JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

EDITED BY

THE HONORARY SECRETARIES.

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

PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
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1905.

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VOLUME XXXVIII.

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AND

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OF THE

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OF

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FOR

1904.

(INCORPORATED 1881.)

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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 the Queen, 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 $4\frac{1}{4}$ in. × $6\frac{3}{4}$ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

CORRIGENDA.

Page 210, in Table II., the word waugue̅ is erroneously printed wangue.

,, 212, all the words from lines 16 to 31 inclusive, must be struck out, owing to slight clerical errors in transcribing from the original draft manuscript.

,, 225, line 8 from bottom, for dhinua, read dhinna.

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.

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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.*]

LIST OF THE MEMBERS

OF THE

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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.		
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1890	P 2	Allan, Percy, M. Inst. C.E., Assoc. M. Am. Soc. C.E., Engineer-in-Charge of Bridge Design, Public Works Department, Sydney.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ld., Cement Works, Granville.
1877		Anderson, H. C. L., M.A., Principal Librarian, Public Library of N. S. Wales, Macquarie-street.
1903		Arnott, Arthur James, A.M.I.C.E., M.I.M.E., M.I.E.E., Electrical Engineer, 83 Pitt-street.
1902		Arnott, John M., 'Strathfield,' Strathfield.
1899	P 1	Atkinson, A. A., Chief Inspector of Collieries, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 8	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1900		Bale, Ernest, C.E., Public Works Department.
1894		‡Balsille, George, 'Lauderdale,' N.E. Valley, Dunedin, N.Z.
1896		Barff, H. E., M.A., Registrar, Sydney University.
1895	P 8	Barraclough, S. H., B.E., M.M.E., Assoc. M. Inst. C.E., Memb. Soc. Promotion Eng. Education; Lecturer in Mechanism and Applied Thermodynamics, Sydney University; p.r. 'Marmion,' Victoria-street, Lewisham.
1901		Bartholomew, Charles P., 361 George-street.
1903		Bayly, Francis William, Assayer, Royal Mint, Sydney.
1894		Baxter, William Howe, Chief Surveyor Existing Lines Office, Railway Department, Bridge-street.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1876		Benbow, Clement A., 48 College-street.
1900		Bender, Ferdinand, Accountant and Auditor, 21 Elizabeth-street, North.
1869	P 2	Bensusan, S. L., Equitable Building, George-st., Box 411 G.P.O.
1901		Birks, Lawrence, B.Sc., Assoc. M. Inst. C.E., A.M.I.E.E., F.G.S., City Electrical Engineer, Christchurch, New Zealand.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Mount Barker, South 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.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1904		Bosch, Ernest, Consulting Optician, Mutual Life Building, Martin Place.
1891		Bowman, Archer S., B.E., 'Keadue,' Elizabeth Bay Road.
1893		Bowman, John, Assoc. M. Inst. C.E., c/o T. A. Kemmis, Esq., 163 Phillip-street.
1876		Brady, Andrew John, Lic, K. & Q. Coll. Phys. *Irel.*, Lic. R. Coll. Sur. *Irel.*, 3 Lyons Terrace, Hyde Park.
1891		Brennand, Henry J. W., B.A., M.B., Ch. M. *Syd.*, F.R.A.S., F.C.S., 231 Macquarie-street.
1902		Brereton, Victor Le Gay, Solicitor, Tattersall's Chambers, Hunter-st.; p.r. 'Osgathorpe,' Gladesville.
1878		‡Brooks, Joseph, F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.
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1904		Cameron, John Mindoro, Engineer, Public Works Department; p.r. 29 Bligh-street.
1900		Canty, M., 'Rosemont,' 13 York-street, Wynyard Square.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Rd. Edgecliffe.
1897	P 3	Cardew, John Haydon, Assoc. M. Inst. C.E., L.S., 75 Pitt-street.
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1878		Chisholm, Edwin, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Roslyn Gardens, Rushcutters Bay.
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1904		Cooksey, Thomas, Ph. D., B. Sc. *Lond.*, F.I.C., Second Government Analyst; p.r. 'Clissold,' Calypso Avenue, Mosman.
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1894		Dick, James Adam, B.A. *Syd.*, M.D., C.M. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., Fellow of the Institute of Chemistry of Great Britain and Ireland, 97 Pitt-street.
1880		Dixson, Thomas Storie, M.B. *Edin.*, Mast. Surg. *Edin.*, 287 Elizabeth-street, Hyde Park.
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1902		Faithfull, William Percy, Barrister-at-Law, Australian Club.
1897		Fell, David, C A.A., Public Accountant, Equitable Building, George-strest.
1881		Fiaschi, Thos., M.D., M. Ch. *Pisa*, 149 Macquarie-street.
1891		Fitzgerald, Robert D., C.E., Roads and Bridges Branch, Department of Public Works, Sydney; p.r. Alexandra-st., Hunter's Hill.
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1897		Gould, Major The Hon. Albert John, Senator, 'Eynesbury,' Edgecliffe.
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1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c. Australian Club.
1899	P 2	Gummow, Frank M., M.C.E., Assoc. M. Inst. C.E., Vickery's Chambers, 82 Pitt-street.
1891	P 11	Guthrie, Frederick B., F.I.C., F.C.S., Chemist, Department of Agriculture, 136 George-street, Sydney. *Vice-President.*
1880	P 2	Halligan, Gerald H., F.G.S., 'Riversleigh,' Hunter's Hill.
1899		Halloran, Aubrey, B.A., LL.B., 20 Castlereagh-street.
1892		Halloran, Henry Ferdinand, L.S., Scott's Chambers, 94 Pitt-st.
1887	P 7	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; Government Analyst, Health Department, Macquarie-street, North.
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.

Elected		
1877	P 18	‡Hargrave, Lawrence, 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.
1890	P 2	Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C. ., Assoc. M. Cam. Soc. C.E., Assoc. M. Am. Soc. C.E., M.M. & C.E., M. Inst. C.E.I., L.S.' 'The Grove,' off Queen-street, Woollahra.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1900	P 3	Helms, Richard, Experimentalist, Department of Agriculture.
1902		Hennessy, John Francis, Architect, Ashpitel Prizeman and Silver Medallist, Royal Institute of British Architects, City Chambers, 243 Pitt-street.
1899		Henderson, J., F.R.E.S., Manager, City Bank of Sydney, Pitt-st.
1899		Henderson, S., M.A., Assoc. M. Inst. C.E., Equitable Building, George-street.
1884	P 1	Henson, Joshua B., Assoc. M. Inst. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1904		Hill, John Whitmore, Architect, 'Willamere,' May's Hill, Parramatta.
1876	P 2	Hirst, George D., F.R.A.S., 379 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st., Ashfield.
1892		Hodgson, Charles George, 157 Macquarie-street.
1901		Holt, Thomas S., 'Holwood,' Victoria-street, Ashfield.
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1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 63 Pitt-street.
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1903		Irvine, R. F., M.A., Examiner for Public Service Board; p.r. Musgrave-street, Mosman.
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 189 Liverpool-street, Hyde Park.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Acting Chief Inspector of Mines, Geological Surveyor, 'Cromer,' 91 Phillip-street.
1900		Jarman, Arthur, A.R.S.M., Demonstrator in Assaying and Chemistry, University of Sydney.
1903		Jenkinson, Edward H., M. I. Mech. E., 13 and 15 Macquarie Place
1904	P 1	Jenkins, R. J. H., Fisheries Commissioner, 'Pyalla,' 13A Selwyn street, Moore Park.
1902		Jevons, H. Stanley, M.A. *Cantab.*, B.Sc. *Lond.*, Sydney University, Glebe.
1903		Johnston, J. Barre-, 20 Loftus-street; p.r. Mosman.
1902		Jones, Henry L., Assoc. M. Am. Soc. C.E., 14 Martin Place.
1884		‡Jones, Llewellyn Charles Russell, Solicitor, Falmouth Chambers, 117 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park; p.r. 'Llandilo,' Boulevard, Strathfield.
1876	P 2	Josephson, J. Percy, Assoc M. Inst. C.E., Stephen Court, 81 Elizabeth-street; p.r. 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.

Elected		
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873		Keele, Thomas William, M. Inst. C.E., President, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1877		Keep, John, Broughton Hall, Leichhardt.
1887		Kent, Harry C., M.A., Bell's Chambers, 129 Pitt-street.
1903	P 1	Kennedy, Thomas, Assoc. M. Inst. C.E., Railway Construction Branch, Public Works Department.
1901		Kidd, Hector, Assoc. M. Inst. C.E., 'Craig Lea,' 15 Mansfield-street, Glebe Point.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Assistant Engineer, Harbours and Rivers Department, Newcastle.
1896		King, Kelso, 120 Pitt-street.
1892		Kirkcaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T, M.D. *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons Terrace, Hyde Park.
1881	P 17	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney p.r. 'Spottiswoode,' 28 Bland-street, Ashfield. *Hon. Secretary.*
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874	P 1	Lenehan, Henry Alfred, F.R.A.S., Acting Government Astronomer, Sydney Observatory.
1901		Lindeman, Charles F., Wine Merchant, Jersey Rd., Strathfield.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1901		Little, Robert, 'The Hermitage,' Rose Bay.
1872	P 54	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. Phy. 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;* Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point. *Vice-President.*
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1892		McDonagh, John M., B.A., M.D., M.R.C,P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street, North.
1897		MacDonald, C. A., C.E:, 63 Pitt-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1868		MacDonnell, William J., F.R.A.S., 4 Falmouth Chambers, 117 Pitt-street.

Elected		
1903		McDonald, Robert, Commissioner, Western Land Board. Castlereagh-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H. *Cantab.*, Hospital for Insane, Gladesville.
1904		MacFarlane, Edward, J.P., Under Secretary for Lands, p.r. 12 Fitzroy-street, Milson's Point, North Sydney.
1900		McKay, G. A., Federal Public Service Commissioner's Office, Macquarie-st.; p.r. 'Edgeroi,' Clifton Avenue, Burwood.
1891		McKay, R. T., C.E., 'Tranquilla,' West-street, North Sydney.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch.M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. 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., Exchange, 56 Pitt-street; p.r. 'Dilkhusha,' Fuller's Road, Chatswood.
1903		McLaughlin, John, Solicitor, Clement's Chambers, 88 Pitt-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, 'Logan Brae,' Waverley.
1900		MacTaggart, A. H., D.D.S. *Phil.* U.S.A., King and Phillip-sts.
1899		MacTaggart, J. N. C., B.E. *Syd.*, Water and Sewerage Board, 341 Pitt-street.
1882	P 1	Madsen, Hans F., Hesselmed House,' Queen-st. Newtown.
1883	P 14	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 Coll. Pharm.; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc. Lond.; Corr. Memb. Pharm. Soc. Great Britain; Bot. Soc Edin.; Soc. Nac. de Agricultura (Chile); Soc. d' Horticulture d' Alger; Union Agricole Calédonienne; Soc. Nat. etc. de Chérbourg; Roy. Soc., Tas.; Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1897		Marden, John, B.A., M.A. LL.B. *Melb.*, LL.D. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1875	P 19	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., Queensland, 'Carcuron,' Hassall-st., Parramatta.
1903		Meggitt, Loxley, Manager Co-operative Wholesale Society, Alexandria.
1896	P 5	Merfield, Charles J., F.R.A.S., Observatory Sydney.
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C S. *Eng.*, The Hospital, Rydalmere, near Parramatta.
1903		Minell, W. Percy, Incorporated Accountant, Martin Chambers, Moore-street.

Elected		
1889	P 3	Mingaye, John C. H , F.I.C., F.C.S., Assayer and Analyst to the Department of Mines, Government Metallurgical Works, Clyde ; p.r. Campbell-street, Parramatta.
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1887		Munro, William John, B.A., M.B., C.M., M.D. *Edin.*, M.R.C.S. *Eng.*, 213 Macquarie-street; p.r. 'Forest House,' 182 Pyrmont Bridge Road, Forest Lodge.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1901		Newtown, Roland G., 'Walcott,' Boyce-street, Glebe Point.
1891		‡Noble, Edwald George, Public Works Department, Newcastle.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street; p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.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.*, 197 Liverpool-street, Hyde Park.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1883		Osborne, Ben. M., J.P., 'Hopewood, Bowral.
1903		Owen, Rev. Edward, B.A., All Saints' Rectory, Hunter's Hill.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1901		Peake, Algernon, Assoc. M. Inst. C E., 25 Prospect Road, Ashfield.
1899		Pearse, W., Union Club; p.r. Moss Vale.
1877		Pedley, Perceval R., 227 Macquarie-street.
1877		Perkins, Henry A., c/o Perpetual Trustee Co. Ld., 2 Spring-st.
1899		Petersen, T. Tyndall, Member of Sydney Institute of Public Accountants, Martin Chambers, 6 Moore-st.; p.r. Harold-street, Gordon.
1879	P 6	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, Lands Office, Moree.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887	P 1	Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B. Sc. *Syd.*, Professor of Physics, Sydney University.
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin*, Ophthalmic Surgeon, 235 Macquarie-street.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges Public Works Department.

Elected		
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1901	P 1	Purvis, J. G. S., Water and Sewerage Board, 311 Pitt-street.
1876		Quaife, F. H., M.A., M.D., Mast. Surg. *Glas.*, 'Hughenden,' 14 Queen-street, Woollahra.
1899	P 1	Rae, J. L. C., 'Endcliffe,' Church-street, Newcastle.
1902		Ramsay, Arthur A., Assistant Chemist, Department of Agriculture, 136 George-street.
1904		Ramsay, David, Surveyor, Lyons Road, Five Dock.
1865	P 1	‡Ramsay. Edward P., LL.D. *St. And.*, F.R.S.E., F.L.S., 8 Palace-street, Petersham.
1901		Raymond, Robert S., Brewer, c/o Messrs. King & Co., Leichhardt
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 159 Macquarie-street.
1870		‡Renwick, The Hon. Sir Arthur, Knt., M.L.C., B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, 325 Elizabeth-street.
1902		Richard, G. A., Mount Morgan Gold Mining Co., Mount Morgan, Queensland.
1903	P 1	Rooke, Thomas, A.M.I.C.E., Electrical Engineer, Town Hall, Sydney.
1893	P 1	Roberts, W. S. de Lisle, C.E., 'Kenilworth,' Penshurst.
1885		Rolleston, John C., Assoc. M. Inst. C. E., Harbours and Rivers Branch, Public Works Department.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Rranch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M., *Edin.*, 147 Macquarie-st.
1895	P 1	Ross, Herbert E., Consulting Engineer and Architect, Equitable Building, George-street.
1904	P 2	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.
1864	P 69	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F. R. Met. Soc., Hon. Memb. Roy. Soc. S. Australia, Sydney Observatory.
1897		Russell, Harry Ambrose, B.A. Solicitor, c/o Messrs. Sly and Russell, 379B George-street; p.r. 'Mahuru,' Milton-street, Ashfield.
1893		Rygate, Philip W., M.A., B.E., *Syd.*, Assoc. M. Inst. C.E., Phœnix Chambers, 158 Pitt-street.
899		Schmidlin, F., 83 Elizabeth-street, Sydney.
892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., University, Sydney.
856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
903		Scott, William B., Principal, Homebush Grammar School, p.r. Albert Road, Strathfield.
1877	P 4	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1904	P 1	Sellors, R. P., B.A. *Syd.*, 'Cairnleith,' Springdale Road, Killara.

Elected		
1891		Shaw, Percy William, M. Inst. C.E., Resident Engineer for Tramway Construction, p.r. 'Epcombs,' Miller-st. North Sydney.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Inspecting Engineer, Existing Lines Office, Bridge-street.
1909		Simpson, R. C., Technical College, Sydney.
1882		Sinclair, Eric, M.D., C.M. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain; p. r. Cleveland-street, Wahroonga.
1893		Sinclair, Russell, M. I. Mech. E., etc., Consulting Engineer, Vickery's Chambers, 82 Pitt-street.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-st., Hyde Park.
1891	P 3	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1904	P 1	Smail, Herbert Stuart Inglis, B.E. *Syd.*, Assistant Engineer, Public Works Department; p.r. 'Clytha,' Neutral Bay.
1893	P 28	Smith, Henry G., F.C.S., Assistant Curator, Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1899		Smith, R. Greig, D.Sc., *Edin.*, M.Sc., *Dun.*, Macleay Bacteriologist, 'Otterburn.' Double Bay.
1886		Smith, Walter Alexander, M. Inst. C. E., Roads, Bridges and Sewerage Branch, Public Works Department; 12A Phillip-st.
1896		Spencer, Walter, M.D. *Brux.*, 13 Edgeware Road, Enmore.
1904		Stanley, Henry Charles, M. Inst. C.E., Royal Chambers, Hunter and Castlereagh-streets.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., Cumberland Heights, Parramatta.
1900		Stewart, J. D., M.R.C.V.S., Government Veterinary Surgeon, Department of Mines and Agrioulture; p.r. Cowper-street, Randwick.
1903		Stoddart, Rev. A. G., The Rectory, Manly.
1883	P 3	Stuart, T. P. Anderson, M.D., LL.D. *Edin.*, Professor of Physiology, University of Sydney; p. r. 'Lincluden,' Fairfax Road, Double Bay.
1901		Süssmilch, C. A., Technical College, Sydney.
1893		‡Taylor, James, B.Sc., A.R.S.M., Nymagee.
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.
1896		Thom, James Campbell, Solicitor, 'Dunoon,' Eurella-street, Burwood.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-atreet.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, The Hon. Dugald, M.H.R., 'Wyreepi,' Milson's Point.
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.
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., Locomotive Department, Eveleigh.
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.

Elected		
1894		Tidswell, Frank, M.B., M.Ch., D.P.H. *Cantab.*, Health Department, Sydney.
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., Wood's Chambers, Moore-st.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'Bay View House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., viâ Fazio 2, Spezia, Italy.
1890		Vicars, James, M.C.E., M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1903	P 1	Vonwiller, Oscar U., B.Sc., Demonstrator in Physics, University of Sydney.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company Ld., 2 Spring-street.
1904		Vogan, Harold Sebastian, Assoc. M. Inst. C.E., Authorised Surveyor N.Z., Chief Draftsman, Existing Railways N.S.W., Bridge-st.
1898	P 1	Wade, Leslie A. B., Assoc. M. Inst. C.E., Department of Public Works
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, Senator J. T., 'Rosemont,' Ocean-street, Woollahra.
1901		Walkom, A. J., A.M.I.E.E., Mem. Elec. Assoc. N.S.W., Electrical Branch, G.P.O. Sydney.
1900		Wallach, Bernhard, B.E. *Syd.*, Electrical Engineer, 'Oakwood,' Wardell Road, Dulwich Hill.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E, Engineer-in-Chief, Harbour Trust, Circular Quay.
1903		Walsh, Fred., 23 Elizabeth-st.; p.r. 'Walworth,' Park Road, City E.
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1898		Wark, William, 9 Macquarie Place; p.r. Kurrajong Heights.
1902		Warren, Ernest W., B.E., B.A., LL.B., Barrister-at-Law, Wigram Chambers, Phillip-street.
1877		Warren, William Edward, B.A., M.D., M. Ch., Queen's University *Irel.*, M.D. *Syd.*, 283 Elizabeth-street, Sydney.
1883	P 15	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney. *Vice-President.*
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 Road, Newtown.
1897		Webb, Frederick William, C.M.G., J.P., 'Livadia,' Manly.
1903		Webb, A. C. F., Consulting Electrical Engineer, Vickery's Chambers, 82 Pitt-street.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Town Hall, Sydney.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1902		Welsh, David Arthur, M.D., M.A., B.Sc., Professor of Pathology, Sydney University, Glebe.
1881		‡Wesley, W. H.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Glencoe,' Lower Forth-street, Woollahra.

