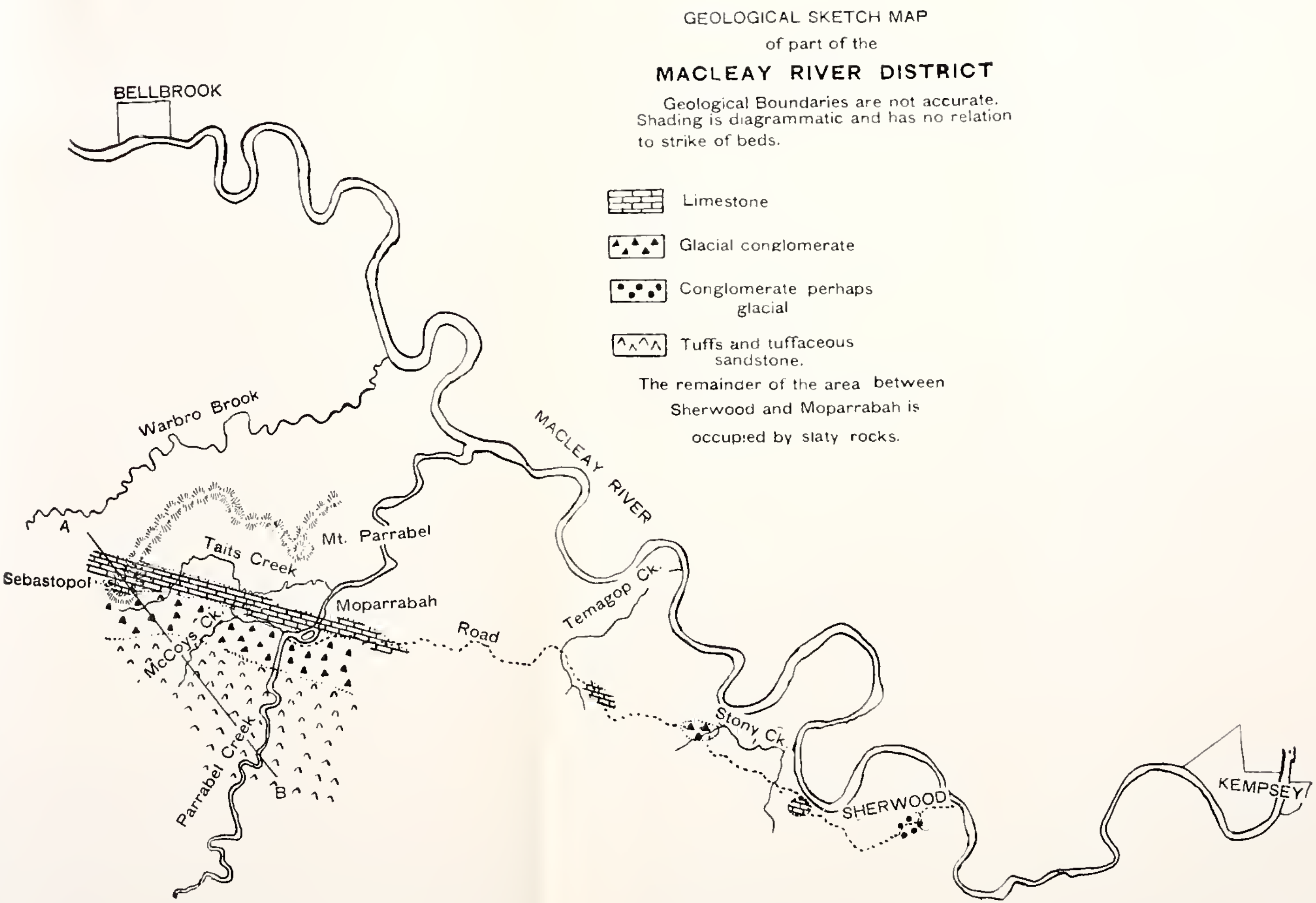
Spicer's Peak showing a precipitous face nearly 2,000 feet sheer.

Cunningham's Gap from the east.

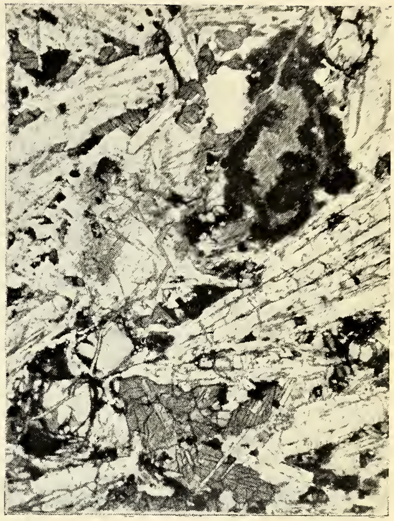
Mount Mitchell from Old Warwick Road.

Plate V.




GEOLOGICAL SKETCH MAP
of part of the
MACLEAY RIVER DISTRICT
Geological Boundaries are not accurate.
Shading is diagrammatic and has no relation to strike of beds.
Limestone
Glacial conglomerate
Conglomerate perhaps glacial
Tuffs and tuffaceous sandstone.
The remainder of the area between Sherwood and Moparrabah is occupied by slaty rocks.
BELLBROOK
Warbro Brook
MACLEAY RIVER
A
Sebastopol
Taits Creek
Mt. Parrabel
Moparrabah
McCoys Ck.
Road
Temagop Ck.
Parrabel Creek
B
Stony Ck.
SHERWOOD
KEMPSEY

1.



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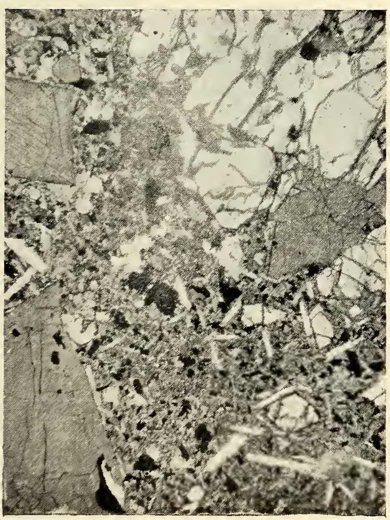
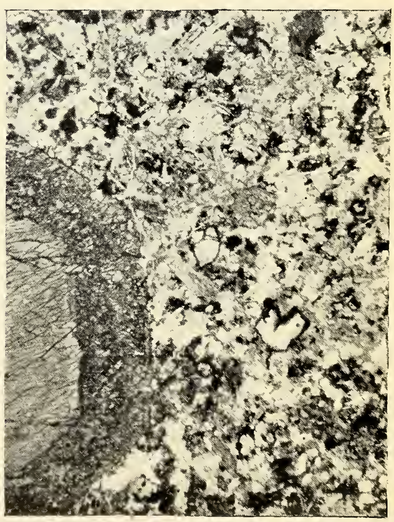
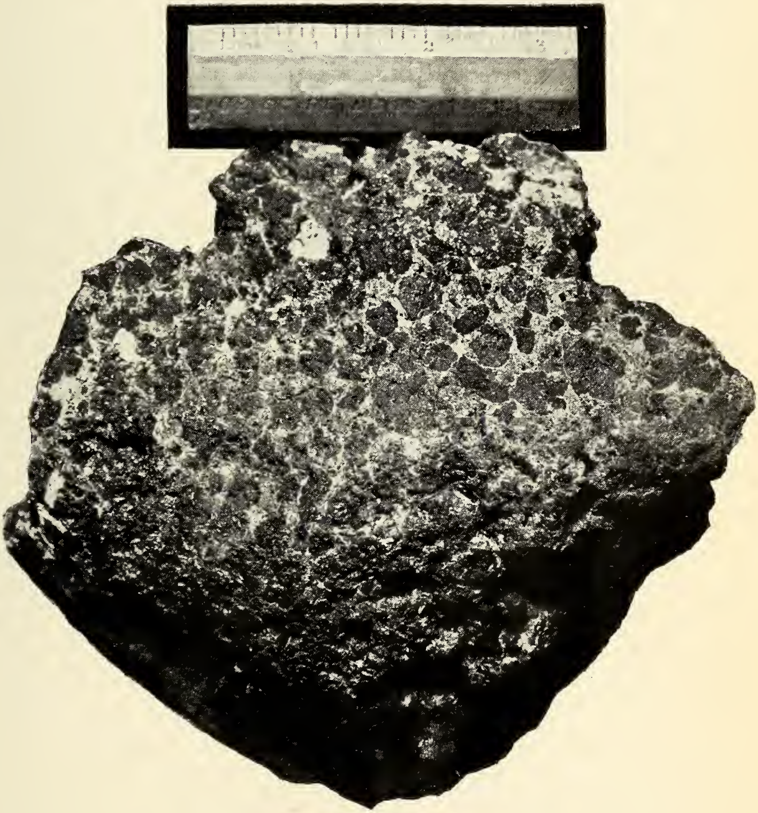


3.



4



Photographs of a bubble of CO_2 being formed in:—

Water.

Fig. 2.