Elected		
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., T.C.D.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 213 Macquarie-street.
1876		Williams, Percy Edward, Comptroller, Government Savings Bank, Sydney.
1901		Willmot, Thomas, J.P., Toongabbie.
1878		Wilshire, James Thompson, F.R.H.S., J.P., 'Coolooli,' Bennet Road, Neutral Bay.
1879		Wilshire, F. R., Police Magistrate, Penrith.
1890		Wilson, James T., M.B., Master Surgeon, *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 10 Bligh-street; p.r. 54 Darlinghurst Road.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1902		Wright, John Robinson, Lecturer in Art, Technical College, Harris-street, Sydney.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1901		Baker, Sir Benjamin, K.C.M.G., D. Sc., LL.D., F.R.S., etc., 2 Queen Square Place, London, S.W.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1900		Crookes, Sir William, F.R.S., 7 Kensington Park Gardens, London W.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., c/o Government Astronomer of Victoria, Melbourne.
1887		Foster, Sir Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Sir Augustus Charles, K.C.M.G., M.L.C., F.R.G.S. Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., late Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., c/o Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1901		Judd, J. W., C.B., F.R.S., F.G.S., Professor of Geology, Royal College of Science, London.
1903		Kelvin, Right Hon. William Thomson, Lord, O.M., G.C.V.O., D.C.L., LL.D., F.R.S., etc., 15 Eaton Place, London, S.W.
1903		Lister, Right Hon. Joseph, Lord, O.M., B.A., M.B., F.R.C.S. D.C.L., F.R.S., etc., 12 Park Crescent, Portland Place, London, W.

Elected		
1901		Newcomb, Professor Simon, LL.D., Ph. D., For. Mem. R.S. Lond., United States Navy, Washington.
1894		Spencer, W. Baldwin, M.A., C.M.G., F.R.S., Professor of Biology, University of Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., B.Sc. F.R.S., F.L.S., Director, Royal Gardens, Kew.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Old Orchard, Broadstone, Wimborne, Dorset.

Obitaury 1904.

Ordinary Members.

1885	Allworth, J. Witter
1876	Gipps, F. B.
1874	King, Hon. Philip Gidley
1878	Low, Hamilton Lambart
1876	Mackenzie, Rev. P. F.
1873	Trebeck, P. N.

Obituary 1905.

1878	Dean, Alexander
1856	Moore, Charles

AWARDS OF THE CLARKE MEDAL.

Established in memory of

The late Revd. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,

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.

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

1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.

1880 Professor Thos. Huxley, F.R.S., The Royal School of Mines, London· 4 Marlborough Place, Abbey Road, N.W.

1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.

1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.

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

1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.

1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.

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

1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.

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

1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.

1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.

1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.

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

1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.

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

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

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

1900 Sir John Murray, Challenger Lodge, Wardie, Edinburgh.

1901 Edward John Eyre, Walreddon Manor, Tavistock, Devon, England.

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

1903 Alfred William Howitt, F.G.S., Hon. Fellow Anthropol. Inst. of Gt. Britain and Ireland, 'Eastwood,' Bairnsdale, Victoria.

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.

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, B.Sc., M.B. *Lond.*, 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.'

PRESIDENTIAL ADDRESS.

By F. B. GUTHRIE, F.I.C., F.C.S.,
(Chemist, Department of Agriculture, N.S.W.; Acting Professor of Chemistry, The University, Sydney.)

[*Delivered to the Royal Society of N. S. Wales, May 4, 1904.*]

ACCORDING to established usage it is my privilege to submit for your information a short *résumé* of the work done by the Society during the past year. I propose to add a few remarks dealing with the position of Chemistry in the State. No special comment is necessary on the work of the Society. Its scientific activity you will be able to estimate from the long list of papers published dealing with original matters, from the large number of our exchanges with foreign scientific societies, and from the programme of popular science lectures submitted to you.

The number of our members has remained at about the same figure as last year, a result which I think we are justified in regarding as satisfactory when all things are taken into consideration.

Financial Position.—The Hon. Treasurer's Financial Statement shows that the financial affairs of the Society are in a fairly satisfactory condition.

The Library.—From the balance sheet submitted this evening, it will be seen that the sum of £85 3s. 4d. was expended on books and periodicals, the binding amounted to £1 19s. 6d.

Exchanges.—Last year we exchanged our Journal and Proceedings with 431 kindred societies, receiving in return 328 volumes, 1,729 parts, 207 reports, 178 pamphlets, 5 chronographical tables, 1 geographical map and 2 geological charts; total 2,450.

Papers read in 1903.—During the past year the Society held eight meetings, at which 19 papers were read, the average attendance of members was 33 and of visitors 2.

ART. I.—PRESIDENTIAL ADDRESS. By Professor W. H. WARREN, Wh. Sc., M. Inst. C.E., M. Am. Soc. C.E.

ART. II.—Language of the Bungandity Tribe, South Australia. By R. H. MATHEWS, L.S., Associé étranger Soc. d'Anthrop. de Paris.

ART. III.—Notes on Tide-Gauges with a description of a new one. By G. H. HALLIGAN, L.S., F.G.S. [*With Plates*]

ART. IV.—The Sand-Drift Problem in New South Wales. By J. H. MAIDEN, F.L.S., Government Botanist and Director of the Botanic Gardens, Sydney.

ART. V.—Aluminium the chief inorganic element in a Proteaceous Tree, and the occurrence of Aluminium Succinate in trees of this species. By HENRY G. SMITH, F.C.S., Assistant Curator Technological Museum, Sydney. [*With Plate*]

ART. VI.—Economic Effect of Sanitary Works. By J. HAYDON CARDEW, Assoc. M. Inst. C.E. [*With Plates*]

ART. VII.—Sand-Drift Problem of Arid N. S. Wales. By COLIN J. McMASTER, Chief Commissioner of Western Lands. [*With Plate*]

ART. VIII.—The Aboriginal Fisheries at Brewarrina. By R. H. MATHEWS, L.S., Associé étranger Soc. d'Anthrop. de Paris. [*With Illustrations*]

ART. IX.—The Separation of Iron from Nickel and Cobalt by Lead Oxide (Field's Method). By T. H. LABY, Junior Demonstrator of Chemistry, University of Sydney. (Communicated by Professor LIVERSIDGE, M.A., LL.D., F.R.S.)

ART. X.—Pot Experiments to Determine the Limits of Endurance of different Farm-Crops for certain Injurious Substances. By F. B. GUTHRIE, F.I.C., F.C.S., and R. HELMS.

ART. XI.—Bibliography of Australian Lichens. By E. CHEEL. (Communicated by J. H. MAIDEN, F.L.S.)

ART. XII.—On the Protection of Iron and other Metal Work. By WILLIAM M. HAMLET, F.I.C., F.C.S., Government Analyst.

ART. XIII.—A Comparison of the Periods of the Electrical Vibrations associated with Simple Circuits. By J. A. POLLOCK, B.Sc., Professor of Physics in the University of Sydney; with an Appendix by J. C. CLOSE, Deas-Thompson Scholar in Physics.

ART. XIV.—A Contribution to the Study of the Dielectric Constant of Water at Low Temperatures. By O. U. VONWILLER, B.Sc., Demonstrator in Physics in the University of Sydney.

Art. XV.—The Narraburra Meteorite. By A. Liversidge, ll.d., f.r.s., hon. f.r.s.e., Professor of Chemistry in the University of Sydney. [*With Plates*]

Art. XVI.—Notes on some Native Dialects of Victoria. By R. H. Mathews, l.s., Corres. Memb. Anthrop. Soc., Washington. U.S.A. [*With Illustration*]

Art. XVII.—On some further observations on the Life-history of *Filaria immitis*, Leidy. By Thos. L. Bancroft, m.b. Edin.

Art. XVIII.—On the Elastic Radial Deformations in the Rims and Arms of Fly-wheels, and their Measurement by an Optical Method. By A. Boyd, B.Sc., B.E., Stud. Inst. C.E. (Communicated by Prof. W. H. Warren, Wh. Sc., M. Inst. C.E.)

Art. XIX.—The Geology of Mittagong. By T. Griffith Taylor, Deas-Thomson Scholar in Geology and D. Mawson, b.e., Junior Demonstrator in Chemistry, Sydney University. (Communicated by Prof. T. W. Edgeworth David, b.a., f.g.s., f.r.s.) [*With Plates*]

Sections.—The Engineering Section held two Sessions at which 13 papers were read and discussed; the average attendance of members was 49 besides many visitors.

Art. XX.—Introductory Remarks. By S. H. Barraclough, b.e., m.m.e., Assoc. M. Inst. C.E., Chairman of the Section.

Art. XXI.—Water Conservation and the Equitable Distribution of Water for Irrigation and other purposes. By H. G. McKinney, M.E., M. Inst. C.E.

Art. XXII.—Property in Water. By George Chamier, M. Inst. C. E.

Art. XXIII.—The Hydraulic Aspect of the Artesian Problem. By G. H. Knibbs, f.r.a.s., University of Sydney.

Art. XXIV.—The question of the Occurrence of Living Organisms in the Artesian Waters. By Professor W. A. Haswell, M.A., D.Sc., F.R.S.

Art. XXV.—The Chemical Nature of the Soils of New South Wales with special reference to Irrigation. By F. B. Guthrie, f.i.c., f.c.s.

Art. XXVI.—A Review of Water Conservation in New South Wales. By L. A. B. Wade, Assoc. M. Inst. C.E.

Art. XXVII.—Relation of Electricity to Irrigation Works and Land Development. By Thomas Rooke, Assoc. M. Inst. C.E.

Art. XXVIII.—Irrigation Geologically Considered with special reference to the Artesian Area of New South Wales. By Edward F. Pittman, a.r.s.m., and T. W. Edgeworth David, b.a., f.r.s. [*With Plates*]

ART. XXIX.—An Economic Aspect of Artesian Boring in New South Wales. By JAMES BOULTBEE, Superintendent of Artesian Bores.

ART. XXX.—The Measurement of the Flow of Streams and Artesian Bores, as carried out by the Public Works Department of New South Wales. By H. S. I. SMAIL, B.E., Assistant Engineer.

ART. XXXI.—The Murray Waters. By R. T. McKAY, C.E.

ART. XXXII.—The High Speed Electric Railway Trials on the Berlin-Zossen Line of 1901, 1902 and 1903. By C. O. BURGE, M. Inst. C.E.

Lectures.—A course of three science lectures and one Clarke Memorial Lecture was delivered during the Session and were well attended.

May 28th—"The Development of the Railway," by C. O. BURGE, M. Inst. C.E.

June 25th—"The Australian Flora," by R. T. BAKER, F.L.S.

Oct. 22nd—"Water," by Prof. LIVERSIDGE, M.A., LL.D., F.R.S.

Sept. 24th—(Clarke Memorial) "The Life and Work of the Rev. W. B. Clarke," by Prof. T. W. EDGEWORTH DAVID, B.A., F.G.S., F.R.S.

Conversazione.—A very successful Conversazione was held in the Great Hall of the University on Thursday, August 27th, 1903.

Roll of Members.—The number of members on the Roll on the 30th April, 1903, was 344. During the past year 22 members were elected: the deaths numbered 6 and resignations 13, leaving a total of 347 to date.

The following is a list of members who have died during the year:—

T. R. Firth; elected 1891.
Hamilton L. Low; elected 1878.
Dr. F. Norton Manning; elected 1876.
Dr. William Morris; elected 1877.
Dr. Thomas Pickburn; elected 1876.
Hon. J. T. Toohey; elected 1876.

On the Present Position of Chemistry and of Chemists in New South Wales.

Following the example of many of my predecessors, I shall address myself to the discussion of the particular science in which I am interested, and shall review briefly the position of scientific chemistry in the State at the present time. The information collected for your perusal may not be quite complete; there may be chemical and analytical work done by private firms of which I am ignorant, but on the whole, I think the following notes indicate fairly the work that is being done in New South Wales. I have added some suggestions as to the manner in which, in my opinion, the value of that work can be increased, and I submit these suggestions for your consideration.

Teaching Institutions.

The University.—Of the teaching institutions, the University makes the most ample provision for the teaching of chemistry. About 300 students are in attendance at lectures, and about 150 do practical work in the laboratories. Courses are arranged for students in arts, science, medicine, pharmacy, dentistry, and in civil, mechanical, electrical and mining engineering; the students in mining and metallurgy as well as those in dentistry going through a course in metallurgy and assaying. Courses of lectures on inorganic and organic chemistry are given, and the laboratory work includes qualitative and quantitative analysis, organic analysis and preparations. Facilities for research are provided, there being a separate laboratory where advanced students can undertake research work under the direction of Professor Liversidge. Some of the investigations carried out have been brought before this Society during the past year. We have had contributions from Prof. Liversidge on "the Narraburra Meteorite"; from Mr. Laby on "the estimation of Ni and Co"; from

Mr. Mawson and Mr. Griffith Taylor on "the Geology of Mittagong," which includes analyses of rocks from the Mittagong district.

Mr. Petrie has obtained a special Caird Scholarship of £100, which has enabled him to investigate the nature of the products obtained by the distillation of New South Wales shale. Mr. Laby is applying for a grant from the Royal Society to enable him to test rigorously the experiments of Landolt, indicating an alteration in weight during chemical change. Mr. Mawson, who has just returned from a scientific expedition to the New Hebrides with Capt. Rason, R.N., is engaged on an examination of the rocks which he has there collected.

Within the last few years a well-equipped metallurgical and assaying laboratory has been erected, where students in mining and metallurgy receive a complete course of instruction in these subjects, including assaying and technical analysis and bulk treament of ores.

Professor Liversidge is assisted by Mr. J. A. Schofield, A.R.S.M., (now Acting Professor) Lecturer and Demonstrator in Chemistry in charge of the Chemical Laboratories, and Mr. A. Jarman, A.R.S.M., in charge of the Metallurgical Laboratory.

Technical Colleges.—At the Sydney Technical College the teaching of chemistry has been recently placed under the direction of Mr. W. J. Clunies Ross, B.Sc., (Lond.) Lecturer-in-Charge of Chemistry and Metallurgy, recently Resident Master-in-Charge of the Bathurst Technical College. The chemistry teaching at the Technical College includes two-year courses in theoretical and practical chemistry for ordinary students, advanced students doing quantitative analysis. There is in addition a two-year course in metallurgy and assaying. Engineering students receive a two-year course and attend lectures in metallurgy during their third year. Similar classes are held in the branch Technical Colleges at Bathurst, Goulburn, Newcastle, Maitland, Broken Hill, Lithgow, and Hillgrove.

The chemical laboratory was first brought into existence by the School of Arts Committee, who were the forerunners of the Board of Technical Education, since merged in the Department of Public Instruction. The School of Arts Committee appointed Mr. W. A. Dixon, F.I.C., in charge of the chemistry teaching of the new institution in 1878. Mr. Dixon remained in charge of the laboratory until a few years ago when he resigned.

The present teacher in metallurgy and assaying is Mr. A. H. Stewart, B.E.

A two-year course in organic chemistry and analysis is given by Mr. H. G. Smith, Assistant Curator and Chemist to the Technological Museum. Mr. Smith has in addition taken up the subject of the chemistry of the Eucalypts, and has brought before you a number of papers embodying the results of his researches. This work has been undertaken in conjunction with Mr. R. T. Baker, Curator of the Technological Museum, and the happy combination of botanist and chemist has resulted in the compilation of a monograph of more than ordinary interest on the subject of our Eucalypts.

Hawkesbury Agricultural College.—At the Hawkesbury Agricultural College, chemistry both theoretical and practical, is taught, including analysis. The instruction is of course mainly directed towards such branches of the science as are of use in agricultural work, but a good grounding in the general principles is insisted upon by the Principal, Mr. H. W. Potts, himself a chemist.

Chemistry is also efficiently taught at some of the larger schools. These however, hardly come within the scope of this address.

Government Laboratories.

The Government Analyst.—Through the courtesy of the present Government Analyst, I am able to place before you some information relative to the first Government Analyst, Mr. J. S. Norrie. Mr. Norrie's was the first chemical appointment made in New South Wales, and consequently (as at that date Australia had not yet been divided into States) in Australia, a fact that will make any details connected with his life to be of interest to a scientific audience. The information is supplied by his son, Mr. T. H. Norrie, now chemist to the Customs Department.

The first Government Analyst, James Smith Norrie, was born at Bethnal Green, London, in the year 1820; and died at Sydney, New South Wales, March 1883, aged 63 years. Mr. Norrie was educated at the Blue Coat School, London, receiving his chemical training in the laboratory and business of John Bell, 338 Oxford Street, London, being associated with his son, Jacob Bell (one of the founders of the Pharmaceutical Society of Great Britain) attending also the scientific lectures at King's College, and was one of the first members of the then recently formed Chemical Society. In the beginning of the year 1840 he came to Australia, intending to join an uncle in charge of British troops in New South Wales, and a little later in the same year, (1840) he established a chemist and druggist business in Pitt Street, and was the first wholesale and retail chemist and druggist here. In the year 1844 he was appointed Government Chemist. As this was before the partition of Australia into States, Mr. Norrie was in fact Government Analyst for all Australia, and his attendance at distant parts of the continent necessitated his absence from Sydney for many weeks and even months together, to the detriment of his business. Mr. Norrie afterwards established his laboratory at Lyons' Terrace, Sydney, where he worked until his retirement. He held the position of Government Analyst till 1871, conducting all Government work for New South Wales, afterwards also for Queensland and Victoria, when these were created separate States. The position carried no fixed salary, but was carried on in conjunction with his pharmaceutical business, various fees being paid for certain classes of work, such as consultations, assaying minerals, examination of waters, foods, and general analyses for legal purposes. This latter portion of the work very often entailed long journies and considerable loss of time, as all evidence had to be given on oath in the colony or district from which the case was received.

In the early days a considerable amount of interesting work arose in connection with gold and silver assays, (all of which had to be sent to the Government Chemist by the banks and Government) and the smelting of the gold received into bars. When the question of the water supply to Sydney was under consideration in 1857, he was appointed to the Committee and carried out the examination of the water and soils of the district which provided what was afterwards known as the Botany Water Supply to the City of Sydney. On the the death of the Prince De Condé (then on a visit to Sydney) at Petty's Hotel, he undertook, by request, the task of embalming the remains and forwarding them to France, and received from the French Government a letter of thanks and a gift for his services. He thus carried out the first embalmment in Australia of human remains.

At the French Exhibition in Paris of 1855 he exhibited a fine collection of minerals from Australia, (the first shown from these dominions) which aroused a considerable amount of interest at the time and drew attention to our mineral resources. For this he received from the authorities a special certificate signed by Napoleon Buonaparte (now in the possession of Mr. T. H. Norrie).

In many of the earlier events of the Colony he was associated with such well known men as W. Wentworth, Richard Hill, W. B. Dalley, John Robertson, and Dr. George Bennett, and was one of the founders of the first Volunteer Force, serving himself with the Mounted Rifles and on the Committee of Defence.

Particulars of a number of sensational trials in New South Wales and Queensland, in which the detection of poison in human remains and blood stains and hair on hatchets and knives led to the conviction and execution of murderers, together with many other interesting mementoes of his official relation with the Government, and pertaining to the early history of the Colony, have unfortunately been destroyed by a fire that took place in his home.

In 1871 Mr. Norrie was succeeded by Mr. CHARLES WATT, who came out from England in 1854 to enter upon the duties of chemist in the soap and candle industry, then about to be established on the strength of the success of the pastoral work of the early squatters, whereby an abundance of raw material, such as tallow and other animal products, could be obtained cheaply. With the development of photography in the young country, came the demand for both nitrate of silver and chloride of gold, which Mr. Watt prepared and supplied to the photographers. Native silver was then unknown, and the only available silver was that to be obtained from the pawnbrokers' shops. It is believed on the testimony of those who knew Mr. Watt that many rare specimens of valuable wrought silver plate were sacrificed to do duty in providing the silver salts used in the wet-plate photography of those days. Mr. Watt was appointed Government Analyst in 1872 and was afterwards made Examiner of Explosives and Inspector of Kerosene. In the years that followed, the work increased so rapidly, that some ten years later a special laboratory was built, which stood for many years at the corner of Albert and Macquarie Streets, near the Water Police Court, on the spot where now stand the offices of the Department of Public Health.

After the gold rush, tin ore was discovered in New England, and as buyers and sellers would only do business on Mr. Watt's certificate, assaying for tin occupied a large part of his time; so that it became necessary to increase the staff of analysts to cope with the influx of samples from the Mines Department. Mr. Watt was assisted by Dr. Max Hartung, Mr. Janitzky, Mr. Mingaye (now head of the Mines Laboratory staff), Dr. Rennie (now Professor of Chemistry in the University of Adelaide), Mr. Doherty, and Mr. Leipner. Mr. Watt and Dr. Leibius were Examiners of Patents for this State. In 1886, Mr. Watt retired and was succeeded by Mr. HAMLET the present Government Analyst.

At this period mining and work of all kinds was prosperous, and assaying and analytical work increased so rapidly that the work of Examiner of Explosives as well as that of Inspector of Kerosene were separated, and the Mercantile Explosives Department established. Also a separate laboratory was established for the assaying work of the Mines Department and for mineral and rock analyses under the control of Mr. Mingaye, and later, on the establishment of the Department of Agriculture, a separate laboratory was founded for agricultural chemical work.

The work of the Government analyst now consists of the analyses of the drinking water supplied to the city of Sydney and all country towns in New South Wales; water from tanks, wells, artesian bores and public watering places; waters collected by sanitary inspectors on the outbreak of any epidemic or zymotic disease in which the water is suspected; waters used for steam purposes on railways. Paints, lubricants, oils, stone, cement, asphalte, metals and materials used in building construction, the clothing of police, soldiers, postmen, prison and asylum warders; foods, drugs, soap and stores used in asylums and charitable institutions are also examined. Foods and drugs taken by the inspectors in the working of the Public Health Act, and stomachs and other internal organs sent by the police and Department of Justice come here together with medicines and drugs used for illegal purposes. Coal, water and general stores used in His Majesty's navy; kerosene, petroleum spirit, motor-car fuel and dangerous goods submitted by the Department of Navigation; articles such as illicit spirits, beer, etc., for the Excise; articles from the the Customs involving questions of duty; spirits from the different hotels sent by the police, methylated spirits and tobacco all contribute to the work of this department. Mr. Hamlet is assisted by Messrs. T. Cooksey, Ph. D., F.I.C., W. M. Doherty, F.I.C., and H. V. Nicholls.

The Analyst and Assayer, Department of Mines.—The chemical work required by the Department of Mines was in the early days of the department performed by Mr. W. A. Dixon, F.I.C., F.C.S., and later, by the late Government Analyst, Mr. Charles Watt. In 1887, the work largely increasing, the Department of Mines decided to equip a chemical laboratory of their own, and a start was made in that direction in the old buildings situated under the Geological Museum in Macquarie-street. Mr. J. C. H. Mingaye, who had held the position of assistant to the Government Analyst for some years, was appointed to take charge. In 1890 the chemical laboratory was removed to the premises at present occupied by the Agricultural Chemical Laboratory, and on the starting of the Government Metallurgical Works at Clyde, in 1896, was again removed to the new buildings. The premises have been added to on several occasions, and are thoroughly equipped with appliances and apparatus.

The staff consists of two chemists (Mr. J. C. H. Mingaye, F.I.C., etc., and Mr. H. P. White); two junior chemists, two assayers, one labourer, one care-taker, and one laboratory attendant.

The work of this branch consists largely in experimental and analytical work in connection with the treatment of ores, metallurgical products, alloys etc., analyses of water, minerals, rocks etc., and wet and dry assays for various metals. The following papers recording the results of chemical investigations undertaken in the Mines Laboratory have lately been published in the Geological Survey Records:—

I. "Analcite-Basalt Rocks from the Sydney District," (Card, Mingaye, White).

II. "Notes and Analyses of Olivine-Basalt Rocks from Sydney District," (Mingaye, White).

III. "Notes from the Chemical Laboratory, Department of Mines," (J. C. H. Mingaye).

IV. "On the Occurrence of Monazite in the Beach Sands of the Richmond River, N.S.W." (J. C. H. M.)

V. "Chemical Notes on Glaucophane Schists from Australia and New Caledonia," (H. P. White).

VI. "Notes on the Composition of Meteoric Iron from Bendoc, Victoria." (J. C. H. M.)

The Laboratory, Department of Agriculture.—In the laboratory of the Department of Agriculture chemical questions relating to agriculture are dealt with, the routine work comprising analyses of soils, manures, waters, fodder-plants and foods, wheat and flour, and all kinds of agricultural products or substances used by the farmers. In addition, all chemical questions relating to the treatment of the soil and of crops receive consideration and investigation. For an account of the work I invite your perusal of the annual reports of the department. Records of investigations which contain matter of more than usual scientific interest have been published in the *Agricultural Gazette* and in the Journal of this Society.

The Laboratory, Customs Department, is under the direction of Mr. T. H. Norrie, with two assistants, the chief being Mr. Peck. In Mr. Norrie's laboratory, which is in the Customs building, work connected with the analysis of articles for revenue purposes is carried out. The work covers a large area, especially since the Federal Tariff has been in operation, and includes the examination of spirits for revenue purposes, alcohol, beer, bitters, extracts, etc., patent medicines, teas, oils—burning and lubricating—kerosene by its flashing point, the discrimination of wool, silk, cotton in dress material and flax, hemp, and jute; paints and enamels, and so forth.

The Chemical Laboratory, Explosives Department, is under the charge of Mr. W. C. Wain, F.C.S. Here are examined all explosives used for commercial purposes, principally mining. Every shipment which arrives is sampled and examined. The explosives for the Imperial Departments are examined by their own inspector of warlike stores. There appears to be no local supervision of ammunition etc. supplied to the State. Mr. Wain also makes examinations for the Railway Department in the case of the carriage of dangerous goods, and acts as Inspector of Magazines throughout New South Wales.

The Laboratory, Royal Mint.—The operations at the Mint are of course principally of a chemical nature and include refining and assaying. This work is in the charge of Mr. Bayly, the chief assayer, with two assistant assayers.

Private Firms Employing Chemists.

The Colonial Sugar Refining Company employs upwards of 70 chemists, partly at their laboratory in Sydney and partly in the different mills in Queensland, Fiji, New South Wales, and the refineries in New South Wales, New Zealand, Victoria, Queensland, and South Australia. As sugar manufacturing and refining are chemical processes, all the different operations are checked by analysis, as are also the waste products. Each mill and refinery possesses its separate laboratory and staff of chemists engaged in routine analytical work, the head chemist at each establishment having control of the manufacture. The laboratory in Sydney, which is under the direction of Mr. T. U. Walton, B.Sc., F.I.C., and Mr. T. Steel, F.L.S., F.C.S., controls the work of the other laboratories and mills. Here also the younger chemists receive their special training. Twenty-three years ago the company employed only a single chemist.

Messrs. Elliott Bros. are the principal manufacturing chemists, and give employment to about 300 hands. They manufacture mineral acids, sulphuric, hydrochloric, hydrofluoric and nitric acids as well as anhydrous ammonia and compressed carbon dioxide. Sulphuric acid is manufactured by the chamber process with all the most recent improvements, the output being about 16,000 tons annually, Japanese sulphur being used in its preparation, and the acid is principally utilized in the manufacture of superphosphates which form the basis of the chemical fertilizers, which are manufactured in large quantities by Messrs. Elliott. Sulphuric anhydride is also manufactured by the 'contact' process. Messrs. Elliott Bros. are also our chief manufacturers of pure chemicals, drugs and pharmaceutical preparations. They are also smelters of Bismuth. Elliott Bros. have a similar manufactory at Brisbane.

The Australian Drug Company are large manufacturers of pharmaceutical preparations, druggists' proprietary articles and storekeepers' sundries, the manufacture of which articles is under competent chemical supervision.

The Ammonia Company of Australia confine their operations to the manufacture of anhydrous ammonia and of "liquor ammoniæ." Large quantities of the first-named product are used in refrigerating and cool storage chambers locally, the liquor ammoniæ being principally used by the pharmacists. The manufactory, which is situated at Clyde, is under the direction of Mr. Alexander.

Messrs. Lever Bros. the well-known soap-makers of Port Sunlight, have an establishment in Sydney, at Balmain, where they manufacture soap, glycerine, coco-nut oil and coco-nut oil-cake.

The Co-operative Wholesale Society, Limited, have also a branch establishment in Sydney, where coco-nut oil and oil-cake, tallow, and manures are manufactured. The works and laboratory are under the control of Mr. Loxley Meggitt, F.I.C., F.C.S.

Chemists and analysts are also employed by other private firms, such as pottery makers, brewers, etc., but not, as far as I am aware, to any large extent.

Statistics.

Returns published by the Government Statistician on April 27th, 1904, under the heading Drugs and Chemicals and including chemicals, drugs, medicines, fertilisers, paints, varnishes and bye-products show that 693 people are employed in chemical industries, and about £26,000 paid in wages. Of those actually employed as chemists the following return is taken from the last Census (1901):—

Manufacturing chemists...	96
Analytical chemists and analysts ...	72
Assayers	171
Metallurgists	50

* * *

It will, I think, be admitted that this is not a very long list, considering the great importance of the science in our manufacturing and industrial life. Chemistry is hardly represented even amongst the few industries which we possess, and which in other countries are carried on with chemical assistance. At the same time this state of things cannot be expected to continue indefinitely. In proportion as our existing industries become more robust and as new ones are established, the need for the advice and co-operation of properly trained chemists will increase; indeed I am convinced that in proportion as the value of chemical assistance is recognised in those industries which involve chemical principles, (and these are very numerous) so will these industries flourish.

The Question of Qualification.

At the present time the number of those who make their livelihood by chemical or analytical work is limited, and the disadvantages under which they labour concern so small a class that they are perhaps hardly worth the serious consideration of the community. These disadvantages do however prevail, and their existence will be more keenly felt, and more difficult to remedy when the times come in which the growth of manufacturing industries, the increasing public interest in matters of public health and of education will create a demand for a larger body of men qualified for chemical work. The most serious disadvantage under which we work, and it is one that has equally serious consequences for the public, is the absence of any recognized chemical qualification. It will never be possible to prevent unqualified individuals from practising any more than it is possible to prevent unqualified men practising the professions of medicine or dentistry, but it should at least be possible for those who employ chemists to be able to insist upon the attainment of some standard of proficiency which shall ensure their competency. At present such a qualification does not exist in Australia. In Victoria, where they appear to possess the power of adapting themselves to changing conditions to a greater degree than we do, and to be able to recognize new requirements, a scheme has been mooted for the granting of certificates, either by the State or by a private corporation, of competency in analytical work.

In continental countries every one practicing as an analyst is obliged to pass a State examination in chemistry. In England, the disadvantages accruing to the absence of any recognised qualification was severely felt many years ago, when it was the custom for the Borough Councils to appoint medical practitioners to act in the capacity of analysts, and prosecutions were undertaken on their certificates in cases of adulteration of foods and drugs, etc. In order to remedy this state of things, the Institute of Chemistry was founded some 20 years ago by some of the leading English chemists. Its object was to provide a severe standard of examination which would ensure that none but properly qualified men should be admitted into its ranks. The value of this qualification is now firmly established in Great Britain, and in the appointmment of public analysts the possession of this qualification is becoming a *sine qua non*. Examinations are also held by the Institute in local centres, a matter of considerable convenience to those who desire to qualify themselves but are debarred by reason of distance from London.

I would like to suggest that the State, as the largest and most responsible employer locally of this class of labour, should recognise this qualification. If the Public Service Board agreed that they would regard qualification by the Institute as an essential to any chemical appointment made by them, the Institute of Chemistry would meet their wishes and sanction the holding of local examinations. Private employers and the public would very shortly fall into line. The time is in my opinion not far distant when some definite steps will have to be taken to ensure proper qualifications among chemists and analysts, just as it has been necessary in the case of medical men and dentists, and it will be far preferable to take advantage of the machinery of an existing institution whose qualification is acknowledged all over the world, than to create a new qualifying board whose decision will be discounted by reason of local jealousies and prejudices.

Co-ordination in Scientific Work.

There is another matter with regard to the chemical work generally performed by the State, on which I would like to make a few remarks. In the brief review I have given of the growth of the chemical work undertaken by the State Departments, it will have been noticed that the procedure followed in the establishment of the different laboratories has been that of decentralisation. Originally the Government Analyst's laboratory conducted the whole of the chemical work required by the State. As the requirements grew, and the work increased in volume with the development of the mining, pastoral, and agricultural industries, the work was split off from the original laboratory and separate establishments were created. In the same way the increase in the work of the Customs and the Explosives Department has led to the establishment of separate laboratories. This procedure is the reverse of that which has prevailed in other countries where the tendency has been towards centralisation and concentration under one control. In England the various Government laboratories dealing with medico-legal investigations, public health, and agriculture have been amalgamated within the last 15 years in the Government Laboratories at Somerset House under the direction of Professor Thorpe.

Our system of splitting up the work does not, I conceive, necessarily imply greater efficiency, and is certainly not as economical as would be the maintenance of a single establishment. I would go even further, and would like to see established a central scientific institute where all the scientific work (not the chemical alone) now conducted in the separate departments would be carried on. From the standpoint of economy there can be no comparison between this and the present system. The number of laboratories with their separate maintenances would be reduced to one. The routine work would be performed with the same efficiency as at present and with no danger of its being duplicated. But the principal advantage to be gained would be the facilities it would afford for research work, which has now to be undertaken always at the risk of neglecting the routine work. Further than that there will be the advantage that definite schemes of investigation of subjects of importance to the community could be systematically carried out, and this applies more especially to investigations which require the co-operation of more than one branch of science.

There are many very important problems that await solution in such domains for example as those of public health, stock, and agriculture, the solutions to which require long and systematic investigations to which it is impossible for the scientific officers in these departments to devote themselves, whilst the routine and administrative part of their work claims so much of their time. With a scientific institute such as I have sketched, investigations of this kind could be placed in charge of qualified men who could devote their whole time and energy to their solution.

Even if it were not considered feasible to establish such an institute at the present time, much might be done to consolidate scientific work and increase its efficiency by the creation of a controlling Science Department, which would administer the different scientific establishments now under separate departmental control.

The results which would shortly be obtained by the labours of such an administrative body, would also impress the public with the value of properly directed scientific work, and lead to a demand for better and more accessible instruction in science, and would assist the material prosperity of the country as nothing else could. For, after all, however much legislation may favour or hinder commerce and industry, the pre-eminence of a country in this regard depends finally upon the energy and the intelligence of its people, and it is in the facility given to scientific research and the diffusion of scientific knowledge that the real foundation of the future prosperity of a country depends.

On the ABSENCE of GUM and the PRESENCE of a NEW DIGLUCOSIDE in the KINOS of the EUCALYPTS.

By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, June 1, 1904.*]

This paper is the first of a series which will deal principally with the tannins and allied substances occurring in the kinos of the Eucalypts. The difficulties experienced in dealing with such a diverse group of substances as Eucalyptus exudations, were considerably simplified by the researches on the essential oils of the genus, and it is now felt that a systematic order and natural arrangement governs Eucalyptus kinos, similar to that previously shown to exist in the oils. The results, so far obtained, strongly support the idea of evolution for the whole genus, as has already been advanced by Mr. Baker and myself.[1]

It has been possible to undertake a systematic investigation of a considerable number of these exudations or kinos, because the Technological Museum is now in possession of, perhaps, the most extensive collection of these kinos, true to name, ever got together. These have been collected very largely by the Museum Botanical Collector Mr. W. Bäuerlen, a few have been obtained from correspondents, and the remainder have been collected by my colleague Mr. R. T. Baker (to whom I am indebted for botanical assistance), by Mr. J. H. Maiden, and by myself. It is not proposed to embody the general results in these papers, but only those having a scientific or economic bearing, the study of which will help considerably towards increasing our knowledge of these very interesting substances, so peculiar to Australia.

If the statements given in the Encyclopædia Britannica (ninth edition), in reference to Eucalyptus kinos, be taken as a fair sample of the general knowledge respecting these exudations, it is seen how meagre and unsatisfactory this information is. The following quotation will illustrate this:—"according to Wiesner[2] of Vienna, Australian kino contains a little catechin (a statement doubted by Fluckiger) and pyrocatechin, no pectinous matter but a gum nearly allied to that of Acacia." I shall eventually show that gum does not appear to be present in any Eucalyptus kino.

In a series of papers by Mr. J. H. Maiden, F.L.S., published in the Proceedings of the Linnean Society of New

[1] Research on the Eucalypts especially in regard to their essential oils, p. 16.

[2] Zeitschr. d, allg. Oest. Apotheker, Vereines, abst. Pharm. Journ. [3] 2, 102.

South Wales for 1889 and 1891, it was shown that Eucalyptus kinos can be divided roughly into groups, judged by their physical appearance, and by their behaviour in water and alcohol. He there divides them into three classes, the Turbid, the Ruby, and Gummy groups. As gum is absent in these kinos, the gummy group of course cannot stand, and for various reasons it would be advisable to discard the turbid group also. This general grouping has perhaps served its purpose by directing attention to their marked differences, but it would not be advantageous to future study, if this arrangement were longer retained, and no useful purpose would be served by so doing. There are several tannins in the Eucalyptus kinos, and the astringent principles of these exudations, together with the other allied substances, must necessarily be the dominant feature governing their classification, and the arrangement thus becomes purely a chemical one.

The numerous constituents isolated from Eucalyptus oils were found to have a gradual increment, until the maximum was reached in certain species. So it is with the kinos, and most of them are, therefore, a mixture of various tannins and allied substances, and there is no line of demarcation sharply separating one class from another. Even the distribution of the kinos in the plants themselves is not similar; in some of the "Ironbarks," for instance, as *E. crebra* and *E. sideroxylon* the kino is largely distributed throughout the bark itself, and consequently this is often charged with it, and then has some value for technical purposes, as in tanning. In the "Stringybarks" the astringent substance appears to be largely contained in the timber. It is worth notice also, that the inner layer of the bark of most of the true[1] "Stringybarks" contains

[1] This term is used to distinguish these trees from such a species as *E. resinifera* (one of the Mahoganies), whose bark is also a "Stringybark" in character, but the kino is allied to that of the "Ironbarks."

a yellow substance, perhaps identical with myrticolorin, the dye material of which is quercetin and the sugar glucose. In several other species of eucalypts the kino is distributed almost entirely throughout the timber, and tannin hardly occurs in the bark. This I have already shown in my paper on the saccharine and astringent exudations of the "Grey Gum" *E. punctata*.[1] The kinos occurring in the timber of this latter group usually contain crystallisable substances, as eudesmin, aromadendrin, etc., which appear to be quite absent in those exudations derived principally from the bark, as in the "Ironbarks." It is thus seen that the location governs, to a certain extent, the constitution of the kino in any particular eucalypt.

The tannin dealt with in this paper is that found in the kinos occurring largely in the bark of these trees, and it is in these kinos that the constituent, which has previously been looked upon as gum, occurs in greatest abundance. The peculiarity of being largely precipitated from a strong aqueous solution by alcohol, together with its practical insolubility in that substance, seems to have been the only reasons for considering it to be gum. During my work on these kinos, now extending over a considerable period of time, it became necessary to determine the class of carbohydrates to which this supposed gum belonged. The results were somewhat startling, because it was found that this particular substance is a peculiar tannin diglucoside and not gum.