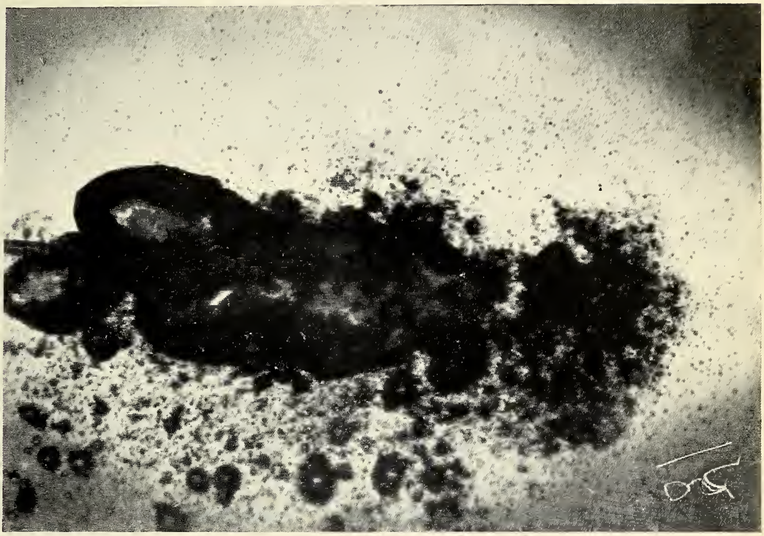
0·1% solution of acetic acid.

Fig. 3.

Photographs of a bubble of CO_2 being formed in:—

Water.

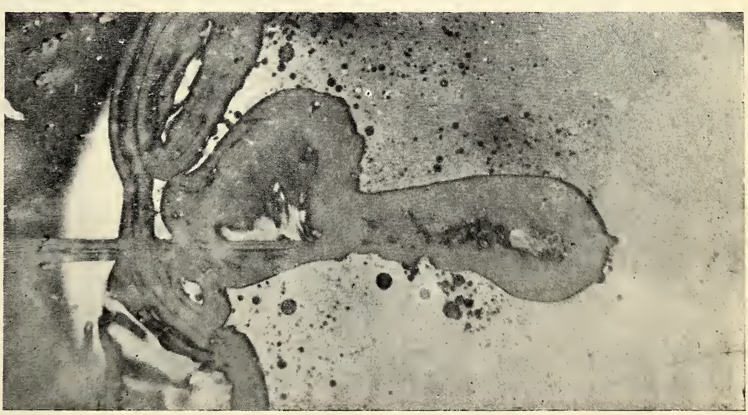
Fig. 4.



0·1% solution of acetic acid.

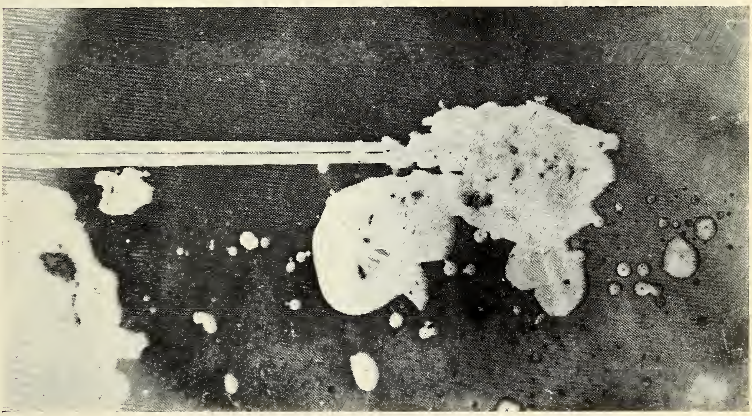
Fig. 5.

Photographs of a bubble of CO_2 being formed in:—



0·1% solution of acetic acid.

Fig. 6.

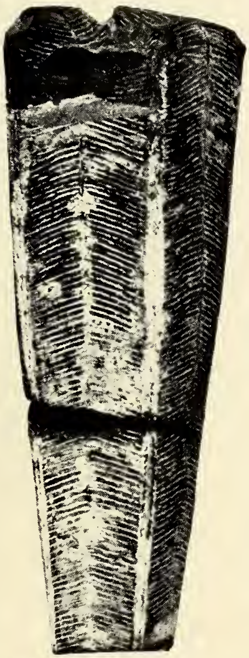


Water.

Fig. 7.

0.1% solution of sulphuric acid.

Fig. 8.



1.

2.

3.

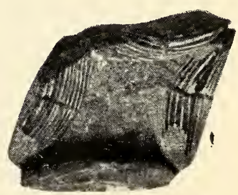
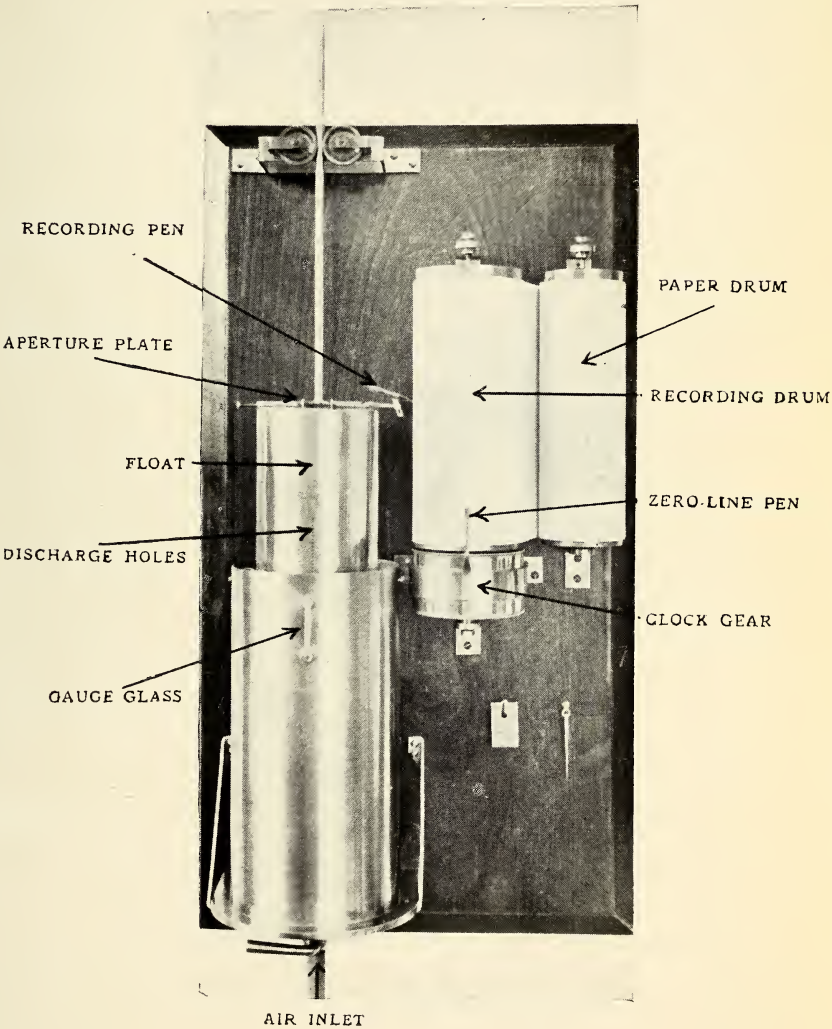


Fig. 1—Conularia *cf.* lævigata, Morris. Lateral view of specimen, natural size, with portion near the aperture removed.

„ 2—The portion of Fig. 1, removed, showing the nature of the ornamentation on the interior of the aperture.

„ 3—The same specimen. View of the aperture, showing the infolding of the walls.



THE AUTOGRAPHIC AIR-FLOW RECORDER.

R.T.B., del. ad nat.   H.J.A.B., lith.

EUCALYPTUS CAMPANULATA,
sp. nov..

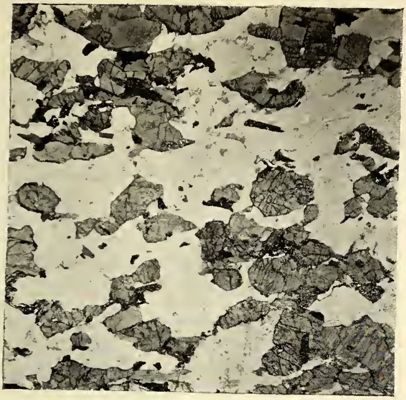


Fig. 1.

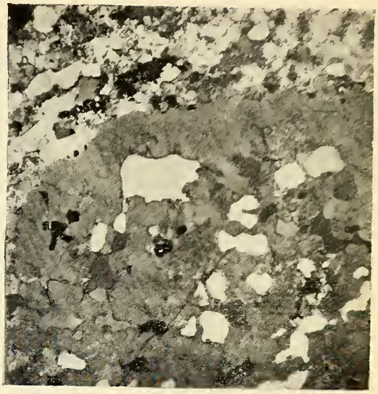


Fig. 2.

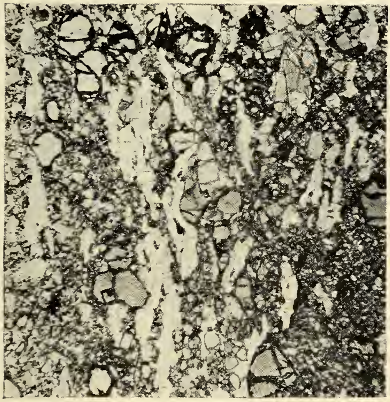


Fig. 3.

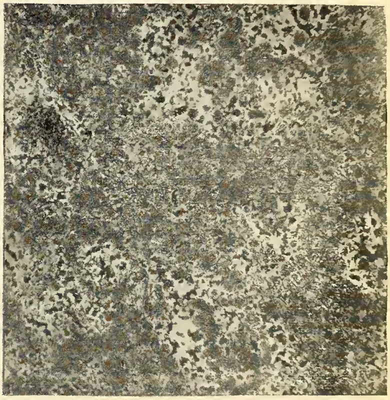


Fig. 4.