The fresh kino of *Eucalyptus paniculata* was taken for the investigation, because it is typical of this class of kinos, is readily soluble in water, and consists almost entirely of the glucoside. The species is also common in the immediate neighbourhood of Sydney, and it was thus possible to collect in quantity the freshly exuded kino. The eucalypts whose

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[1] Roy. Soc. N. S. W., Aug. 1897, p. 177.

kinos contain this glucoside are somewhat numerous; it is present in a maximum amount in such species as *E. sideroxylon*, *E. crebra*, *E. siderophloia* and *E. paniculata*, or those known as "Ironbarks" generally, and consequently the kinos from these trees are practically insoluble in alcohol, and for this and other reasons useless for tinctures; but in some species in which it can be detected, the greater portion of the kino is soluble in alcohol, the glucoside not being present in sufficient amount to render the kino insoluble. This again is characteristic of the chemical products of Eucalyptus species generally, each one having diminishing constituents in some direction.

Besides the insolubility in alcohol of this kino glucoside, its peculiarity is shown in another direction, as the sugar consists of a substance probably isomeric with melibiose—that portion of Eucalyptus sugar, originally named eucalyn, which is split off from levulose when melitose (raffinose) is heated with dilute acid—the only difference apparently being that it is inactive to light. This affinity is shown by the melting point of its osazone, and by the fact of this being entirely soluble in hot water. The sugar is also slowly but entirely fermented by yeast. According to E. Fisher, the osazones of the simple glucoses are all insoluble in hot water, the diglucoses, however, such as lactose, gave an osazone soluble in hot water. Several different samples of the osazone were obtained from the sugar, but in no instance did the melting point exceed 178° C., the simple glucoses thus appeared to be absent. C. Scheibler and H. Mittelmeier in a paper on the inversion products of melitose,[1] show that the osazone of melibiose melts at 176 – 178° C., and that it is soluble in hot water. They also show that the complete inversion of melitose requires protracted heating with sulphuric acid.

[1] Ber. 22, 1678 – 1686.

When a glucosidal Eucalyptus kino is hydrolised by boiling with sulphuric acid a "kino red" is formed in quantity, and the sugar appears to be scarcely changed into simple glucoses at this stage, because only a trace of an osazone insoluble in hot water was formed from it when thus separated.

It thus appears probable that this tannin diglucoside, found in those Eucalyptus kinos which occur principally in the bark of certain species, takes the place of melitose found in those barks (*E. punctata* for instance) in which the tannin does not occur in sufficient amount to form a compound with the sugar present. Besides the tannin in the kinos of this group is different.

There appears to be no record that melitose (Eucalyptus manna) has ever been found on any species of Eucalyptus the kino of which contains this tannin diglucoside, nor on any species whose kino contains an identical tannin, but which is free from sugar in combination. This suggests the idea that melitose itself may be a glucoside, in which a member of the glucose group takes the place occupied by the tannin in the diglucoside. E. Fisher and E. F. Armstrong have synthetically prepared[1] several disaccharides, as

Glucosidogalactose
Galactosidoglucose
Galactosidogalactose

which have the properties and behave like glucosides. A similar combination may perhaps be produced with the sugar of these kinos and the necessary member of the glucose group to form melitose, attempts in this direction will eventually be carried out.

The tannins occurring in this glucoside, and also that of the kinos of the "Stringybarks," as *E. macrorrhyncha* etc.,

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[1] Ber. 1902, 35, 3144.

and of the "Peppermints," as *E. dives* etc., as well as in a few others, appear to be identical substances, and have probably the same structural formulæ. The "kino red" formed from all these had identical dyeing properties with mordanted cloth, and when fused with potash all gave protocatechuic acid and catechol; phloroglucinol was not formed by this method. The tinctures of the kinos of all these groups gelatinized with equal rapidity, and all gave very similar reactions with reagents which act on the tannin alone, except with ferric chloride.

It may thus be supposed that one of the hydrogen atoms in one of the hydroxyl groups belonging to a catechol nucleus, is replaced in the kinos of the "Ironbarks" particularly, by one Eucalyptus sugar residue, thus forming the tannin diglucoside. In the "Stringybarks" and the "Peppermint" kinos this sugar appears to be absent, and my discovery in one of the "Stringybarks" (*E. macrorrhyncha*) of the glucoside myrticolorin, the sugar of which is glucose, also points to this conclusion.

The sugar in the tannin diglucoside appears to protect the tannin molecule from that alteration common with the "Stringybark" and "Peppermint" kinos, because no matter how long the kinos of the "Ironbarks" are kept, they retain their ready solubility in water almost unimpaired, but when the same tannin is free from the sugar, change commences at once after exudation, and although but little coloured when freshly exuded, yet, as the phlobophenes form the kinos become darker and less soluble in water and alcohol, and after many years they are almost black and insoluble. By investigating, therefore, a freshly exuded non-glucosidal kino containing this particular tannin, and also free from the other tannins of these kinos, it may be possible to work out the structural formula for the tannin of the whole class of these kinos, glucosidal and otherwise. At present the kino of *E. pilularis* seems a desirable one for this purpose.

It will also be necessary to obtain a quantity of the sugar by the decomposition of the glucoside, so that its chemistry may be determined. So far as this investigation has gone, it appears that as the sugar is inactive to light it cannot be that portion of the melitose molecule known as melibiose, because that is dextrorotatory. C. Scheibler and E. Mittelmeier (*loc. cit.*) show the final inversion products of melitose to be as follows:—

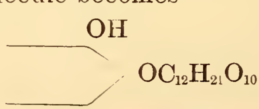
$$C_{18}H_{32}O_{16} + 2\ H_2O = \underset{\text{Galactose}}{C_6H_{12}O_6} + \underset{\text{Dextrose}}{C_6H_{12}O_6} + \underset{\text{Levulose}}{C_6H_{12}O_6}$$

but that it first splits up into

$$\underset{\text{Melibiose}}{C_{12}H_{22}O_{11}} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

As the sugar of the glucoside is inactive to light, it is supposed that the optical activity is neutralised by internal compensation. If this is so, then levulose probably forms a part of the original molecule of the first formed portion of Eucalyptus sugar. The osazone being identical with that obtained from melibiose may not influence the result, because it is well known that several distinct sugars give identical osazones.

The products formed from the "kino red" by fusion with potash is protocatechuic acid, and this indicates that two hydroxyls in the tannin molecule are in the ortho position relatively to each other, and as the product is the same with the non-glucosidal tannin, the sugar probably replaces the hydrogen atom in one of these hydroxyls, so that this portion of the molecule becomes



That the amount of sugar present represents a diglucose is indicated in two directions, assuming of course a probable value for the tannin molecule, first by the actual amount of sugar and "kino red" obtained, and secondly by the relative astringency value of kinos containing a maximum amount of the glucoside, when compared with that of the non-glucosidal kinos containing the same tannin.

The name *Emphloin* is proposed for this Eucalyptus kino diglucoside, because of its being ostensibly a bark product, which often accurs in great abundance throughout the bark of certain species. I would like to reserve to myself the further investigation of the sugar.

Experimental.

The glucosidal kinos of the "Ironbarks," of which that of *E. paniculata* may be considered a type, are, when freshly exuded, transparent, and of a red garnet colour, but become much darker after exposure to light and air. They are exceedingly tough when fresh and air dried, but become less so by age, and are very brittle and readily powdered when the water has been driven off. They usually contain about 18 to 20 per cent. of water, but a little more when quite fresh. The "Ironbark" kinos consist almost entirely of the glucosidal tannin; this is shown by the relative astringency of the original kino, and of the purified glucoside; also by the colour reactions with ferric chloride, all of which indicate the absence of but a small amount of free tannin.

Astringency value of kino, *E. paniculata* containing 22·78% water = 412.

Astringency value of purified glucoside containing 11·75% water = 423.

Glucoside corrected for 22·78% water = 371.

Reactions with reagents.—After experimenting with a number of reagents, I have chosen the following, as being apparently, of the greatest value for discriminative purposes between the several groups and tannins of Eucalyptus kinos.

1. Ferric chloride.
2. Ferric acetate.
3. Bromine water.
4. Iodine in potassium iodide.
5. Potassium dichromate.
6. Cobalt acetate.
7. Zinc acetate.
8. Uranium acetate.
9. Calcium hydrate.
10. Cupric sulphate and afterwards ammonia in excess.

Lead acetate was of little value because it gave identical precipitates in solutions of all kinos.

The solutions of the kinos were all one gram per litre, and all reactions given in this and subsequent papers are with that strength, excepting those with the ferric salts, as these reagents gave reactions more delicate and distinctive when the solutions were further diluted to 1 of kino to 2 parts water, adding one drop of a strong solution of the ferric salt and allowing this to fall through the solution in test tube without agitation. With the kinos of the "Ironbarks," and also with the glucoside, ferric chloride gave a brown-grey coloration becoming much lighter on standing, and a dirty brown-grey flocculent precipitate was deposited after some hours. With ferric acetate, however, the colour was blue with a tinge of violet, and a dense dark blue precipitate quickly formed; this reaction is identical with that given by the kinos of the "Stringybarks" and the "Peppermints" with either ferric chloride or ferric acetate, and it is thus evident that the sugar combination prevents the reaction with ferric chloride, although not with ferric acetate.

The purified glucoside did not give precipitates with either 3 or 4 and the "Ironbark" kinos gave only traces, due evidently to the small amount of free tannin which they contain, because the "Stringybark" kinos all give dense precipitates with these. The glucoside gave similar results in every other respect with the original "Ironbark" kino. The kinos of the "Stringybarks," etc., and the "Ironbarks," as well as the glucoside, gave precipitates and behaved similarly with 5, 6, 7, 8, and 10, although with 5 the precipitate with the glucosidal kinos was longer in forming. With 9 the "Ironbark" kinos gave a pinkish colour and a pink-brown precipitate, the "Stringybark" kinos giving a purplish colour and a purple-brown precipitate. With 10 at first a greenish precipitate, and on adding ammonia in excess a dense dark brown flocculent precipitate was obtained.

Preparation of the glucoside.—About half a pound of the freshly exuded kino of *E. paniculata* was dissolved in the smallest possible quantity of water, it was strained through cloth and to the clear liquid about 3 litres of alcohol added and allowed to stand over night. The precipitate had then separated as a solid somewhat dark coloured cake. The alcohol was removed, the cake broken up, washed in fresh alcohol, dissolved in the smallest quantity of water and again precipitated by alcohol. This process was repeated for the third time, and although the alcohol was scarcely coloured, yet the precipitate was somewhat dark and this was difficult to remove even by boiling with animal charcoal for a long time. The precipitate was finally dried at a low temperature and powdered. When heated at 100° C. it darkened considerably. The powder as thus prepared was of a cinnamon colour, had scarcely any odour, was astringent to the taste, was readily soluble in cold water, but quite insoluble in alcohol and in ether. Attempts to remove it from solution by solvents were not successful. It gave reactions similar to those of the original kino, and was entirely precipitated from solution by gelatin, separating well if a trace of alum was added; the original kino, of course, acted similarly. When boiled with dilute acid the solution soon changed to red, and after continued boiling a copious deposit of a "kino red" was obtained. This had dyeing properties and gave a series of browns with mordanted cloth. To the filtrate from the "kino red" basic acetate of lead was added in excess. The excess of lead in the colourless filtrate was removed by sulphuric acid, the filtrate neutralised and boiled with Fehling's solution; a copious precipitate of cuprous oxide was obtained. The substance in the kino precipitated by alcohol was thus shown to be a glucoside.

Composition of the glucoside.—One gram of the powdered glucoside, containing 11·75% of water, was boiled for six hours with dilute sulphuric acid. The "kino red" which separated on standing over night was filtered off, washed, and dried at 130° C. The amount obtained was 0·4733 gram equal to 47·33%. The acid was removed by carbonate of barium, the small amount of tannin in solution by basic acetate of lead, and the excess of lead by sulphuretted hydrogen. The sugar in the filtrate was heated in water bath until constant in weight; this took several hours, and slight decomposition had taken place as indicated by the darkening and strong caramel odour. It is also doubtful whether it had been rendered perfectly anhydrous. The amount was 0·4447 gram or 44·47%. As one molecule of water of hydrolysis had entered into the calculation the decomposition was apparently fairly complete, so that the general results indicate that two molecules of a glucose are present. A larger amount of the glucoside was then boiled in dilute sulphuric acid for six hours and the sugar prepared as above. When treated with yeast and inverted over mercury it slowly fermented, much more quickly when the temperature was raised to 28° C. or 30° C. When prepared for the polarimeter the sugar was found to be without rotation.

Preparation of the osazone.—The osazone was prepared by heating on the water bath with phenylhydrazine in dilute acetic acid, but owing to its marked solubility in acetic acid it was difficult to prepare in quantity. The osazone was a yellow crystalline powder, soluble in hot water but separated again in microscopic crystals on cooling. It was somewhat soluble in alcohol and ether-alcohol, but did not dissolve readily in either ether, benzene or chloroform. It melted at 176 – 178° C.

Decomposition of the "kino red" by caustic potash.—A portion of the "kino red" obtained from the kino of *E. paniculata* was fused with 10 times its weight of caustic potash, adding a little water, and heating for half an hour at 150 – 170° C. The melt, which was of a very dark brown colour, was dissolved in water, acidified with sulphuric acid and extracted by ether. No volatile acid was detected when the solution was acidified. On evaporating the ether a crystalline substance was obtained; this was dissolved in water, acetate of lead added in excess, and the precipitate removed. The filtrate was acidified with sulphuric acid and extracted by ether, but only the merest trace of a substance was obtained and this did not give the reaction for phloroglucinol. The lead precipitate was decomposed by sulphuric acid, filtered, and extracted by ether. The ether on evaporation gave a well marked crystallised mass which when purified from water melted at 195 – 197° C., and gave all the reactions for protocatechuic acid, which acid it evidently was.

The "kino red" obtained in a similar manner from the kino of *E. pilularis*, and from two or three other species belonging to this class, all gave identical results with the above when fused with caustic potash.

Astringency values of the kinos.—After several trials the following method was adopted, and the values taken on the air dried kinos of nearly 100 species of Eucalyptus. The astringency value of some of these is very low, but these will be dealt with in a subsequent paper. The following solutions were prepared:—

1. Indigotin 5 grams and sulphuric acid 50 grams per litre, and filtered through paper before using.
2. Potassium permanganate 1 gram per litre.
3. Kino (carefully picked) 1 gram per litre.
4. Gallo-tannic acid 1 gram per litre.
5. Standard colour solution.

The kinos were dissolved by heat if necessary. 10 cc. of the kino solution was added to 20 cc. of the indigotin in $\frac{3}{4}$ litre of water contained in a large beaker, and titrated with the permanganate. The end reaction was best determined by placing a beaker alongside, of the same size as the one containing the tannin, and holding the same amount of liquid which was coloured to the exact yellow-green tint given by the indigotin solution when changing from the greenish tint to the yellowish one. This tint was easily adjusted by using the green solution obtained by boiling a few drops of alcohol with potassium dichromate solution, together with a solution of potassium chromate. The titration was carried out before a window with a good light, and the end reaction determined by looking through the liquids towards the light; one drop of permanganate was sufficient at this stage to bring about a readily detected change of colour. The permanganate was always added in the same manner. The astringency value of gallotannic acid containing 14·43% water was taken as 1000, and on this basis the following results were obtained:—

Eucalyptus pilularis	containing	18·32%	water	= 838
E. macrorrhyncha	,,	18·06%	,,	= 835
E. eugenioides	,,	18·10%	,,	= 811
E. paniculata	,,	20·25%	,,	= 423
,,	,,	22·78%	,,	= 412
E. siderophloia	,,	20·28%	,,	= 459
E. sideroxylon	,,	19·46%	,,	= 459
E. crebra	,,	18·77%	,,	= 470
Glucoside	,,	11·75%	,,	= 423

It is thus seen that the kinos of the "Ironbarks" have only about half the astringency value of the other three kinos, although the tannin appears to be the same in all of them.

Tanning value by hide powder.—The ready and entire precipitation of the tannin of the glucosidal kinos by gelatin, makes it difficult to understand why it is that the tannin is not more readily absorbed by hide. The technical difficulty of the sluggishness of "Ironbark" liquors has long been known, but no scientific explanation has been advanced to account for this peculiarity. The reason is now apparent that it is the glucosidal nature of the "Ironbark" kinos (the kino being the principal tanning agent) that causes the unsatisfactory behaviour of this tanning material. To overcome this difficulty and thus make the tannin of the bark of *E. sideroxylon*, for instance, available for rapid absorption by hide, it will be necessary to devise some method of hydrolising the glucoside while in the pits, perhaps by means of an enzyme or corresponding substance.

The following results were obtained with the kino of *E. paniculata*, and from which it is apparent that when pure, the tanning action of "Ironbark" kino is particularly slow. Ten grams of air dried kino containing 2·025 grams of water and 0·064 gram bark and residue, were dissolved in 800 cc. of water, so that 100 cc. contained 0·989 gram solids. The solution was then passed through a column of hide powder by the method adopted in tannin determination by this process, when it was found that 100 cc. contained 6·8 grams, therefore 7·911 − 6·8 = 1·111 gram, or 11·11% of the ordinary kino was absorbed by hide powder, or 14·04% on the anhydrous kino. The residue thus obtained had all the characteristics of the original kino, and did not differ from it in any respect.

On some NATURAL GRAFTS between INDIGENOUS TREES.

By J. H. Maiden, F.L.S.,
Government Botanist and Director, Botanic Gardens.

[With Plates I., II.]

[*Read before the Royal Society of N. S. Wales, June 1, 1904.*]

Some months ago, Mr. R. Chappelow of George's River, near Oatley, brought to me a fragment of wood bearing a rough and a smooth bark. On following the matter up he brought to me the remarkable specimen which I exhibit to-night. It is a composite log of timber showing the smooth bark and the red wood of White Gum (*Eucalyptus hœmastoma*, Sm. var. *micrantha*, Benth.) and the fibrous bark and pale brown wood of Stringybark (*E. capitellata*, Sm.)

The facts concerning the log are these: they were collected by Mr. J. L. Boorman, Collector, Botanic Gardens, on my behalf :—"There was originally a Stringybark tree, hollow with age and the top had disappeared. From near the bottom a sucker of the old tree had sprung up, inside the tree. Inside, presumably springing from a stray seed, a young White Gum had also grown. So that there were two young trees, a Stringybark and a White Gum, the old Stringybark serving as a "pot." In process of time the young trees became "pot-bound" and the two young trees became squeezed together and finally fused."

A few weeks afterwards Mr. C. T. Musson, of the Hawkesbury College, Richmond, published in the College Journal of the 18th January last, an account of a natural graft to be seen on the farm. Out of a tree of *Eucalyptus tereticornis*, Sm.,[1] there is growing a smaller tree of *Angophora subvelutina*. This natural graft is in rather a bad way, and will apparently not live long. Mr. Musson furnished the following very interesting report to the Principal who has been kind enough to favour me with it: "It appears to me that a seedling *Angophora subvelutina* started in a hollow made by a branch of the Eucalyptus breaking, and that the roots eventually reached the ground. he eucalypt is splitting where the Angophora is thickest; *i.e.*, where it comes out of the surrounding gum trunk. That part of the Angophora which is seen has expanded somewhat close to the point of attachment where seen, after the manner of a girdled tree.

"With regard to the species of Eucalyptus it appears to me to be the Cabbage Gum (*E. tereticornis*), but as there are no fruits or buds, and as the leaves are mostly the result of dormant buds developing and thus mostly are of the sucker type, I am not sure." (I have confirmed the determination, with the result stated in the foot note).