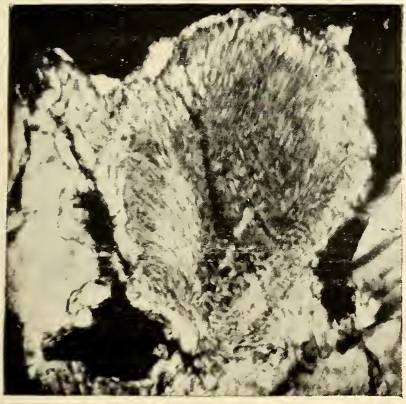


Fig. 5.

Fig. 6.

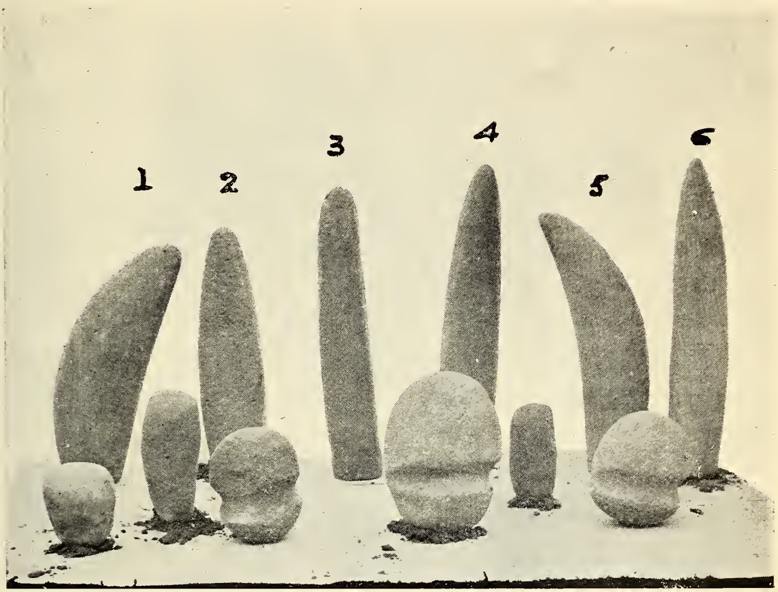


Fig. 2—*Six Magical Stones and Six Hatchets.*

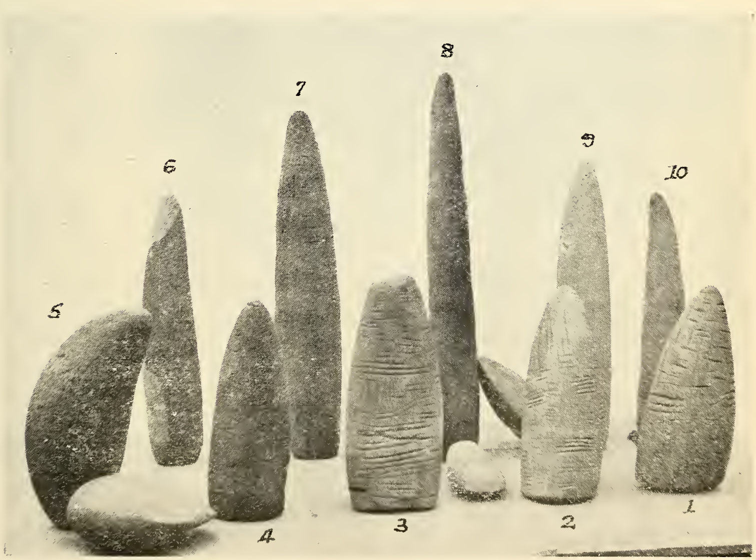
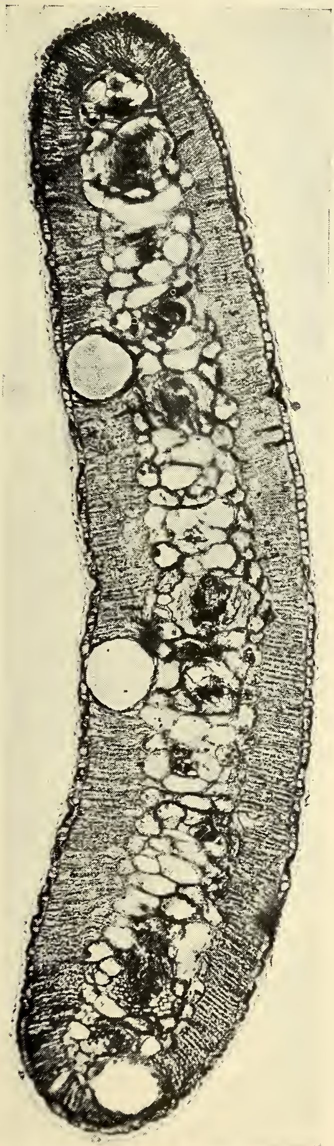


Fig. 3—*Ten Magical Stones and Three Hatchets*

MELALEUCA GENISTIFOLIA,
Sm.

Journal Royal Society of N.S.W., Vol. XLV, 1911. *Plate XVII.*



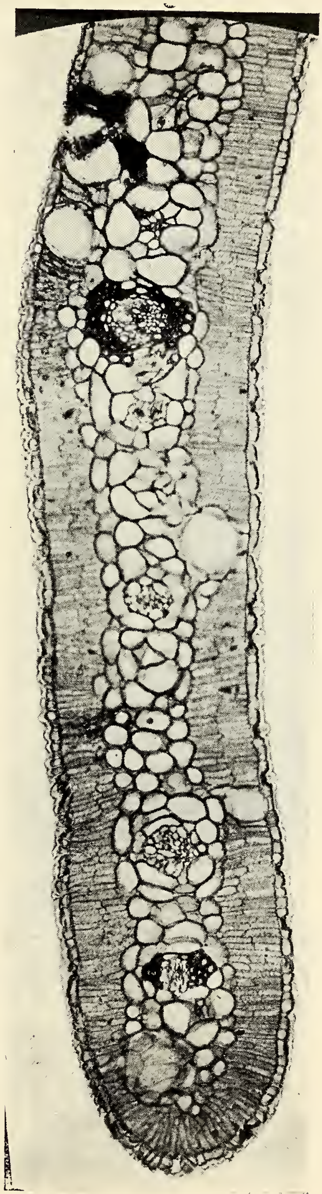
× 110.

Fig. 1.

× 110.

Fig. 2.

Melaleuca genistifolia.



× 140.

Fig. 3.

Melaleuca genistifolia.

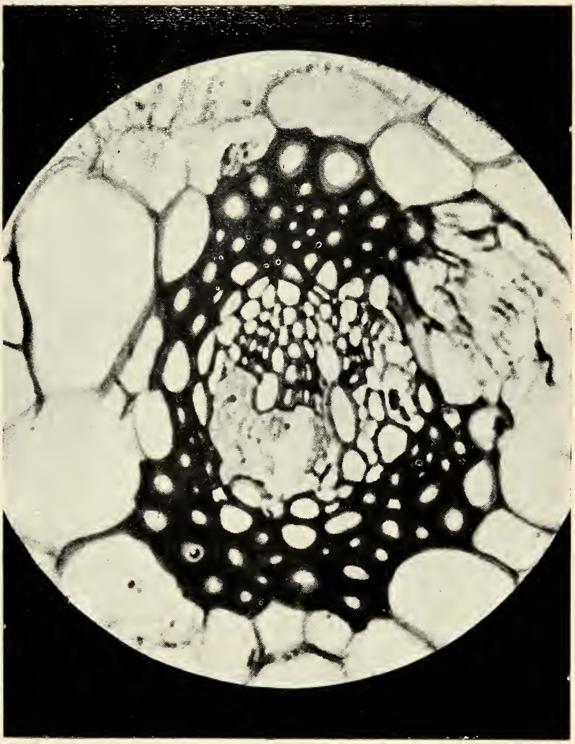


Fig. 4. × 450.

Melaleuca genistifolia.

× 140.

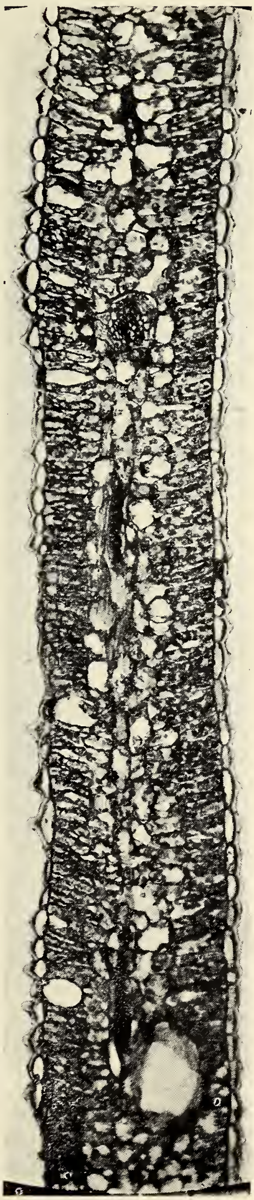
Fig. 5.

Melaleuca genistifolia.

× 140.

Fig. 6.

Melaleuca gibbosa.