It is not proposed to disturb the graft at present and therefore it cannot be stated whether the woods of the two trees are in absolute organic union as they are in the specimen first described. It may be pointed out that Mr.

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[1] It is a "Swamp Gum" and is provisionally referred to var. *latifolia*, Benth. It is the *E. amplifolia* of Naudin.

Musson's specimen is especially interesting because two different genera are concerned in the graft.

I have called this a "natural graft." Maxwell Masters in his *Vegetable Teratology* speaks of this adhesion of the axes of plants belonging to different species as of rather rare occurrence. The adhesion of two individuals of the same species is not rare. We are of course familiar with the amalgamation of the woody tissues of our Mistletoes (*Loranthus*) and their numerous hosts.

Masters quotes Moquin Tandon, where "by accident a branch of a species of *Sophora* passed through a fork made of two diverging branches of an Elder (*Sambucus*). The branch of the *Sophora* contracted a firm adhesion to the Elder, and what is remarkable is that, although the latter has much softer wood than the former, yet the branch of the harder wooded tree was flattened, as if subject to great pressure."

"It is possible that some of the cases similar to those spoken of by Columella, Virgil,[1] and other classical writers, may have originated in the accidental admission of seeds into the crevices of trees; in time the seeds grew, and as they did so, the young plants contracted an adhesion to the supporting tree."[2]

This is obviously the case with Mr. Musson's specimen; the origin of my George's River specimen is not quite similar.

Reverting to the George's River specimen, the fact is evident that the woods and barks of two different species have adhered to each other, have fused in fact, and the different textures of the barks and the different colours of the woods enable us to note the organic union very readily.

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[1] Daubeny, "Lectures on Roman Husbandry," p. 156.

[2] Masters' "Vegetable Teratology," p. 56.

We have indeed a composite log, but the timbers are joined together by an art transcending that of the most skilful woodworker. The union appears to be nearly as complete as if the log were homogeneous and the result had been arrived at by staining. And yet, looking more closely at the specimen, one observes the lack of continuity of the kino rings which are very abundant in the red wood (*E. hœmastoma*) both in the mature and sap wood, but which largely cease at the junction with the pale wood (*E. capitellata*). That there is organic union between the two timbers is borne out, not only by their obvious fusion, but also by the fact that the red wood "runs" here and there into the paler timber as if the woody fibres, pigmented by red colouring matter (perhaps phlobaphenes or other tannin derivatives), had lent some of their colouring matter to the fibres of the paler timber with which they are in close juxtaposition.

An anatomical study of the wood at the line of junction might throw light upon the relations of the cells and vessels of the two timbers at their points of contact, and I hope some one will make the examination. I suppose the sections would have to be treated as opaque objects unless we are fortunate to find a similar natural graft at a far earlier stage. Obviously the fusion is analogous to the artificial union of parts which occurs in grafting and budding. But in his important paper[1] Shattock but cursorily alludes to the subject.

Since the above was written, the Hon. Dr. Nash, M.L.C., has informed me of the case of a natural graft between a White Gum and an Ironbark at Wallsend near Newcastle, and it is hoped that further instances may be observed and recorded.

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[1] "On the reparative processes which occur in vegetable tissues," by Samuel G. Shattock, Proc. Linn. Soc., XIX., 1.

Explanation of Plate.

Plate 1—Composite log of White Gum and Stringybark. The line of demarcation between the smooth bark of the White Gum and the fibrous bark of the Stringybark is evident; the letter A has been repeated four times to roughly show the line of demarcation of the two woods, which is very evident in the original or in a coloured drawing.

Plate 2—The dark coloured stem of an Apple-tree (*Angophora*) growing out of the smoother, paler trunk of a Swamp Gum (*Eucalyptus tereticornis*). [C. T. Musson, photo.]

POSSIBLE RELATION BETWEEN SUNSPOTS AND VOLCANIC AND SEISMIC PHENOMENA AND CLIMATE.

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(Communicated by Prof. T. W. E. David, B.A., F.R.S., etc.)

[*Read before the Royal Society of N. S. Wales, June 1, 1904.*]

Part I—Possible Relations between Sunspots, Earthquakes and Volcanic Eruptions.

SYNOPSIS;

I. *Introduction.*—The present paper is a sequel to my note communicated to this Society on June 4th, 1902

Since that time I have succeeded in collecting numerous facts which throw further light on the question and strengthen my former conclusions.

Since 1902 the frequency and violence of earthquakes and eruptions have declined almost to a minimum; at the same time there has been a marked rise in solar activity. The last sunspot minimum occurred approximately at 1901·8, but the total spotted area was in 1902 lower than in 1900. The previous cycle was a long one, lasting from 1889·3 to 1901·8, or 12·5 years. The maximum occurred in 1893, after a period of increase in sunspot activity lasting only 4·3 years. The period of decrease was long, lasting 8·2 years.

The mean spotted area as given in the Monthly Notices Roy. Astr. Soc. was in the minimum year 1901 only 29 millionths of the sun's disc (corrected for foreshortening) as compared with

111	millionths	in 1899
75	,,	,, 1900
62	,,	,, 1902

From September 18th, 1902, spots began to appear regularly on the sun's disc, while violent earthquakes and volcanic eruptions became of much less frequent occurrence. The chief outbursts of volcanic and seismic disturbances since that time were at the September Equinoxes of 1902 and 1903, the Santa Maria eruptions in November 1902, and the Andijan earthquake in December 1902. The compilation (Appendix II.) shows that 1903 was, as compared with 1902, a very quiet year. This was only to be expected if the theory advanced in my previous paper holds true.

II. *Causes of Earthquakes.*—Milne in his "Earthquakes"[1] states that the *primary* causes of earthquakes are telluric

[1] Vol. LVI., International Scientific Series.

and solar heats, and variations in gravitational influences. As due to *secondary* causes, he mentions the following classes of earthquakes:—

1. Those due to faulting.
2. Those due to explosions of steam.
3. Those due to volcanic evisceration.
4. Those due to chemical degradation.
5. Those due to effect of oceanic tides.
6. Those due to variation in barometric pressure.
7. Those due to fluctuations in temperature.
8. Those due to rain and snow.

1. Loss of telluric heat leads to secular contraction, and this latter process brings about normal faulting. In regions where radial exceeds circumferential contraction it brings about overthrust faulting as well. Reverse and overthrust faults are, however, more frequently due to the expansion, folding and contortion of strata, resulting from rise of isogeotherms in heavily sedimented areas. Both varieties of faulting may be said to be primarily due to the constant exchange of heat between the hot core of the earth and its outer shell, and again between the earth's crust and space.

Since it has been shown probable (see my previous paper and Part II of this), that the earth receives more heat from the sun in sunspot maximum periods than in minimum periods, it is apparent that sunspot effect must vary in accordance with the geological nature of particular regions. When most heat is received from the sun radiation into space is checked, and secular contraction is delayed. At the same time, in regions undergoing heating from within, consequent upon the rise of isogeotherms, the thermodynamic processes might be accentuated.

In areas like Japan, Java and Argentina, where many districts are undergoing slow elevation, summer earthquakes are more frequent than winter ones, for the reason just stated, and similarly, seismological and volcanic disturbances might be expected to increase in number and violence in sunspot maximum years.

On the other hand, in regions like parts of North America, Australia, Central Asia and the European continent, where elevation of land by rise of isogeotherms has ceased, and any changes of level may naturally be ascribed to *isostasy*, winter earthquakes are commonest. Denudation and the consequent unloading hasten secular cooling, and contraction goes on most rapidly in periods when least solar energy is received in compensation for heat radiated into space.

2. Earthquakes due to steam explosions are apparently very often the result of the opening of a fissure admitting water to reservoirs of hot magma. The frequent earthquakes in Japan of this nature[1] are due to faulting in the great geosyncline to the east of Japan. Sometimes, no doubt, water accumulates by capillary infiltration for years, and is transformed to steam by hot magmas. The steam under pressure filling a cavity in the earth would be most likely to explode during the passing of a great cyclone at the earth's surface. The gravitational influence of the sun and moon could also play the part of a liberating force enabling the imprisoned vapours to burst through. Meteorological and gravitational forces must have greatest influence where large masses of steam and gas are contained in subterranean reservoirs. As "Mathematicus" writes in the "English Mechanic"[2]:—"No solar or lunar influence, lasting only some hours, can move the magma to rise thirty or forty miles in a narrow channel, whose friction alone would keep the *thick*, *adhesive*, fluid back. But gases acting during many years, heated to thousands of degrees, and cooped up between the clumps of magma,

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[1] See "Earthquakes" by J. Milne, pp. 228 and 281.

[2] "English Mechanic and World of Science," No. 1951, Aug. 15, 1902.

perhaps *forming* among them, as the gases from burning powder between the projectile and the breech of the gun, might do it."

3. Earthquakes resulting from volcanic evisceration are not very frequent. Trough faults like the great Rift Valley[1] may owe their origin to volcanic extravasation, but even in areas thus undermined, the actual collapse is most likely to take place when cooling proceeds most rapidly, as at sunspot minima, and the cohesion of rock strata thereby overcome. Closely allied are earthquakes connected with the intrusion of sills and laccolites, as the Port Resolution uplifts in island of Tanna, New Hebrides, in 1878 and 1888.[2]

4. Earthquakes due to chemical degradation are rare, and are mainly confined to districts in which there are rocks of a soluble nature, such as gypsum, rocksalt or limestone. Molten lava, says Milne ("Earthquakes," p. 283) may by chemical action eat out great hollows in volcanic regions. Earthquakes and landslips dependent on the first kind of chemical degradation (*e.g.*, that which in 1840 caused Mt. Cernans in the Jura to fall) would take place in wet periods; those dependent on the corrosive properties of molten lava would be most likely to occur at times when other secondary causes are in full operation; thus the sudden expansion of heated vapours and gases consequent on fall of barometric pressure at the earth's surface would induce the corrosive magma to well out of its vent, and on the return of normal atmospheric conditions the spot is weakened and rendered liable to collapse.

5. Changes of atmospheric pressure in themselves, and changes of the gravitational influence of sun and moon, are

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[1] See Prof. Gregory's work "The Great Rift Valley," Part III., Ch. XII., pp. 214 - 236.

[2] See "Report of Aust. Assoc. for the Advancement of Science" for 1893 p. 209.

causes quite insufficient singly to cause seismic disturbances. Still several of these secondary causes co-operating might perhaps cause an earthquake, or one of them alone might, in a somewhat unstable region, precipitate seismic disturbances. Temperature changes indirectly also play a small part in seismology. It has been noticed that in temperate and arctic regions more earthquakes occur in winter than in summer. This may be due in some parts to secular cooling proceeding more rapidly, in other parts to the heavy loading of the earth with ice and snow.

In my paper, read before this Society on June 4th, 1902, I gave an account of work done by various physicists, meteorologists and astronomers on the subject of sunspots and their meteorological and magnetic effects. I advanced in my paper that sunspots likewise bear a relation to seismic and volcanic disturbances. At the same time Sir Norman Lockyer advocated similar views in England. In a letter to the *Times*, May 19th, 1902, Sir Norman Lockyer writes that earthquakes and eruptions are most frequent at sunspot *minima and maxima.* My view was, and is, that these phenomena are at a maximum when sunspots are at a minimum, although from my later researches it seems that at sunspot maxima there sometimes is a violent and spasmodic outburst of volcanic violence. I wish here to investigate more fully than before the reasons of the interdependency of these terrestrial and solar phenomena.

The great objection to the sunspot theory of seismic and volcanic disturbances is the fact that rocks conduct heat at a very slow rate. Rocks are also impenetrable to electrical waves, Hertzian waves, etc. The annual variations of earth temperature at a depth of thirty feet are almost nil. Hence, assuming that we receive more solar energy during sunspot maxima it certainly cannot affect rocks at some depth, if it has to pass thither in the form of heat, or even ordinary electricity. When, however we consider that the earth as a whole behaves as a magnet, and that the earth's atmospheric magnetism is instantaneously influenced by solar prominences, that magnetism, heat and electricity are transmutable forms of energy, and that many ferruginous volcanic lavas are fair conductors of magnetism, it becomes quite feasible that the sun's radiant energy should penetrate the earth's crust rapidly, and once having reached the volcanic foci, be transformed into heat. In order that this transformed energy might again escape, conduction through rock masses, a very slow process, would be essential. As I have already before suggested, there may also be solar rays[1] which are quite capable of permeating rock masses without producing any heating effect until they meet with conditions favourable for their transmutation. Rock masses would then be warmed, not by the direct solar radiation, but by heat conducted from foci within where transformation of energy can take place, a process analogous to the heating of our atmosphere, which is effected chiefly by heat conducted from the earth's surface and not by the direct solar rays.

Increase in the amount of solar heat received by the earth (as at sunspot maxima) may also have the direct effect of checking the leakage of heat from the earth's surface by radiation into space, and this diminution of leakage will tend to check somewhat the outward creep of heat in the earth's crust by conduction. Thus the amount of pent up heat in volcanic foci is increased, its slow escape being hampered. In this way alone can we explain why

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[1] Compare also the recent investigations by the Curies and Rutherford on the penetrating powers of the α, β and γ rays of the new radioactive elements. A recent paper by Sir Norman Lockyer—"Simultaneous Solar and Terrestrial Changes," (*Nature*, Feb. 11th 1904)—will also be read with interest in connection with the above discussion on terrestrial magnetism.

solar phenomena react so rapidly on the magmas of the earth, and the rise of isogeotherms so slowly.

For the purposes of this paper I propose now to classify earthquakes in accordance with the causes producing them.

(1) *Earthquakes caused by the cooling, hence contraction of the contracting zone of the earth's crust.*—These should be of greatest violence and frequency when the earth radiates most heat, or other energy, into space, that is, at *sunspot minima.* The great majority of earthquakes and earthquake shocks undoubtedly fall in this group.

(2) Earthquakes which arise from the heating of strata. Tangential strain and shearing, especially where beds which are suffering a rise of isogeotherms (and consequently expansion and folding) abut on strata undergoing contraction must result in faulting. In parts of Japan, in Java, in parts of the Peruvian and Bolivian Andes, which are regions undergoing elevation from isogeothermal rise, earthquakes of this type are frequent; and in such localities no true earthquake periodicity can be expected. The increase of solar heat during sunspot maxima may accelerate the folding of sedimentary strata by screening the earth from radiation into space. This would result in earthquake shocks. At times of sunspot minima the increased shrinkage of adjoining rock masses would also result in fractures along the lines of weakness of the earth's crust, and the junction of old rocks with recently upheaved and expanding sediments is usually a line of weakness.

The Mendoza earthquake of 1861 was probably the result of rise of isogeotherms in the recently upheaved sediments of the La Plata region.

In the Argentine region sediments were deposited when the Amazon was yet an insignificant stream, and the La Plata drained the Peruvian area. Later on the latter river blocked its southern course with masses of boulders and rolling stones that now are scattered over the Bolivian plain (as at Santa Cruz de la Sierre). Then the Peruvian waters forced their way through the Matto Grosso ranges, and the waters of the Beni joined those of the Madeira, after a flighty leap at the Esperanza Falls.—(" Frem," May 14th, 1899.

(3) Earthquakes connected with volcanic eruptions.—These depend on the same cause as volcanoes which will presently be discussed. They are partly comprised in the class just discussed.

(4) Earthquakes resulting from other causes insufficient in themselves to bring about disturbances, but frequently important liberating forces.—Occasionally two or more of these secondary causes acting simultaneously in a region of great instability, may precipitate an earthquake. Such events as perigee, equinoxes, cyclonic disturbances and the attraction of the planets I would be inclined to consider secondary causes. Under this heading we may also place the earthquakes which are attributed (*a*) to the loading of parts of the earth's crust by sedimentation or organic growth; and those due to (*b*) unloading of portions by subaerial denudation and erosion. The Charleston earthquake of 1886 was probably in no small way connected with the immense sedimentation and organic growth in the Mexican Gulf and in the Atlantic to the south-east of the United States of America. The Cutch earthquake of 1819, and the Cachar earthquake of 1869, were probably due to a similar cause.

The extensive earth disturbances of the year 1811 in Europe, the earthquakes of 1833, 1855 and 1887, the Herzogenrath shocks between 1874 and 1877 and the Rhineland earthquake of 1846 were probably all connected with unloading by denudation, a process which must hasten secular cooling. Hence such earthquakes should be most frequent at sunspot minima.

III. *Sedimentation.*—The importance of sedimentation and rise of isogeotherms in sedimentary rocks as factors in the production of volcanic action is not to be overlooked. We have only to consider the fact that the majority of the earth's active volcanoes at the present time, and several areas of high earthquake frequency are situated on the western shores of the Great Ocean basins, or on strings of islands lying in the western portions of the oceans.

The most notable exceptions are the Alaskan volcanoes and those of the Andes. Off the Alaskan coast, however, sedimentation is going on at a rapid rate, partly by the deposition of the suspended detritus of the great Alaskan rivers, partly from the destruction of organisms by the meeting of a hot and a cold current, the Japan current flowing northwards along the east coast of Japan, and the Behring current flowing southwards from the Arctic Ocean. Volcanic activity in the Andes is dying out, sedimentation on the west coast of South America having been reduced to a minimum; the volcanic cones of the Andes are connected, probably, with a period of sedimentation of no great geological antiquity, when the elevation of the Andean chain was just commencing, and a kind of 'Sargasso' sea existed around Galapagos island.

We have no very definite evidence, as far as I am aware, of great sedimentation having taken place in Tertiary and Post-Tertiary time in the Pacific Ocean around Galapagos Island, yet there are many geological facts pointing that way. In Dall's "Tertiary Mollusca," (Vol. III., Pt. iv., Transactions of the Wagner Free Institute of Modern Science), an interesting discussion on the "Tertiary Fauna of Florida" is given. In this, on p. 1550, it is stated as probable that the Isthmus of Panama was formed and the two Americas were united at the commencement of the Miocene. . . In "The Palæontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California," by

Mr. Ralph Arnold (Memoirs of the Californian Academy of Sciences, Vol. III.) we find on p. 69 that the elevation of California took place in the geological periods from Miocene to Post-Pliocene, and that the Pleistocene Fauna of San Pedro bears a close resemblance to that of Japan, on account of similar geographical conditions at the time. Hill shows in his valuable paper, "Geology of the Isthmus of Panama," (Bulletin, Museum of Comparative Zoology, Vol XXVIII., pp. 95 – 98.) that there was continued sedimentation in the Eocene and Oligocene Epochs, but there is no trace of Miocene or Pliocene sedimentation, a fact which points to the land area being much larger in these periods than now. Hence elevation took place at the beginning of the Miocene. These periods were followed by a Pleistocene subsidence, and lastly a further elevation of at least ten feet. During the Pleistocene subsidence the isthmus was at least partly submerged. To the north of Panama, in Costa Rica and Nicaragua, deposits of Pliocene Age exist, hence there is a possibility that a passage existed then between the Atlantic and Pacific.

If some such strait existed during the Miocene and Pliocene periods, the Atlantic Equatorial Current, instead of being diverted into the Gulf Stream, would pass into the Pacific and meet the cold South American (now Chili) current off the Peru-Ecuador coast, and organisms would die in profusion and fall to the bottom. At this time the Antilles probably was a plain connected no doubt by land with Venezuela and Florida. The highest mountains of South America were the Matto Grosso and Venezuelan ranges. From these long rivers flowed westward into the Pacific. Around Galapagos Island a kind of *Sargasso Sea* existed, caused by the above mentioned currents. From the researches of modern geographers we know also that at no remote geological period, probably in late Pleistocene time, the sea covered the Argentine pampas and the Paraguayan plains. Probably it stretched even further, right across the Bolivian plain, taking in Lake Titicaca and joining on to the Pacific. The final disappearance of Atlantic waters from the pampas took place perhaps about 20,000 years ago.