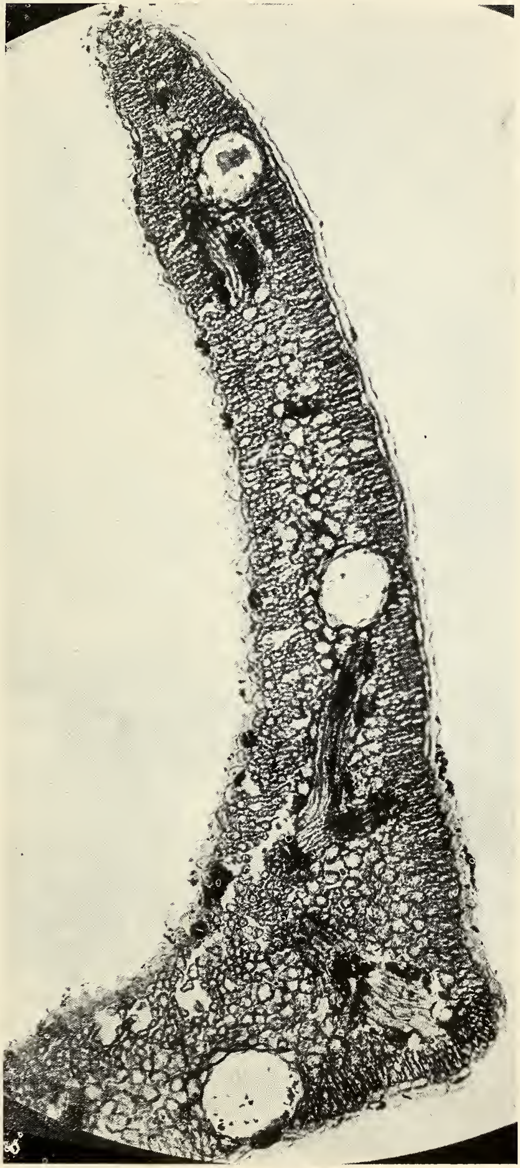
× 150.

Fig. 7.

× 140.

Fig. 8.

Melaleuca gibbosa.



× 110.

Fig. 9.
Melaleuca gibbosa.

× 140.

Fig. 10.

Melaleuca gibbosa.

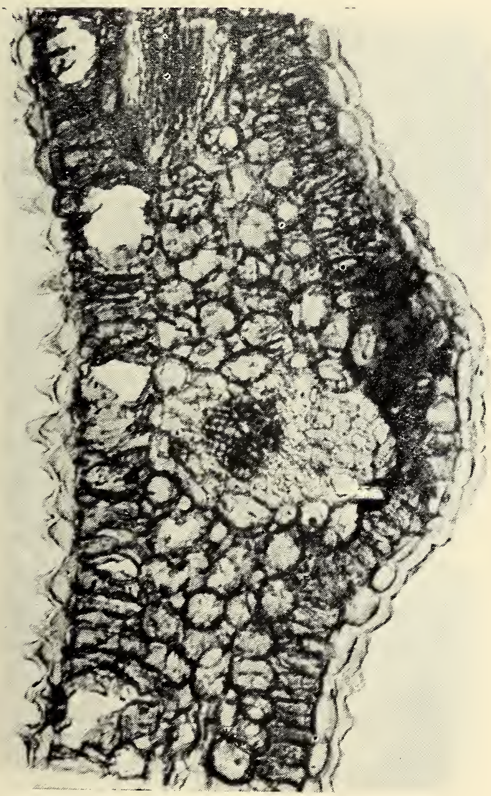


Fig. 11.—Melaleuca gibbosa. × 225.

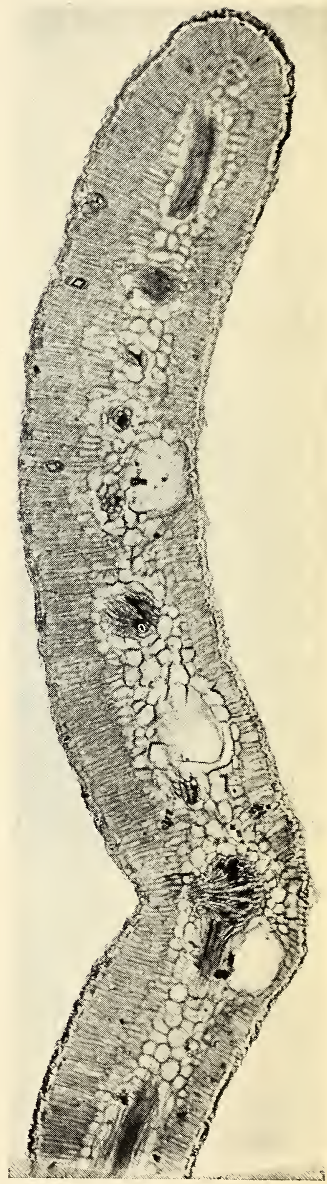


Fig. 12.—Melaleuca pauciflora. × 110.


GEOLOGICAL MAP
OF THE
ERUPTIVE & ASSOCIATED ROCKS
OF
POKOLBIN. N.S.W.
BY
W.R Browne, B.Sc. & A.B Walkom, B.Sc.
SCALE
40 CHAINS
PERMO CARBONIFEROUS
Post Office Hill
Drakes Hill
Mt Bright
Mt View School
Matthews Gap
Tuffs
LEGEND
Granodiorite
Rhyolite and Tuffs
Rhyolite agglomerate
Trachyte (Leucocratic)
Trachyte (Melanocratic)
Volcanic agglomerate
Trachyandesite
Andesite
Pitchstone
Dacite
Basalt
Dolerite
Conglomerates Shales and Sandstones
Cherty Shales
CARBONIFEROUS
Basalt
Conglomerates and Sandstones
FAULT
PERMO-CARBONIFEROUS

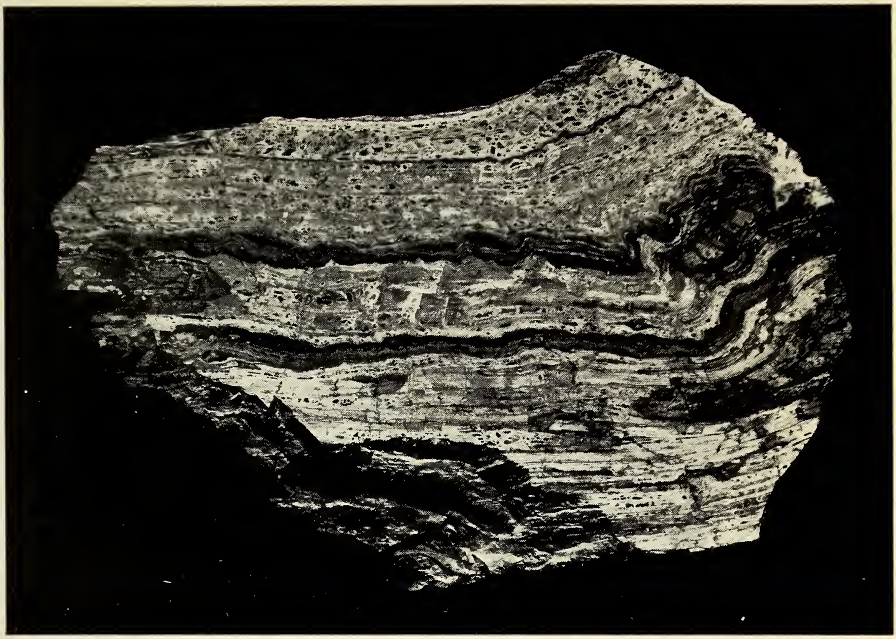


Fig. 1.

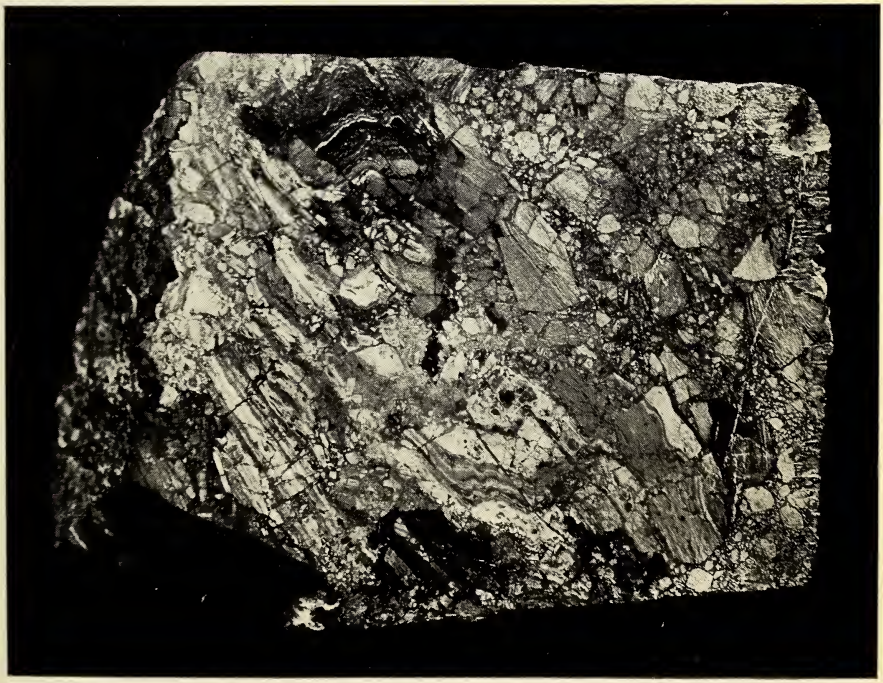


Fig. 2.

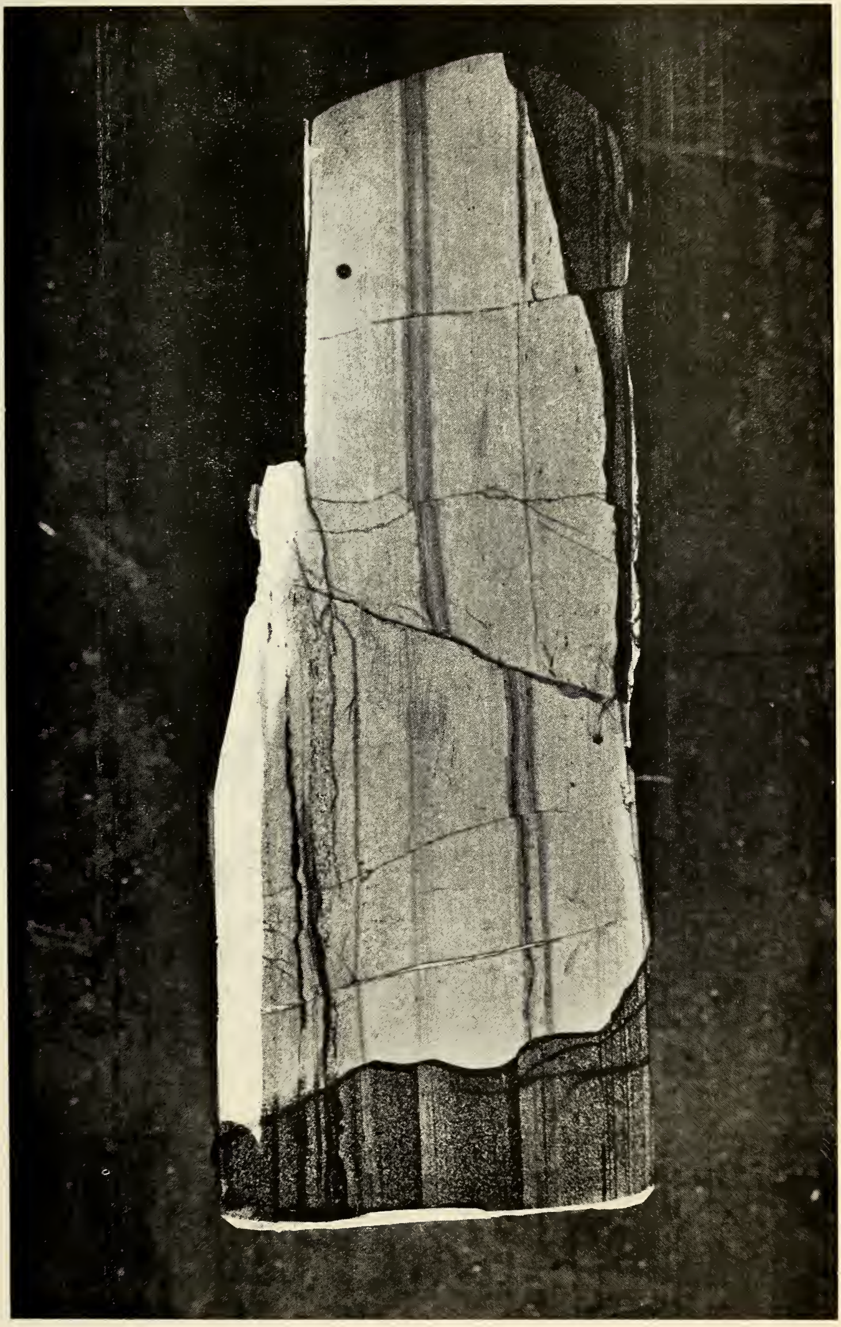
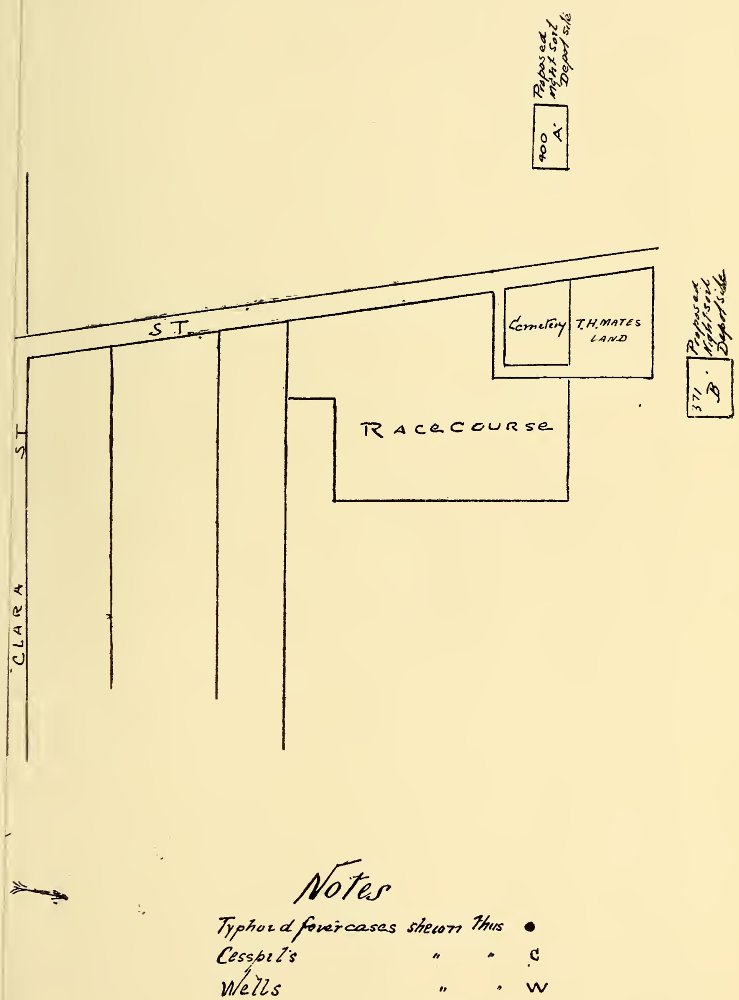


Fig. 3.

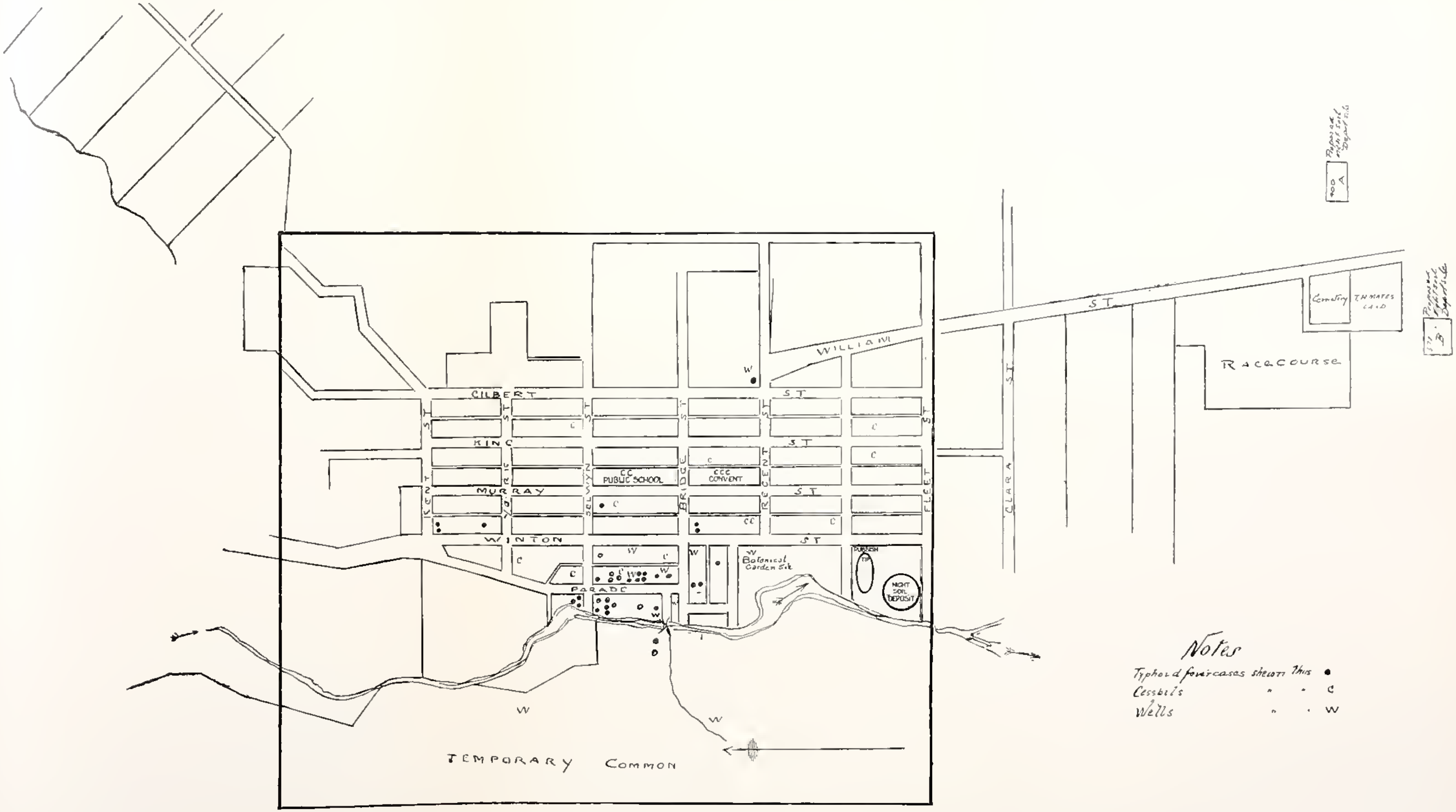
Fig. 4.