("*Geografi. Argentina's Tidligste Tilstand*"; see "Frem," published by "Det Nordiske Forlag," May 14th, 1899). Perhaps up to this time remnants of a South Pacific continent may have existed, and additional conditions may have obtained which were very favourable to keep up the heavy sedimentation with which the origin of the Andes and the commencement of vulcanism in this region were connected. On biological evidence alone, the German naturalist Ochsenius puts the separation of Lake Titicaca from the Pacific, and the elevation of the Bolivian plain in a comparatively recent geological period. (See "*Geografi. Hæoninger af Jorbunden*," "Frem," March 19th, 1899.)

The probable reason that the great majority of the volcanoes of the earth are grouped along the western borders of the Pacific and around the Gulf of Mexico, is *primarily* that these regions are, or have until recently, been areas of great sedimentation. The longest rivers flow into these parts, but the most potent factor, perhaps, in bringing about this heavy sedimentation is the profuse organic growth, consisting of corals, nullipores, Lithothamnion and Halimeda, of polyzoa and foraminifera, and marine mollusca. The Equatorial currents in both the Atlantic and the Pacific, flowing from east to west, ensure that the waters in the western portions of these basins are several degrees warmer than in the eastern parts.[1] Everything is favourable to the sustenance of life. The heavy sedimentation going on induces subsidence, thus gradually accentuating in these parts the folds that mark the oceanic borders. It must not be understood that I look upon sedimentation and erosion as the main causes of inequalities of the earth's surface. This fallacy has been ably exploded by Hutton.[2]

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[1] "Allegemeine Erdkunde," Vol. I., pp. 2938, 294, and fig. 84, by Hr. J. Hann.

[2] Presidential Address in Section C.—A.A.A.S., Vol. II., 1890, Melbourne Session—"Oscillations of the Earth's Surface."

It will be noticed from the foregoing that according to my contention many volcanoes are situated in those abnormal regions in which heating of strata, expansion and elevation are in progress, and in which earthquakes may occur at sunspot maxima when most heat is received from the sun. As these regions coincide with lines of weakness in the earth's crust it is apparent that any influence which affects the earth as a whole, such as shrinkage of the outer crust, the zone of compression, from loss of heat in the zone of contraction, must have greatest disturbing effect in these places. Hence although seismic and volcanic disturbances may occur here at sunspot maxima from local expansion, greatest volcanic and seismic intensity will be experienced at sunspot minima when the earth as a whole is affected.

IV. *Volcanoes.*—Professor Judd, in Chapters x., xi. and xii., of his work entitled "Volcanoes," gives an account of what we learn about the earth's interior from volcanoes and of the various theories advanced to account for volcanic action. These theories may be summarised as follows:—

(1) That of David Forbes and Dana in favour of a liquid earth nucleus.

(2) That of a potentially liquid nucleus.

(3) That of local development of sufficient heat to produce volcanic outbursts by the shearing resulting from the tangential strain between the zone of contraction and the zone of compression.

(4) That of Humphry Davy attributing volcanic energy to the oxidation of deep seated rocks.

(5) The theory that volcanic action is produced by the combination of various gases occluded in deep-seated minerals, and liberated by degrees, as the cooling of the earth proceeds.

(6) The theory that enormous quantities of water find access to hot magmas through gradual infiltration by capillarity, as well as occasionally by way of fissures.[1]

For the purpose of this paper I propose to discriminate between (1) eruptions of a violently explosive character, and (2) those of a gentler nature, usually accompanied by lava flows. The latter kind seem to depend, essentially, on the same causes as earthquakes, and predominate at sunspot minima; they are usually preceded by the opening of a fissure which allows deep seated magmas an upward passage. The eruptions of the former kind are commonest in very unstable and much faulted areas, and in regions undergoing heating from rise of isogeotherms, especially where the volcano is situated in an artesian or subartesian basin. Here water would be continually finding its way down to the volcanic foci, and perhaps more in wet than in dry years.

Vesuvius, situated in a basin of porous sedimentary rocks, seems to bear out this supposition. In its eruption of 1872, a very wet year (close to a sunspot maximum), its lava was very liquid, and on cooling became extremely cindery and scoriaceous from its volumes of enclosed steam. While previous lava flows offer no impediment to the pedestrian, the flow of 1872 is practically impassable (See Judd's "Volcanoes," pp. 98 and 99, Internat. Scientific Series). It is interesting to note that the year 1872 was exceedingly wet and stormy throughout Europe; this was the year of the *great Baltic storm.* A violent north-west wind was blowing at the time of the Vesuvian eruption of April, 1872. The peculiar meteorological conditions prevalent at the time may have played some part in bringing about ths eruption. (See "Volcanoes," pp. 24 – 29.)

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[1] This theory of earthquake and volcanic action is supported by the fact that most of the earthquakes of Japan originate beneath the sea, where infiltration must be greatest; and the violent explosions accompanying many volcanic eruptions are undoubtedly due to steam.

From this we may conclude that the wetter seasons accompanying a sunspot maximum lead to increased percolation, and may in such cases help to produce volcanic eruptions, especially when, as in the case of Vesuvius in 1872, meteorological conditions are favourable or gravitational influences are at work.

Many of the eruptions referred to in my previous paper as not fitting in with the theory which I advanced, fall in this category. The great Javan eruptions of Papandayang 1772, Tomboro 1815, and Krakatoa 1883, all occurred in years of sunspot maxima ; but Java is one of the abnormal areas, referred to above. It is a region undergoing elevation and folding, and its rocks are composed almost wholly of porous Tertiary sedimentaries and volcanic tuffs.

The main uplift that made Java a low plain (according to Messrs. Verbeek and Fennema), *took place in the Pliocene.* In the Pleistocene, Borneo, Sumatra and Java, were connected with one another, and with the Asiatic continent. Violent volcanic action now set in and folding commenced. During Quaternary and Recent times these processes have built up the mountains of Java, though they also were the cause of local subsidences and the reseparation of the main islands of the Malay Archipelago. (See " Description Géologique de Java et Madoura ": Troisième Section *i.e.* 'Géologie genérale de Java,' pp. 995 – 1034 ; and 'Les Sédiments Quaternaire,' p. 1019, by Verbeek and Fennema. See also their geological map of Java and Madoura accompanying their work).

The geological history of Java beautifully illustrates the process of mountain building. First we have the rise of isogeotherms causing a general uplift ; then the commencement of folding and volcanic action (here in Pleistocene times); lastly volcanic extravasation and the formation of subsidence areas (Senkungsfelder). We see also that volcanic action is a concomitant of mountain building. Rise of isogeotherms and folding are still in progress in Java, hence volcanic action is still violent. [H.I.J.]

It is curious that Borneo, so close to Java, is almost free from earthquakes, and does not possess any active volcanoes, although in early Tertiary times this island was the seat of both. Borneo retains, however, several continental characteristics; unlike Java it contains palæozoic rocks covering considerable areas.[1]

It seems then, that in Java conditions are favourable to volcanic action, water continually filtering through the porous beds to volcanic foci. Hence many of the great eruptions of Java have partaken of the nature of steam explosions, and lava flows are not common. The Papandayang eruption blew up the mountain of that name, reducing its height from 9,000 to 5,000 feet, and burying forty villages in the débris. The Tomboro and Krakatoa eruptions were on a similar gigantic scale, and of a similar nature.

V. *Sunspot Minima and Earthquakes and Eruptions.*—Since my previous paper on the connection between sunspot minima and earthquakes and volcanic eruptions, I have kept collecting data to test the correctness of the theory which I then put forward. Two letters appeared in the "English Mechanic," on August 15th and August 22nd, 1902 respectively, criticising my paper. Their author, Mr. T. E. Espin, examined a number of earthquake records as well as records of volcanic eruptions, and reduced them by the formula

$$T = D \times \frac{10}{m}$$

where D = actual time difference between the eruption and minimum ahead.

m = the interval between the two minima between which the eruption took place.

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[1] "Borneo" by Posewitz (translation by Frederick H. Hatch, Ph.D., F.G.S.)

T then gives us the period in which to place the earthquake or eruption, namely its distance from the minimum ahead in terms of the interval between the two minima in which it occurred.

Mr. Espin found it a difficult matter to reduce his earthquakes and eruptions exactly,

(1) because of the impossibility of giving the sunspot maxima or minima correctly to the decimal of a year;

(2) because the records of eruptions are very imperfect.

Mr. Espin also calculated earthquake frequency for perigee, using *m* for the period of the moon's perigee. The results which he obtains do not seem to bear out the views advanced by Sir Norman Lockyer and independently by myself. On the other hand they seem to indicate a relation between earthquakes and perigee.

Mr. Espin's tables and curves seem to indicate a violent paroxysmal outburst of volcanic and seismic energy at sunspot minima, but no regular gradation from a maximum to a minimum. Being interested in Mr. Espin's method of reducing eruptions, I applied it to those eruptions and earthquakes tabulated in my last paper.

[These had been impartially taken out of standard text books, such as Milne's "Earthquakes," Judd's "Volcanoes," and Lapparent's "Traité de Géologie," partly because of the tediousness of wading through the numberless magazines in which original accounts are published, partly because it was the fairest way of getting a representative collection of great earthquakes.]

In working out the earthquake frequency by Mr. Espin's method, I was hampered, as he, by the impossibility of getting sunspot minima fixed to a decimal of a year, and the impossibility with the books at my disposal of getting exact dates for all the earthquakes. However, the result is based on 120 earthquakes and 95 eruptions, in all 215 disturbances.

The result of my enquiry is expressed in the following table, and graphically in figures 1–3:—

T	Earthquakes.	Eruptions.	Total.
*0 – 1	35	28	63
1 – 2	12	11	23
2 – 3	8	6	14
3 – 4	4	6	10
4 – 5	7	4	11
5 – 6	5	5	10
6 – 7	9	7	16
7 – 8	12	6	18
8 – 9	7	7	14
9 – 10	21	15	36
	120	95	215

Curve showing Earthquake Frequency in a Sunspot Period.

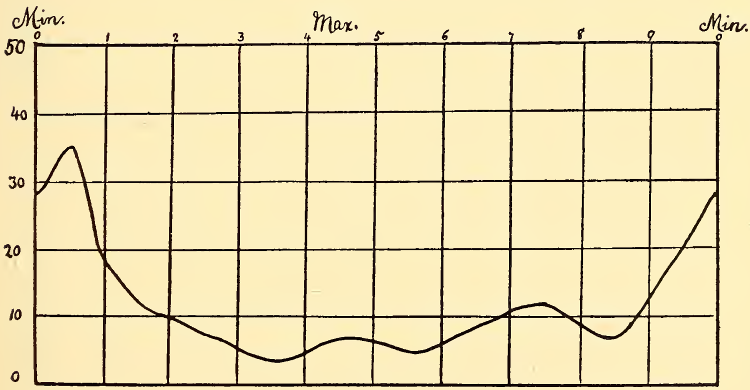

Fig. 1.

*0 = Minimum.

Curve showing Eruption Frequency in a Sunspot Period.

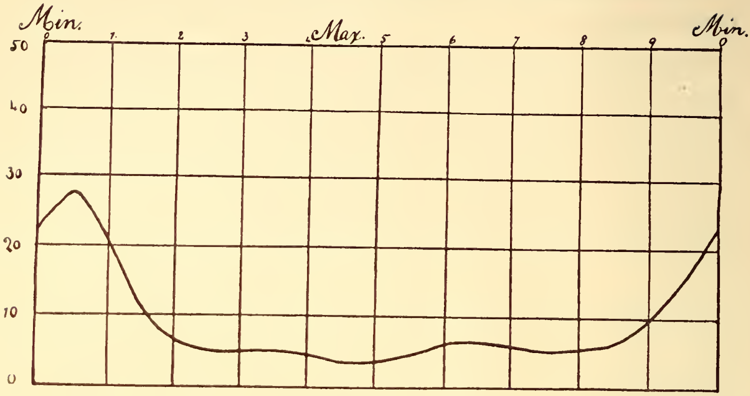

Fig. 2.

The two curves just given comprise all the disturbances since 1810 given in my list. Hence they can be called curves of mean earthquake and eruption frequency during a sunspot period, being the mean curves for a period extending over 90 years.

Taking eruptions and earthquakes together, we get the following curve:—

Sunspot Minima and Total Volcanic and Seismic Activity Curve.

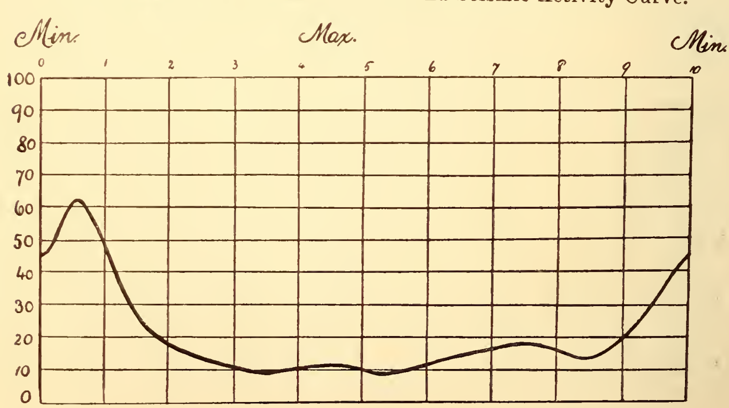

Fig. 3.

In the above curves I have written Max., *i.e.* Sunspot Maximum in period 4—5, because the average interval between a minimum and a maximum and the following maximum has during this century been between 4 and 5 years.

VI. *Seismic and Volcanic Activity and Moon's Perigee.* —To satisfy myself about the above relation, I have catalogued all the earthquakes and eruptions which have taken place, so far as I can ascertain, between April 1st, 1902 and December 1903, together with declination and phases of the moon.

In a letter to the "Scientific American" June 21st, 1902, p. 433, Mr. Elmer J. Still discusses the possibility of forecasting earthquakes and eruptions from lunar observations. Although it will be noticed that I hinted at the same possibility in my paper of June 4th, 1902, it seems that Mr. Still has too much confidence in the moon's capacity to bring about such disasters. Mr. Still points out that seismic and volcanic activity are increased at (*a*) perigee, (*b*) new moon, (c) and when the moon crosses the earth's equator.

According to Mr. Still's scheme there should have been great disturbances on June 13th, 1902, for then the moon crossed the equator; but the disturbance came on June 19th and 20th, at apogee and full moon. Again violent earthquakes might have been expected on October 1st because on September 30th the moon crossed the equator, and on October the 1st it was new. At this time however no great disturbances were reported, whereas on October 17th, at full moon, severe earthquakes were widely experienced. On October 13th, 1902, however, at new moon, a violent earthquake and volcanic eruption was reported from Savaii in Samoa, the first since 1866. On November 13th, again full moon, the volcano Santa Maria in Guatemala, erupted and covered the towns of Palmar, Columbia, and Coatepec with débris. This was the beginning of another grand series of disturbances, lasting till November 18th, 1892. Yet there is undoubtedly in years of violent disturbances a tendency for these to fall at such times as Mr. Still indicates in his above mentioned letter.

In September 1902 we had the moon crossing the equator on the 17th, full at the same time, the equinox on the 22nd and perigee on the 23rd, and this combination was accompanied by a violent and extensive series of disturbances, including earthquakes in Ecuador, Honduras, Guatemala and St. Vincent, and a violent eruption of La Soufrière, all between September 20th and 23rd. The great disturbances of November 15th and 16th may have been precipited by the occurrence of perigee and full moon on those days. We see then that several causes co-operating may bring about what each acting singly was, as on June 13th and October 1st 1902, unable to achieve.

The compilation of earthquakes and eruptions between April 1st, 1902, and December 31st 1903, which is given in Appendix II., contains 55 earthquakes and 46 eruptions. These were collected from *Sydney Morning Herald* files and checked by comparison with those recorded from time to time in "*Nature*." The deductions to be drawn from this list are corroborative of the above contentions. Compiling under the heading "perigee" all the earthquakes that occurred from 3 days before to 3 days after perigee, and likewise for apogee, full, new, and moon crossing the equator we obtain the following tables.

Table I.

Perigee.		Apogee.	
Earthquakes.	Eruptions.	Earthquakes.	Eruptions.
32	14	8	10
or 58·0%	30·5%	14·5%	18·0%
Total disturbances at and about Perigee 46, or about 46%.		Total disturbances at and about Apogee 18, or about 18%.	

This leaves 36% of the disturbances to fall at times other than perigee or apogee.

Table II.

New Moon.		Full Moon.	
Earthquakes.	Eruptions.	Earthquakes.	Eruptions.
16	12	12	11
or 29%	26%	22%	24%
Total disturbances 28%.		Total disturbances 23%.	

This leaves 49% of the disturbances to fall when the moon is more than three days from full or new.

Table III.

Moon Crosses Equator.

Earthquakes	Eruptions
21	23
or 38%	or 50%

Total disturbances 46%, leaving 54% to occur when the moon is markedly in N. or S. declination.

The percentages are given to the nearest whole number. It may be gathered from Tables I., II., and III. that there is a connection between perigee and volcanic and seismic disturbances, 58% of the earthquakes (more than half) and 30·5% (nearly one-third) of the eruptions falling at or within a three days period from perigee. Between apogee and seismic frequency there is no relation. Very little influence can be ascribed to lunar phases, and the same might be said of "Crossing the Equator." A very good verification of these contentions is that no disturbances were felt between March 20th – 24th, 1903, the equinox itself, but at the previous and following perigee, of March 10th and April 5th both eruptions and earthquakes were recorded. New moon and full moon were likewise beyond the three days' limit. In September 1903, however, perigee, new moon, and moon crossing the equator, all happened to occur close together and at the time of the equinox. At the same time four violent earthquakes were experienced—apparently brought on by a co-operation of secondary causes. Of all these secondary causes the equinox is perhaps next to 'perigee' the most potent, owing partly to its disturbing influence on atmospheric conditions, and partly to the sun's gravitational influence at such times.

VII. *The evidence afforded by the Earthquakes of Japan*—Milne divides the earthquakes of Japan into two classes: (1) those that originate beneath the sea, many of which are seen on the seismograph diagrams to be of the same nature as explosions. (2) those that accompany folding and shearing processes and the consequent fracturing of strata.[1]

In regions like Japan where the rocks are largely of a porous nature, percolation of water by capillarity may constantly be admitting water to volcanic foci, and to reservoirs of hot magma such as sills or laccolites. Fissuring resulting from the folding processes going on in the expanding Tertiary rocks of Japan, and in the ocean east of Japan, may also cause admission of water from the great oceanic geosyncline.

Dr. Koto, in his excellent paper on "The Scope of the Vulcanological Survey of Japan,"[2] divides the earthquakes of his country into two classes, (*a*) the purely volcanic ones which have a very limited area of shocks, such as that of Bandaisan 1888; and (*b*) those which are tectonic in origin, related to great earth movements and with shocks affecting a wide area. Dr. Koto disagrees with Prof. J. Milne, who supports the Humboldt-Naumann or vulcanistic theory of earthquakes.

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[1] "Earthquakes by J. Milne, pp. 228 and 281.

[2] "Publications of the Earthquake Investigation Committee," No. 3, pp. 89 - 103, Tokyo 1900.

Perhaps we may go a little further than Dr. Koto and divide those earthquakes which he calls '*tectonic*' into (*a*) those whose centre lie in areas undergoing fissuring through cooling and contraction; and, (*b*) those which originate in areas undergoing expansion, folding and heating by rise of isogeotherms; that is areas in which the fracturing is due to strain caused by folding more than the elasticity of the strata can stand.

In answer to this question a paper by Dr. F. Omori comes to our aid.[1] Dr. Omori shows that Japan is divisable into two distinct earthquake regions, in the one of which (*A*) the earthquake frequency is greatest in winter, in the other (*B*), it is greatest in summer. The (*A*) region is shaken mostly by earthquakes of an inland origin, and the (*B*) region chiefly by earthquakes of a submarine origin. The *B* region comprises the present volcanic chain, or fissure line, passing from the Kurile islands, through Japan and the Riu-kiu (Lu-Tschu) Islands to Formosa. This region becomes submarine a little north of Tokyo which lies in the *A* region, and is continued in the eastern part of Sikok. On comparing Dr. Omori's map (Fig. 7 of his paper) with the geological map of the Japanese Empire issued 1902, we see that the *A* region corresponds with the older portions of Japan, adjoining the Senkungsfeld of the Sea of Japan; it is an area where elevation from rise of isogeotherms has probably long ago ceased, in which volcanic action is practically extinct, and in which ancient granites, gneisses, palæozoic sedimentaries and mesozoic rocks have had time to become exposed. The *B* region in Niphon and Yesso is an area of great Tertiary and Quaternary uplift. Most of the late volcanic rocks are in this region.

[1] "Annual and Diurnal Variation of Seismic Frequency in Japan" by Mr. F. Omori, D.Sc., in "Publications of the Earthquake Investigation Committee," No. 8; also figure 7 in same. (Tokyo, 1902.)

In the island of Sikok, the north-west portion consisting of ancient crystalline schists, falls in the *A* region (winter earthquakes), whereas the south-east portion consisting of mesozoic sedimentary rocks, falls in the *B* region. But probably most of the earthquakes here (summer earthquakes) are connected with submarine elevation and folding along the volcanic line east of the island.

In the island of Kiu-Siu volcanic rocks and Tertiary sedimentary beds are plentiful, yet it belongs to Dr. Omori's *A* region. Perhaps elevation by rise of isogeotherms and volcanic action has ended here, and contraction processes may have set in.

It would be of great interest and importance to this branch of science if our Japanese confrères would ascertain exactly what relations obtain between earthquakes and eruptions in each of these regions and (1) solar conditions, (2) lunar phases and declination, (3) atmospheric conditions, cyclones and anticyclones, cold winters, hot summers, etc.

Some of this work they have already commenced, perhaps all; indeed Japanese scientists, hampered by want of funds and semi-isolation from the rest of the scientific world, have done wonders; again and again they have shown their ability in geology, metallurgy, the study of alloys, meteorology and physics, and we should not wonder if the whole of this work has been almost completed by them.

VII. *Summary.*—From my researches it appears that (1) a marked connection exists between sunspot minima and seismic disturbances. Sunspot maxima have a much less well defined influence.

(2) Perigee is a powerful secondary cause of earthquakes.

(3) The equinox has likewise a marked influence.

(4) New and full moon and the crossing of the equator by the moon are only capable of inhibiting earthquakes

and eruptions, when acting in conjunction with other influences.

(5) Earthquakes are most prevalent in years of notoriously cold winters, and more frequent in winter than in summer as far as Europe is concerned. The years 1811-12, 1846, 1855-56, 1880-81, and 1889, which were all years of maximum winter frost in England and Europe, and periods of drought in various parts of the world, were also noted for violent seismic and volcanic disturbances.

(6) It has often been pointed out that a certain correspondence exists between the occurrence of droughts and earthquakes, red rain and earthquakes and eruptions, and usually these events occur contemporaneously at sunspot minima.[2]

Part II.—On the Connection between Sunspot and Meteorological Phenomena.

SYNOPSIS:

I. Cause of Sunspots.
II. Sunspots and Temperature.
III. Sunspots and Barometric Pressure.
IV. Sunspots and Rainfall.
V. Sunspots, Earth-magnetism and Solar Corona.
VI. Index to Literature.
VII. Appendices.

I. *Cause of Sunspots.*—Various theories have been advanced to account for sunspots. Some of these are intimately bound up with the various hypotheses to account for the sun's maintenance of his own heat. They might briefly be summarised as follows. They are caused by

(1) Meteoric swarms, a hypothesis bound up with the meteoric theory to account for the sun's heat.

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[1] "Possible connection between Sunspot Minima and Earthquakes and Volcanic Eruptions," by H. I. Jensen—Proc. Roy. Soc. of N.S.W., xxxvi., June 4th, 1902.

[2] "Periodicity of Good and Bad Seasons," by H. C. Russell—Proc. Roy. Soc. of N.S.W., xxx., June 3rd, 1896; and Professor David's discussion on Mr. Russell's paper.

(2) The attraction of the planets; a theory which has in its favour the fact that the sunspot cycle is of approximately the same length as the period of revolution of the planet Jupiter.

(3) Clouds of cooling metallic vapour and carbon in a fine state of division, a hypothesis obviously related to Dr. Siemen's theory of solar heat.

(4) There is also a theory advanced by Sir Norman Lockyer which has the merit of accounting at the same time for coronæ, prominences and sunspots. From the time of a sunspot maximum masses of vapour and solid matter in a fine state of division rise from the sun's photosphere by centrifugal force often to the immense distance of ten millions of miles. They keep rising and expanding until we have a sunspot minimum, when the density of these masses obscure photospheric phenomena. We then have a magnificent equatorial corona such as was seen in 1868, 1878, 1889, and 1900-01. Then through cooling the vapour masses liquify or solidify, and fall with a splash into the photosphere, causing renewed solar activity and the production of great heat. The constant association of sunspots with protuberances of the eruptive type and with faculæ gives a sunspot very much the appearance of having been caused by a fall of darker and cooler matter into the more luminous and hotter atmosphere, throwing the photospheric matter up in long streamers.

(5) Finally we have Herr J. Halm's theory,[1] which accepts Helmholtz's theory of solar contraction creating heat to compensate for radiation into space. The sun is a star whose loss of heat by radiation is greater than gain of heat produced by contraction. The result is that the temperature of the layer of maximum incandescence must decrease. Hence it sinks to a level where the temperature is sufficient

[1] Astr. Nachr. Nos. 3723 and 3724; or Nature, Vol. LXV., Feb. 13, 1902.

to keep the particles incandescent. The space outside this layer will then be filled with particles at a lower temperature, which act as a screen absorbing and reflecting part of the heat radiated. This cooling goes on and the photosphere moves closer to the sun. At length such a stage is reached that the amount of reflected heat overheats this photospheric layer. The vertical temperature gradient rises to such steepness that thermal equilibrium becomes impossible and the overheated vapours break through the photospheric envelope.

Hence Halm comes to the conclusion that at sunspot maxima there should be minimum radiation into space. In support of this contention he adduces Köppen's temperature curves,[1] which agree with the inverted sunspot curve from 1820 to the present time, and the widening of lines in the sunspot spectra at times of sunspot maximum. From the same fact Sir Norman Lockyer deduced the opposite inference, namely that the matter composing the spots must be at a higher temperature at sunspot maxima, and hence the sun must radiate more heat into space at such times.

Of the above theories, the two last explain most facts, but Herr Halm weakens his case by drawing inferences from the meteorological curve of Köppen. The amount of cloud, moisture of the atmosphere, and the prevalence of cyclones probably give a better clue to the amount of solar heat received by the earth than mere temperature curves. The temperature at the earth's surface is modified by so many local causes, precipitation, evaporation, humidity, and barometric pressure, that it can scarcely give us any idea of the quantity of heat received from the sun.

The relations between sunspot intensity and terrestrial phenomena which have already been shown to exist, (by Dr.

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[1] Reproduced in Herr Halm's paper, see Nature, No. 1685, Vol. LXV., p. 353.

W. J. S. and Sir Norman Lockyer, and others) may be summarised briefly as follows :—(1) Violent outbursts of prominences (which have their maximum and minimum at the same time as sunspots) are immediately followed by magnetic storms, auroral displays, and often weather changes in the earth's atmosphere.

(2) Prominences and sunspots have a periodicity of approximately eleven years, with a superimposed cycle of 35 years. This 35 year cycle corresponds exactly with the Brückner weather cycle of 35 years in accordance with which long-period variations in climatic conditions take place.

II. *Sunspots and Temperature.*—(*a*) The curves of Köppen and Nordmann[1] showing mean temperature for tropical districts seem to indicate that the mean annual temperature is highest at sunspot minimum and lowest at maximum, the temperature curve corresponding to the inverted sunspot curve. The main conclusion to be drawn from M. Charles Nordmann's paper is that "The mean terrestrial temperature follows a period sensibly equal to that of solar spots; the effect of spots is to diminish the temperature, *i.e.* the curve which represents the variations of temperature is parallel to the inverse curve of sunspot frequencies."

Mr. Alex. B. McDowall, F. R. Met. Soc., has arrived at the opposite conclusion by a careful study of the meteorological statistics of last century. He finds that England receives more heat when the spots are many than where they are few, and he has dealt with his subject from many standpoints. He finds that in England there are more frosty days at, and a few years after, a sunspot minimum than is normal, and in years of spot maximum the number of frost

[1] Nature, No. 1685, Vol. LXV., p. 353, and Comptes Rendus No. 18.

days is below normal; further, his curve of variation in number of frosty days agrees with the sunspot curve.[1]

Not satisfied with this evidence alone, Mr. McDowall examines the dates of flowering of various plants and finds that they bloom earlier in sunspot maximum years.[2] [This may be due either to the prevalence of warmer, or of moister winters, or probably of both together.—H.I.J.]

As already pointed out in my previous paper, many distinguished European meteorologists endorse the same views as Mr. McDowall.

In Australia we experience in years of *maximum sunspot intensity* (at any rate as far as New South Wales and Queensland are concerned) moister and more chilly seasons than usual. *In tropical parts* the *summer* becomes long, moist, sultry at times, but usually cooler than normal; the *winter* becomes short and somewhat warmer than normal. In *temperate parts* (like New South Wales from Sydney southward) the *summer* becomes long, cool and moist; warm north-west winds and their concomitants the southerly bursters are less frequent, monsoonal conditions and easterly winds being more prevalent; the *winter* becomes short, and very wet and chilly, inasmuch as it is the rainy season. The anticyclone belt is very much reduced in width in such periods, and is continually broken by disturbances, in summer chiefly of monsoonal nature, in winter connected with the antarctic V disturbances. The Central Australian cyclone assumes great dimensions in the summer, and the outblowing winds do not descend to the earth's surface within the limits of the continent, hence we do not often experience the north-westerlies, whereas the easterlies blowing towards the depression are fairly persistent.

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[1] Nature, No. 1773, Vol. LXVIII., October 22nd, 1903.

[2] "Sunspots and Phenology," Nature, No. 1765, Vol. LXVIII.

In years of *minimum sunspot intensity* Queensland experiences scorchingly hot summers, and every part has very cold winters for its latitude. In New South Wales (Sydney for example) the summers are hot with frequent north-west winds, relieved at times by southerly bursters; the winters are cold and rather protracted, but as the atmosphere is dry the cold is not felt as much as in the wet winters accompanying a sunspot maximum, and the nights are not rendered unpleasant by rain, fog or snow. In years of minimum sunspot intensity the Central Australian cyclonic area in summer is of comparatively small dimensions, and consequently, the outwardly blowing hot winds reach the surface of the earth in the coastal districts, giving us in Sydney frequent north-west winds. In winter this area is covered by a vast permanent anticyclone, from which the cold, dry, westerly winds originate. The anticyclone belt is greatly widened, and the rainbringing monsoonal and antarctic V disturbances are consequently not frequent.

The deductions which, I would suggest, to be drawn from the work of Köppen, Nordmann, and McDowall, are that *the curve representing the annual variations in temperature does in tropical regions agree with the inverted sunspot curve*, and *in temperate regions with the actual sunspot curve.* The importance and explanation of this apparent anomaly I shall now proceed to discuss.

(*b*) For well known reasons, depending on the sun's apparent motion to the north or south of the Equator, the *tropical regions of the earth have their greatest rainfall in summer*, *whereas the temperate regions have theirs in winter.* Assuming that sunspot maxima induce strong atmospheric circulation and great evaporation, we find that in such periods the earth's atmosphere is very humid. Then in the torrid zone the earth is screened by a canopy of vapour; the otherwise excessive temperature is lowered also by the voluminal (adiabatic) expansion of the atmosphere, and also by great evaporation. Hence the summer may be sultry, but evaporation, condensation, cloudiness and adiabatic expansion reduce the actual temperature as recorded by the thermometer. The winter would for the same reason also be mild. In years of sunspot minimum, however, the tropics would in summer be less protected by vapour, and the compression of the whole atmospheric shell would also raise its temperature. In temperate regions, however, the effect of a sunspot maximum would be to raise temperature somewhat in winter, the wet season, and to make the summer drier and subject to intensely hot days. A sunspot minimum would however be accompanied in the temperate regions by cool summers and excessively cold frosty winters. It will be seen that with these explanations, the results obtained by Nordmann, Köppen, Hann aud McDowall are not inconsistent, and agree well.

III. *Sunspots and Barometric Pressure.*—Regarding sunspots and barometric pressure it seems to be quite certain that there is a connection. Meldrum has shown for the West Indies and Mauritius that *more cyclones pass in years of maximum sunspot effect than in minimum years.* This probably involves a diminution of pressure. Blanford has shown for the India area that the mean yearly pressure undergoes variations which correspond to the inverted sunspot curve, being highest at sunspot minimum. The later researches of Dr. Lockyer, Professor Bigelow and others, show that the earth is divisible into two areas over which the pressure variations are reciprocal.[1] Dr.

[1] "Monthly Weather Review," Vol. xxx., No. 7, p. 347, and Roy. Soc. Proc., Vol. LXX., p. 500, and Vol. LXXI.

Lockyer in his researches has arrived at the result that all Malaysia and Australia follow short period barometric variations exactly similar to those at Bombay, whereas Cordoba in South America has the conditions reversed, and many of the North American towns follow the Cordoban variations. We are told by Professor Bigelow, who comes to the same conclusions as Dr. W. J. S. Lockyer, that the values do not exactly cancel one another; the Bombay area is much the larger, comprising most of Asia, Europe, part of North America, and all of Australia; hence Prof. Bigelow thinks "*that some external force is at work to raise and lower the total atmospheric pressure by a small amount each year.*" Assuming that the small period variations, which Dr. Lockyer discusses, correspond in extent with longer period variations, we may conclude that the excess of pressure above normal at Bombay, and throughout the area which follows the Bombay type of variations, does not counterbalance the deficiency in the Cordoban area in a year of sunspot minimum. The reverse would hold under sunspot maximum conditions.

What then can thus minimise the total atmospheric pressure in years of sunspot maximum and raise it in years of minimum? Evidently the answer is, "*variations in total heat and energy received from the sun.*" When more solar energy is received the earth's atmosphere undergoes a voluminal expansion, which by increasing the height of our atmosphere also increases the effect on it of centrifugal force, and hence lessens the influence of gravity and the pressure at the surface. When less energy is received, the atmosphere undergoes contraction and pressure increases.

We have only got to examine our own Australian meteorology to find ample illustration. During sunspot maximum years, such as 1893, 1894, 1895, 1896, far more cyclonic and monsoonal disturbances affected our latitudes than during the minimum years 1897 – 1903. In fact in the period of sunspot maximum the antarctic V disturbances extend further north, and the monsoonal influences further south than usual, with the result that the anticyclone belt is narrowed, and the frequency of anticyclones reduced. During minimum years on the other hand the anticyclone belt widens and anticyclones pass across our continent in rapid succession. The researches of Professor K. Kassner[1] seem to show the reverse relation to obtain for the North American cyclone track, cyclones there being according to him more frequent at sunspot minima.

The connection between pressure and temperature is stated by Dr. Lockyer, as follows:—"The Indian meteorologists have abundantly proved that the increased radiation from the sun on the upper air currents at sunspot maximum is accompanied by a lower temperature in the lower strata, and that with this disturbance of the normal temperature we must expect pressure changes."

IV. *Sunspots and their connection with Rainfall.*—The majority of meteorologists were a few years ago full of eagerness to embrace the theory that sunspots brought rainfall and their absence drought. This idea was strengthened by the fact, as shown by Jevons,[2] that many great Indian famines closely followed sunspot minima. Many of our own Australian and many European droughts coincide with sunspot minima. Lately, however, Sir Norman and Dr. W. J. S. Lockyer have shown that India has two rainfall pulses, one at maximum and one at minimum sunspot conditions, and that often a very wet year in Mauritius is a dry year in parts of India and *vice versa*. Mr. H. C. Russell, B.A., C.M.G., F.R.S., has also shown that wet seasons

[1] Annalen der Hydrographie und Maritimen Météorologie, March 1903.
[2] Nature, Vol. LXIII., p. 107.

in England are often coincident with times of drought in Australia. Yet a large number of German meteorologists, and Mr. Alex. J. McDowall amongst English meteorologists still think, not without a large amount of evidence in their favour, that sunspot maxima are usually accompanied by wet years and sunspot minima by dry years. It is an indisputable fact that many of the periods of great seismic frequency and volcanic activity coinciding with sunspot minima during the past century, were at the same time periods of drought, famine and great winter cold, with red rain, grey rain, fireballs and other concomitants of such seasons. The work of Dr. Lockyer and Mr. H. C. Russell does, at the most, show us that periodic forecasts of good and bad seasons cannot be made on sunspot data alone, but that other potent causes are at work to modify sunspot influence.

Perhaps, indeed, Mr. Russell's "Nineteen Year Cycle" exerts a modifying influence causing the rains at one time to preponderate in the southern, at another in the northern hemisphere. Certainly lunar influence is not negligible in seasonal weather forecasting. A Russian meteorologist M. Demchinski, is at present becoming quite famous through successful forecasts based on lunar data.

Yet surely it is no mere coincidence that 1811–1812, 1844–1846, 1864–1869 and 1896–1902, were years of drought in the greater part of the world, and at the same time periods of sunspot minimum. In 1902 the Nile flood was the lowest on record; the Argentine, India, Russia and parts of North America suffered very severely from drought, though Australia, on account of its peculiar physiographical nature, suffered most. The period from 1896 to 1900 was also very dry in England, and the year 1901 was exceptionally dry in Siberia as well as in the above mentioned regions.

Mr. John Foster Frazer writes in the autumn of 1901, as follows: "Old Siberians told me that as long as they could remember, there never had been such a spell of fine weather. So I was fortunate."—(See "The Real Siberia," p. 148). By the term spell of fine weather, a tourist naturally means dry weather such as would afford him good roads for walking, riding and cycling.—(H. I. J.)

Nor does it seem a coincidence that 1864, 1870-72, 1893-4, periods of sunspot maximum were wet years over the greater part of the earth's surface.

The Rothesay rainfall record, extending over about one hundred years, corresponds with the sunspot curve to a considerable extent, very dry times having occurred in 1822, 1855, 1887, years of sunspot minima and high seismic frequency. At all events, if the world's rainfall does not correspond exactly with the eleven year sunspot period, it has been shown and is, I believe, accepted by the majority of modern meteorologists including Herr Hoffrath Julius Hann, the greatest living meteorologist, that climate as a whole, including rainfall, temperature, cyclonic frequency, *et cetera*, undergo a long period variation of 33 – 37 years, corresponding with the 35 year sunspot period. Thus, climate, earth-magnetism, solar prominences, the auroras, and sunspots are closely related phenomena, all dependent on a common cause within or without the sun.

It is to further our knowledge of the primary causes of climatic variation, and to discover the secondary or modifying causes that meteorologists of the future must devote their energies, an exceedingly difficult task, considering how hard it is to unravel what is cause and what is effect.