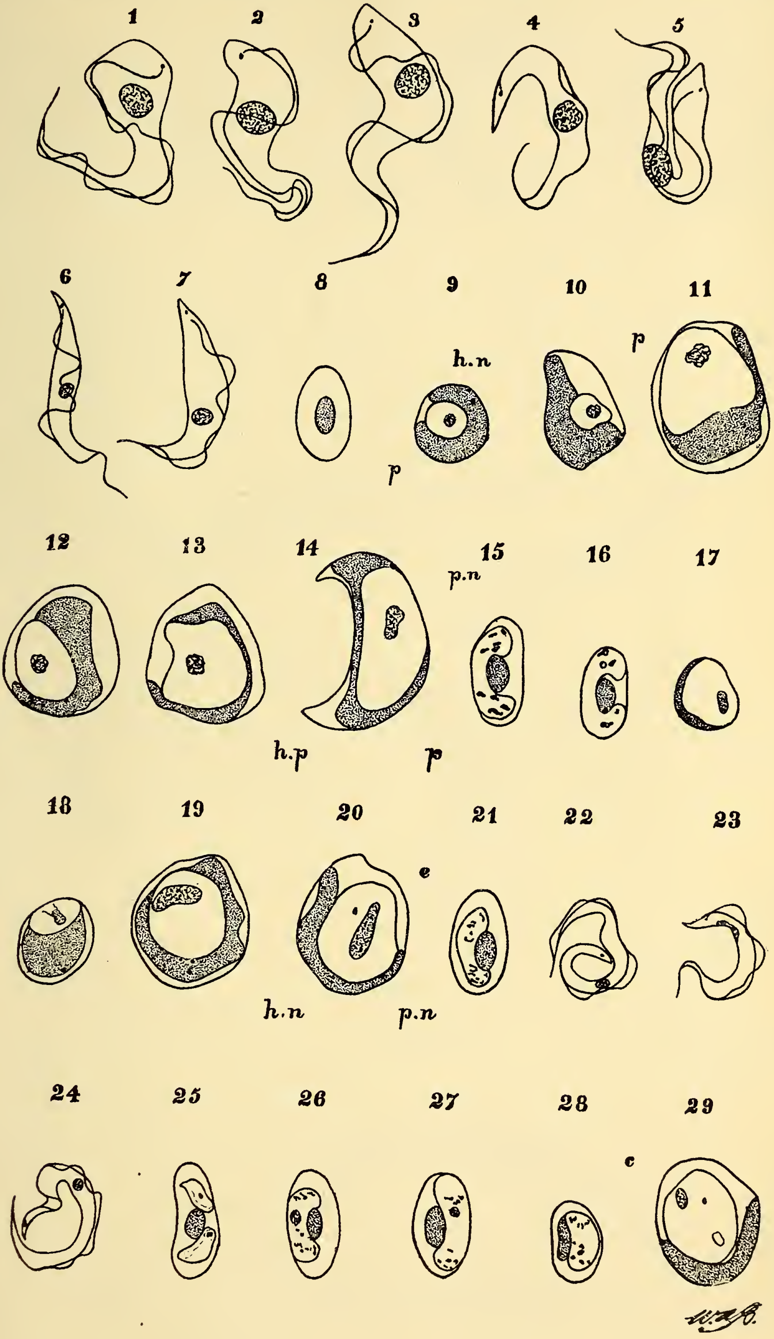
Fig. 5.

Plate XXIX.



Proposed night soil Depot site
700 A
ST.
Cemetery
T.H. MATES LAND
Proposed night soil Depot site
371 B
RACECOURSE
CLARA ST
Notes
Typhoid fever cases shewn thus ●
Cesspits " " C
Wells " " W


GILBERT
KING
MURRAY
WINTON
WILLIAM
ST
KENT
SELWYN
BRIDGE
REGENT
FLEET
CLARA
PUBLIC SCHOOL
CONVENT
PARADE
Botanical Garden Site
NIGHT SOIL DEPOSIT
RACECOURSE
Cemetery
TEMPORARY COMMON
Notes
Typhoid fever cases shewn thus ●
Cesspits " " C
Wells " " W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10
11
h.n
p
p
12
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17
p.n
h.p
p
18
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23
e
h.n
p.n
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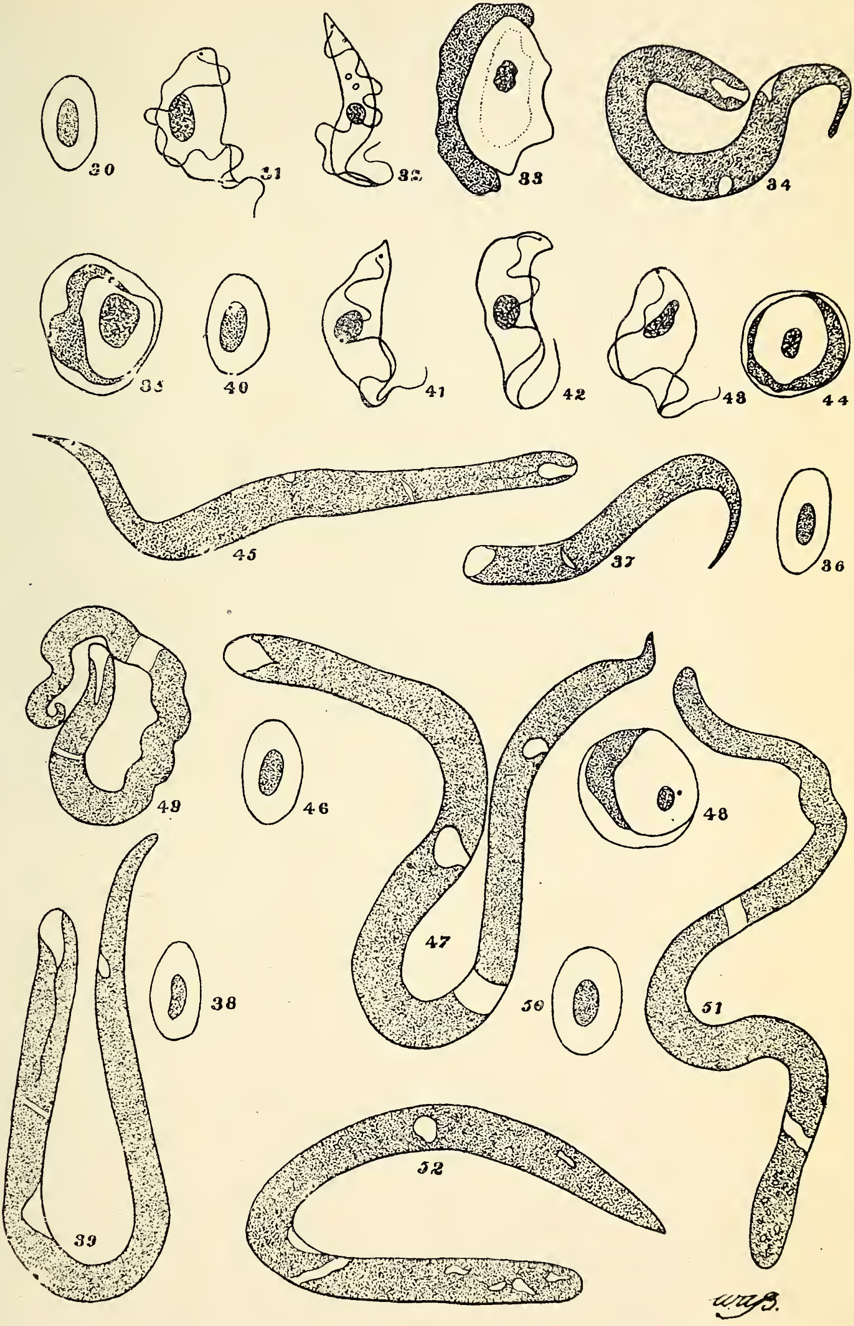
27
28
29
c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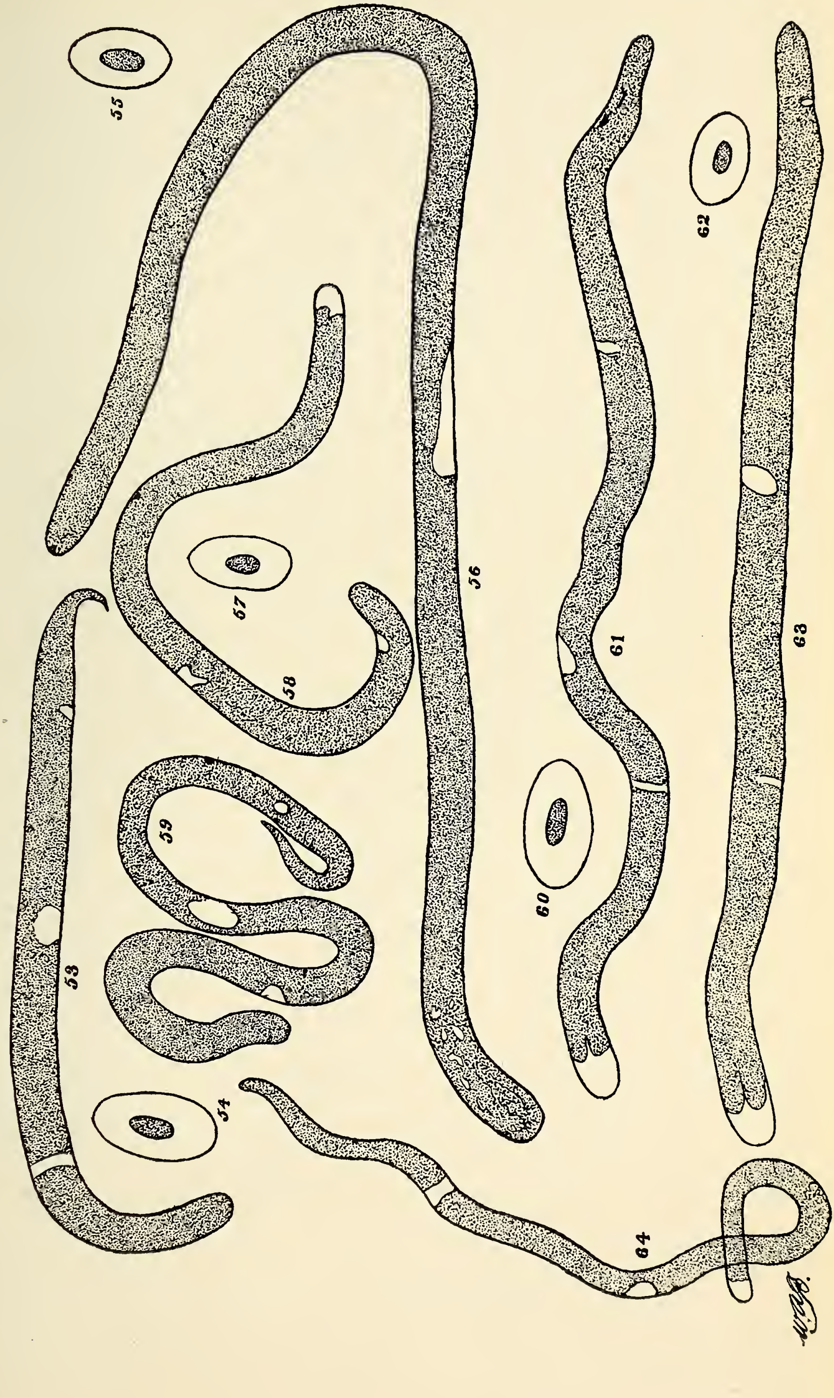
W.W.B.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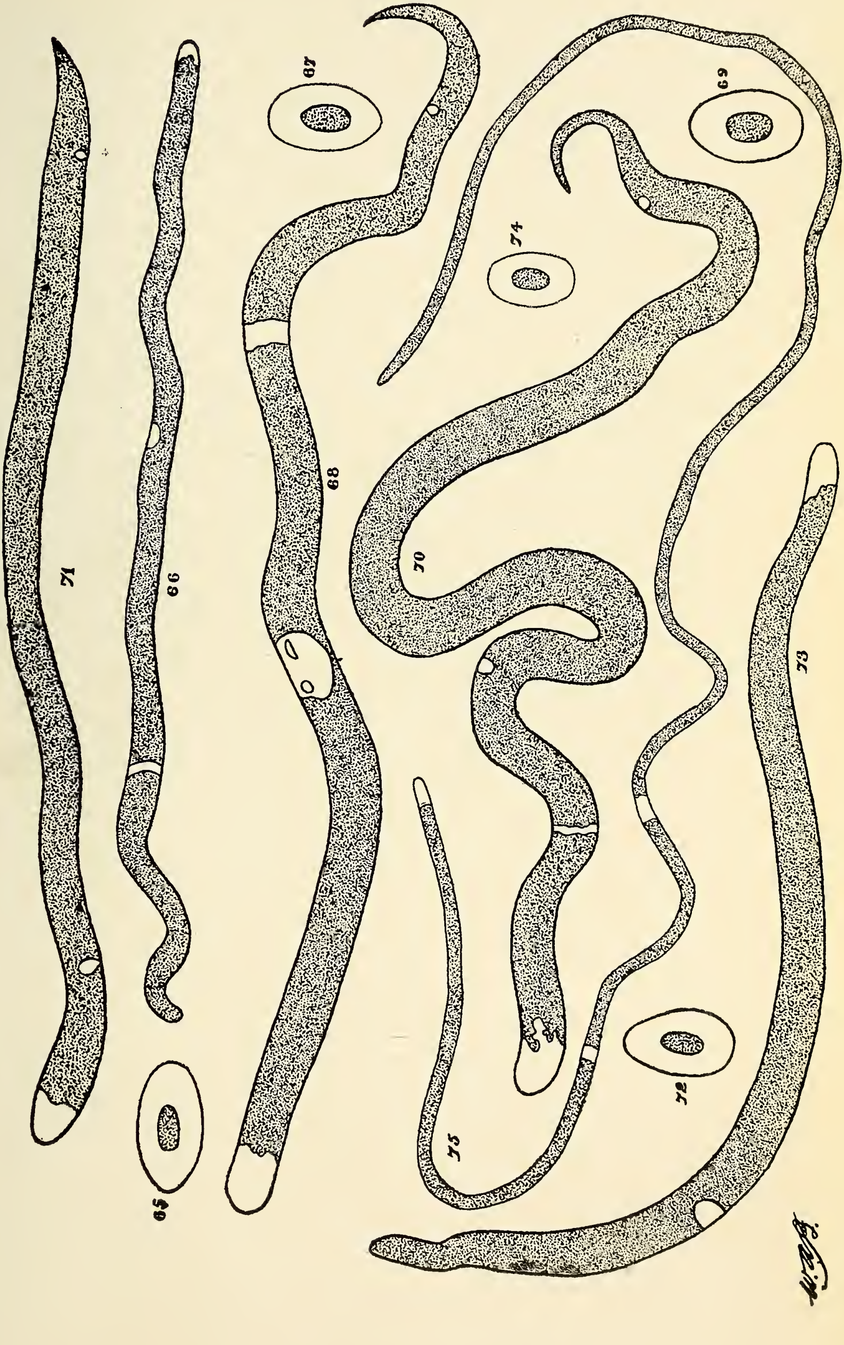
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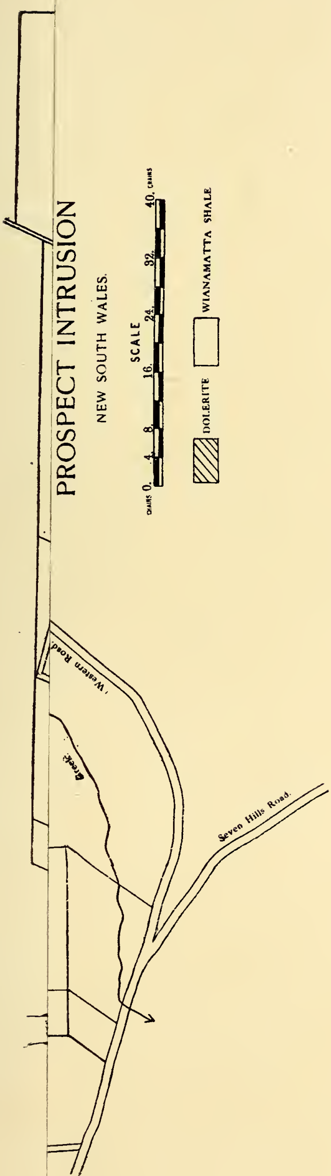
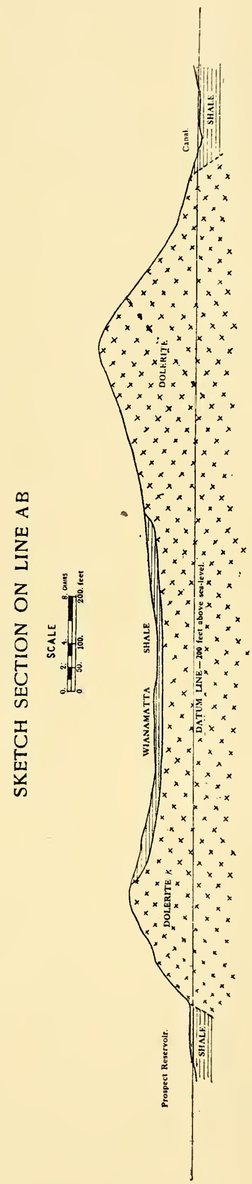
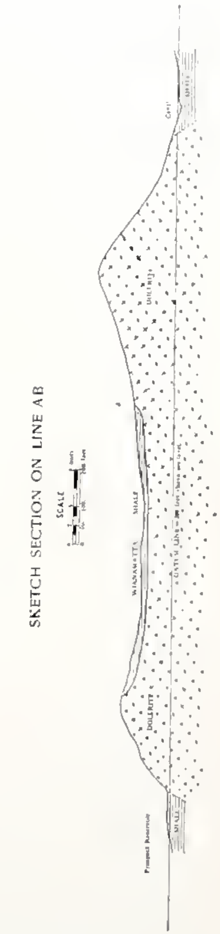
Plate XXXIV.

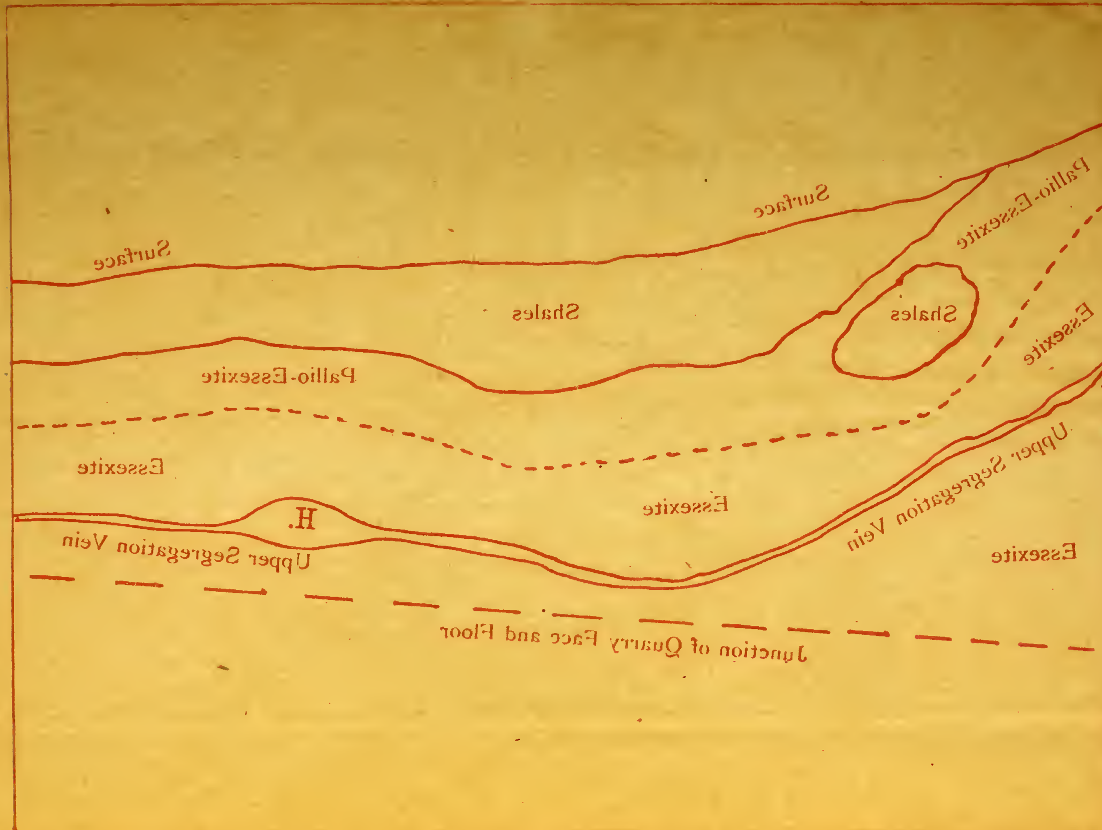

PROSPECT INTRUSION
NEW SOUTH WALES.
SCALE
CHAINS 0. 4 8 16 24 32 40. CHAINS
DOLERITE
WIANAMATTA SHALE
Western Road
Creek
Seven Hills Road.

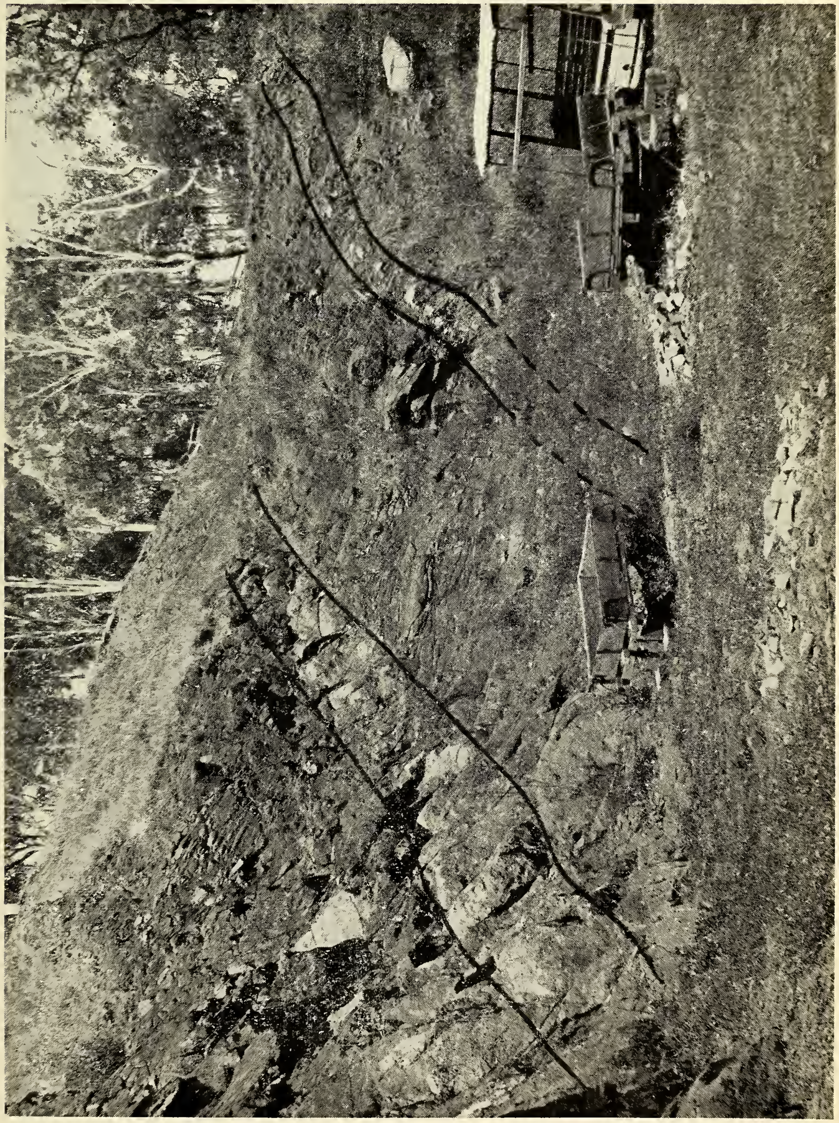

SKETCH SECTION ON LINE AB
SCALE
0. 2. 4. 8. CHAINS
0 50. 100. 200. feet
Canal.
SHALE
DOLERITE
WIANAMATTA SHALE
DATUM LINE—200 feet above sea-level.
DOLERITE
SHALE
Prospect Reservoir.


GEOLOGICAL MAP
OF THE
PROSPECT INTRUSION
NEW SOUTH WALES
SCALE
DOLERITE
WIANAMATTA SHALE
PROSPECT RESERVOIR
WIANAMATTA SHALE
DOLERITE


SKETCH SECTION ON LINE AB
SCALE
DOLERITE
WIANAMATTA SHALE
SHALE


Surface
Pallio-Essexite
Essexite
Upper Segregation Vein
H.
Shales
Essexite
Surface
Shales
Pallio-Essexite
Essexite
Upper Segregation Vein
Essexite
Junction of Quarry Face and Floor


Surface
Surface
Shales
Shales
Pallio-Esssexite
Pallio-Esssexite
Esssexite
Esssexite
Esssexite
Esssexite
H.
Upper Segregation Vein
Upper Segregation Vein
Junction of Quarry Face and Floor



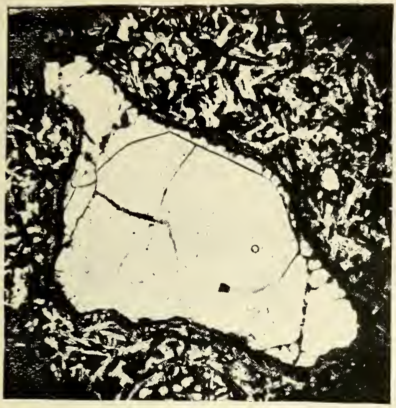


Fig. 1.

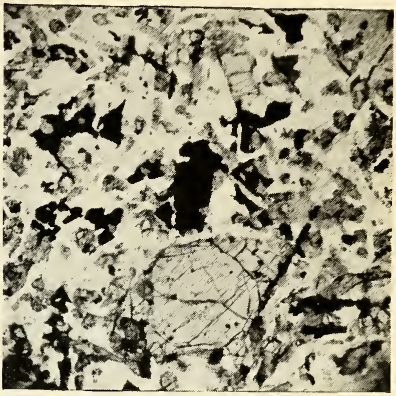


Fig. 2.

Fig. 3.

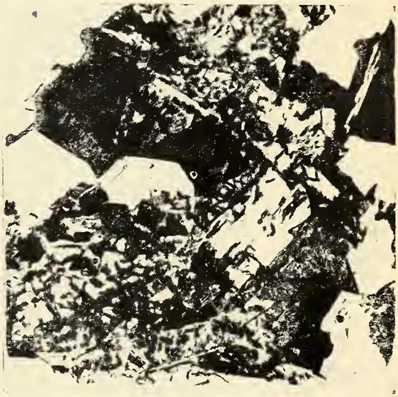


Fig. 4.

Fig. 5.

Fig. 6.