Geographical facts have not been given importance enough in the past in this connection. Mauritius often has heavy rainfalls in years of sunspot minimum with a drought raging at the time in part of India, *e.g.* in 1876, when the West Indies, South America, Australia, South Africa, Spain, the Barbary States and Russia were suffering from the drought lasting from 1875 – 79. But at the great minimum of 1864 to 1869 Port Louis in Mauritius had a much lower rainfall than usual, and at the great maximum 1870, the Port Louis rainfall again rose to more than normal. It may be noted that the sunspot minimum of 1864 – 1869 was accompanied by droughts in Australia, Orissa, Bengal, Russia, and South America as well, and as has already been shown by me,[1] this was a period of intense volcanic disturbances and earthquakes, especially the years 1867 and 1868.

It is well known that in years of great drought, as this last one of 1897 – 1902, which we have just passed through, heavy rains are often experienced out at sea. It seems that, perhaps on account of the deficiency in our supply of solar energy, our atmosphere circulates too feebly to bring the moisture landwards. The vapours are not brought into the higher regions at all, and consequently condense over the areas whence they were drawn. Mauritius, an island, lying in our warmest ocean, and not many hundred miles from where the cold Antarctic drift often carries its icebergs along, is particularly liable to receive rain when other parts of the earth, less advantageously situated, have to suffer. Geographical considerations like the above, would perhaps, go far to explain anomalies in rainfall.

The following quotations from a book by Prof. J. W. Gregory, D.Sc., F.R.S., entitled "The Climate of Australasia," seem pertinent to the subject just discussed :—

(1) "We cannot expect that rainfall will anywhere vary with mathematical regularity. Rainfall is one of the most complex of meteorological products, and is the resultant of a series of conflicting agencies."

And (2) discussing the rainfall of Mauritius—

"It is found at this period the south-western monsoon gives India its maximum of rainfall, while India as a whole, being con-

[1] Proc. Roy. Soc. N. S. W., June, 1902.

tinental, is under cyclonic conditions. At the same time, Mauritius being an oceanic island, is naturally under anticyclonic conditions, and has a minimum of rainfall."

And (3):

"The rainfall curve of Mauritius is comparatively simple and shows an eleven (11) years cycle ; but the rise and fall is inverted when compared with *parts* of India."

It is readily seen that these conclusions are identical with those which I have here put forward, and indicate that rainfall, as well as many other aspects of climate, is largely a geographical problem, which *can* and *must be* solved, but which is rendered somewhat complex by the numerous factors which have to be considered.

The importance of observations on the advance and retreat of ice-sheets and glaciers is often overlooked and wrong inferences are often drawn from observations made. Glaciers in the Alps advance in years of sunspot maximum,[1] a fact which shows, not that such a period is colder than normal, but that precipitation at high altitudes is greater, in other words that the vigour of atmospheric circulation is above normal. In January, 1903, I paid a visit to Mount Kosciusko, and found that all the snow had melted away. Usually large drifts remain throughout the summer in the deep and sheltered valleys. Local residents informed me that very little snow fell during the winter of 1902, and that already in November, Mount Kosciusko had lost his snowcaps. Under normal conditions the precipitation of snow is great in the Australian Alps and the drifts are practically perennial. During the winter of 1898, when I was one of the meteorological observers there, we were

[1] The annual number of deaths of tourists and others in the Alps from avalanches, etc., is greater than normal in years of sunspot maximum. During the past year such accidents have been abnormally frequent. The cause is obviously that the accumulation of snow is at such times unusually great, and spells of very hot weather loosen large masses, giving thus rise to frequent avalanches.

snowed up from May till November. During the present year a great snowfall may be expected in our Australian Alps, just as during the past winter in Europe, the Swiss Alps received an unusually large snowfall.

It would be interesting, indeed, to know how the great Antarctic icesheet behaves from year to year. From a meteorological point of view the establishment of a settlement in Victoria Land, and the further scientific exploration of this region would be a great boon.

V. *Earth-magnetism, Sunspots and Solar Corona.*—The connection existing between sunspot maxima and earth-magnetism and aurora has already been demonstrated in my previous paper. Since that time several violent sunspot disturbances have been observed and at least one outburst, that on and about October 31st, 1903, was accompanied by terrestrial magnetic storms.[1] On that day telegraphic communication was interrupted in part of Europe for eight hours on account of a violent magnetic storm. At the same time a fine display of Aurora Australis was seen as far north as Sydney, N.S.W. Mr. A. Fowler in a letter to "Nature," Nov. 5th, 1903, writes that the C Hydrogen line in the neighbourhood of the great sunspot group near the central meridian was reversed on October 31st, between 9 and 10 a.m. This fact beautifully instances the close simultaneity between terrestrial and solar atmospheric phenomena.

In the Index to Literature (Section VI., Part II. of this paper) references are given to interesting papers on the connection between prominences, corona, earth-magnetism and auroras, and also to Professor Dewar's address to the British Association, in which he discussed the existence of the rarer gases helium, neon, crypton, xenon, and argon in

[1] See also Dr. W. J. S. Lockyer in "Nature," No. 1775, Vol. LXIX., Nov. 5th, 1903.

the earth's atmosphere and in the corona of the sun. The matter of these papers is of such extreme interest in connection with the subject discussed in this paper that an apology for inserting them in the "Index to Literature is unnecessary.

VI. *Index to Literature.*—Astronomical and Meteorological.

A. Astronomical Journal

1. No. 530, "Sunspot Observations, July 12th to Dec. 22, 1902," by A. W. Quimby (published Jan. 31st 1903).
2. Nos. 542 and 543 (July 21st, 1903) "Sunspot Observations Jan. 1st to June 30th, 1903," by A. W. Quimby.
3. Nos. 540 and 541 (June 18th, 1903), "Sunspot Observations Oct. 6th, 1902 to May 1st, 1903," by Jones and Tucker.

B. British Association for the Advancement of Science, Report for 1902

"Presidential Address," by Professor Dewar.

C. Monthly Notices, Royal Astronomical Society

1. "Mean Daily Areas of Sunspots for each degree of Solar Latitude for each year from 1874 to 1902." M.N., R. A.S., June 1903.
2. "Areas of Faculæ and Sunspots compared with Diurnal Ranges of Magnetic Declination, etc., in the years 1873 to 1902." M.N., R.A.S., Vol. LXIII., No. 8, June 1903.
3. "Mean Areas and Heliographic Latitudes of Sunspots, 1902, etc." M.N., R.A.S., June 1903.
4. "On a Possible Relation between Solar Prominences and Corona" by William J. S. Lockyer, M.A. M.N., R.A.S. Vol. LXIII., No. 8, June 1903.
5. "Council's Note on Solar Activity in 1902." M.N., R. A.S., Feb. 1903, pp. 249 – 251,
6. M.N.. R.A.S., Vol. L., p. 8.
7. M.N., R.A.S., Dec. 13th, 1901.

D. Nature

1. Vol. LXII., No. 1616, Oct. 18th, 1900. "Sunspots and Cold Winters," by Alex. B. McDowall.
2. Vol. LXIII., No. 1622, pp. 107 and 128. "On Solar Changes of Temperature and Variations in Rainfall in the Region Surrounding the Indian Ocean." (Lockyer.)

3. Vol. LXIII., p. 299. "Sunspots and very Cold Days."
4. Vol. LXV., Feb. 13th, 1902. "A New Solar Theory by J. Halm (Paper abstracted from Astr. Nachr., Nos. 3723-4.)
5. Vol. LXVII., No. 1732, Jan. 8, 1903. "On the Similarity of the Short Period Barometric Variations over Large Areas." (Dr. Lockyer.)
6. Vol. LXVII., No. 1733, Jan. 15th, 1903. "Sunspots and Summer Heat." (McDowall.)
7. Vol. LXVII, No. 1738, Feb. 19th, 1903. "Solar Prominences and Terrestrial Magnetism." (Dr. Lockyer.)
8. Vol. LXVII, No. 1746, April 16th, 1903. "Solar Prominences and Spot Circulation 1872 – 1901." (Dr. Lockyer)
9. Vol. LXVIII., No. 1749, May 7th, 1903. "The Solar and Meteorological Cycle of Thirty-five Years." (Dr. Lockyer)
10. Vol LXVIII., No. 1765, August 27th, 1903. "Sunspots and Phenology." (McDowall)
11. Vol. LXVIII, No. 1773, Oct. 22nd, 1903. "Our Winters in Relation to Brückner's Cycle." (McDowall)
12. "Simultaneous Solar and Terrestrial Changes," by Sir Norman J. Lockyer. (Paper presented to the International Meteorological Committee at Southport, Sept. 11th 1903, abstracted in Nature Feb. 11th, 1904.)

E. Royal Society Proceedings

Vol. LXX., p. 500. "On Some Phenomena which suggest a Short Period of Solar and Meteorological Changes," by Sir Norman Lockyer, K.C.B., F.R.S., and Dr. W. J. S. Lockyer, M.A., F.R.A.S.

F. Royal Society of New South Wales

1. "Periodicity of Good and Bad Seasons," by H. C. Russell, B.A., C.M.G., F.R.S., June 3rd, 1896.
2. "Recurrence of Rain," by H. C. Russell, B.A., C.M.G., F.R.S. September 4th, 1901.
3. "Possible Relation between Sunspot Minima and Volcanic Eruptions," by H. I. Jensen, June 4th, 1902.

VII. *Appendices.*—Appendix I., Periodicity in Eruptions.

Eruptions of Colima.

Colima	1856	(sunspot minimum)
,,	1870	(just after minimum)
,,	1881	,, ,,
,,	1891	,, ,,
,,	1903	,, ,,

Appendix II.—Table of Seismic and Volcanic Disturbances from April 1st, 1902 to Dec. 31st, 1903.

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
April 6	Crosses Equator			
„ 8	New			
„ 10	Perigee			
„ 19	Crosses Equator	In Guatemala		
„ 22	Full and at Eclipse Node			
„ 23		... ...	Mount Pelée showed a plume of smoke.	
„ 25	Apogee			
May 3	Crosses Equator	... ...	Mt. Pelée's crater lighted up with incandescent lava.	
„ 4	... ...	... ...	Mount Pelée covers surrounding district with a shower of ash.	
„ 5	... ...	... ...	Stream of lava and mud from Pelée engulfed the sugar factory. La Soufrière in St. Vincent also active.	Sea recedes 300 feet.
„ 7	New and at Eclipse Node	In Martinique	La Soufrière, St. Vincent in violent eruption.	
„ 8	Perigee	... ...	A sea of fire destroys St. Pierre.	
„ 10	... ...	... ...	Mt. Tacoma (U.S.A.) and Mt. Redoubt (Alaska) in eruption.	

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
May 11	... ...	... ...	... ...	Geyser in Dominica disappeared.
„ 12	... ...	... ...	... ...	Hot spring at bath in Jamaica boiling.
„ 13	... ...	... ...	Terrific explosions in La Soufrière	Mt. Colima in Mexico smoking.
„ 15	... ...	... ...	Pelée still active.	
„ 16	Crosses Equator			
„ 17	... ...	... ...	La Soufrière still active.	
„ 18	... ...	In California	... ...	Great tornado in Texas, Mine explosion in Frazerville, U.S.A.; during this week the mineral waters at Teplitz in Bohemia, turn brown.
„ 19	... ...	... ...	Violent eruption Mt. Pelée	
„ 20	... ...	... ...	Pelée eruption continues.	
„ 21	Full	... ...	Ditto	Coal Mine explosion in British Columbia.
„ 23	Apogee			
„ 24	... ...	... ...	Torrent of lava-mud from Pelée; lava flows from La Soufrière, St. Vincent	Blood-rain in Hamburg (containing *Carabus cochinella* and ashes)
„ 25	... ...	... ...	... ...	Grey snow at Geneva.
„ 26	... ...	Earth shock at Vienna		
„ 27	... ...	... ...	New eruption, Mt. Pelée	
„ 28	... ...	In Cape Peninsula	Ditto	

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
May 30	... ...	... ...	Pelée and St. Vincent's Soufrière violent.	
„ 31	Crosses Equator			
June 1	... ...	... ...	The Hawaiian volcanoes Kilauea and Mokuoweoweo active.	
„ 5	Perigee and New	Earthshock in Cornwall	Mud volcanoes near Baku in eruption	Volcanic dust falls in England.
„ 7	... ...	Upheavals of the sea between St. Vincent and Santa Lucia	Violent outbursts near Fort de France, Martinique, and La Soufrière, St. Vincent, active.	Plains covered with hot mud.
„ 12	Crosses Equator			
„ 17	... ...	Earth shocks at Mallilla South Sweden, and at Oloron St. Marie, France.		
„ 19	Apogee	Earthquakes in India, extending from Simla to Chitral in the Himalayas.	Basse Point in Martinique buried in mud.	
„ 20	Full	... ...	Several rivers boiling in Martinique.	
„ 22	... ...	Violent earthquake at Cassano in Calabria.		
„ 27	Crosses Equator			
July 4	Perigee			

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
July 5	New			
„ 8	... ...	... ...	The volcanoes Miraballes and Rinçon, Costa Rica active.	See *S. M. Herald*, July 10, 1902.
„ 9	Crosses Equator	... ...	Terrifying eruption of Mt. Pelée.	See *S. M. Herald*, July 12, 1902.
„ 13	... ...	Earthquakes at Bunder Abbas in Persia commence.		
„ 14	... ...	Violent earthquake in Venezuela.		
„ 15	... ...	Earthquakes in the Bunder Abbas region continue till July 20, and violent earthquakes in the Caucasus region last from July 16th to the 19th.		
„ 16	Apogee			
„ 17				
„ 18				
„ 19	... ...	Caucasus ends.		
„ 20	Full	Bunder Abbas ends.		
„ 21	... ...	Terrific earthquake in St. Vincent.	... ...	Sea recedes.
„ 24	Crosses Equator			
„ 29	... ...	... ...	Eruption of La Soufrière.	Tidal wave: depth of sea N. of St. Vincent increased 6,600 feet.

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
July 30	... ...	75 earth shocks in California in five days.		
August 1	Perigee	Shocks in California continue.		
,, 3	New			
,, 6	Crosses Equator	Shocks in Portugal and Italy.	... ...	Annual flood of the Nile the lowest on record (*S. M. Herald* August 7th, 1902).
,, 13	Apogee			
,, 18	Full			
,, 19	... ...	... ...	Volcano in Tori Shama, Japan, has broken out and overwhelmed the island.	
,, 20	Crosses Equator	... ...	Mt. Pelée in eruption.	
,, 23	... ...	Earthquakes in Central Asia (probably between Aug. 17 and 20 *S.M.Herald* Aug. 22).	... ...	Rains in India, famine averted (*S. M. Herald* August 23).
,, 28	Perigee	Severe earthquake in the Philippines.		
,, 30	... ...	Earthquakes in Venezuela and the whole Caribbean area.	Mt. Pelée again violent.	
Sept. 1	New			
,, 2	Crosses Equator			

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions	Notes.
Sept. 6	... ...	Earthquake caused disappearance of the island of Bermega.	La Soufrière violent.	
,, 9	Apogee			
,, 10	... ...	... ...	Vesuvius active.	
,, 11	... ...	... ...	Kilauea, Stromboli, and two Alaskan volcanoes active.	
,, 12	... ...	Earth shock at Adelaide South Australia.		
,, 17	Full and crosses Equator			
,, 22	... ...	Earthquakes, Ecuador Guatemala, Honduras and St. Vincent.	Violent eruption of La Soufrière.	Equinox Season.
,, 23	Perigee			
,, 28	... ...	Earth shocks at Montièrs in France.	Etna active.	
,, 30	Crosses Equator			
Oct. 1	New			
,, 3	... ...	Tremors at Clarendon, South Australia.	Lake Eacham near Herberton, Q., reported to be boiling.	
,, 7	Apogee			
,, 14	Crosses Equator			
,, 16	Full			
,, 17	... ...	Tremors in Scotland.	St. Vincent's Soufrière in full eruption.	
,, 19	Perigee			
,, 20	... ...	Shocks in Tennessee; shocks at Young, N.S.W., and in N.W. Georgia, U.S.A.	La Soufrière violent.	Ashes falling in the Barbados.
,, 27	Crosses Equator			

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
Oct. 29	... ...	... ...	Eruption in Savaii, Samoa	
,, 30	New			
Nov. 4	Apogee			
,, 11	Crosses Equator			
,, 12	... ...	... ...	The volcano Santa Maria in Guatemala buried the towns of Palmar, San Filipe, Coatepec and Columbia.	See *S. M. Herald*, Nov. 13th. Duststorms and fireballs in Australia; Leonid meteors.
,, 13	... ...	... ...		
,, 15	Full	... ...	Stromboli detonating, Nov. 15th to 18th.	
,, 16	Perigee			
,, 18	... ...	Severe earthquakes in Algeria; two shocks in Utah, U.S.A.	Great eruption of Stromboli.	
,, 19	... ...	... ...	Soufrière in violent eruption.	Cone of Mount Pelée growing at a rate of 100 metres per month.
,, 20	... ...	... ...	... ...	Tidal wave in South Australia (Glenelg).
,, 23	Crosses Equator			
,, 29	New			
Dec. 2	Apogee			
,, 8	Crosses Equator			
,, 14	Full			
,, 15	Perigee			
,, 16	... ...	Andijan earthquakes, continued some time.		

1902. Date	The Moon.	Earthquakes.	Volcanic Eruptions.	Notes.
Dec. 20	Crosses Equator			
,, 23	... ...	Earthquakes at Andijan and Askabad		
,, 29	Apogee : New			
1903 Jan. 4	Crosses Equator			
,, 12	Perigee			
,, 13	Full			
,, 17	Crosses Equator			
,, 25	Apogee			
,, 28	New			
Feb. 1	Crosses Equator			
,, 10	Perigee			
,, 11	Full			
,, 13	Crosses Equator			
,, 22	Apogee	... ...	Mount Colima in eruption from Feb. 21 to 24.	
,, 26	New			
,, 28	Crosses Equator			
Mar. 7	... ...	Earthquake Dominica, West Indies, and at Aquila near Rome.		
,, 10	Perigee			
,, 12	... ...	... ...	Eruption of Vesuvius.	
,, 13	Full, crosses Equator			
,, 21	Apogee			
,, 27	Crosses Equator			
,, 28	New			

1903. Date	The Moon.	Earthquakes.	Volcanic Eruptions.
April 3	... ...	S. Urals and Andijan,	
,, 4	... ...	Catania and Mentone	
,, 5	Perigee		
,, 9	Crosses Equator		
,, 11	Full		
,, 18	Apogee		
,, 24	Crosses Equator		
,, 27	New		
,, 29	... ...	Severe in Armenia.	
,, 30	Perigee		
May 6	Crosses Equator		
,, 11	Full		
,, 16	Apogee		
,, 21	Crosses Equator		
,, 26	New		
,, 28	Perigee		
June 4	Crosses Equator		
,, 9	Full		
,, 13	Apogee		
,, 17	Crosses Equator		
,, 24	New		
,, 25	Perigee	Earthquake in Hungary	
,, 30	Crosses Equator		
July 9	Full		
,, 10	Apogee		
,, 15	Crosses Equator		
,, 21	... ...	At St. Vincent	
,, 23	Perigee		
,, 24	New		
,, 26	Crosses Equator	Severe shocks, Grenada July 26th to 28th	
,, 31	... ...	Shocks at Fillatiera and Mulazzo in Italy	
Aug. 6	Apogee		
,, 7	Full		
,, 9	... ...	Earthquake at Lisbon.	
,, 11	Crosses Equator	Malta, Naples, Canea,	
,, 21	Perigee	Syracuse disturbed.	
,, 22	New	... ...	Violent explosions in Vesuvius.
,, 24	Crosses Equator		
,, 26	... ...	... ...	Crater of Vesuvius opened and lava flows from it.
Sept. 2	Apogee		
,, 6	Full		
,, 7	Crosses Equator		

1903. Date	The Moon.	Earthquakes.	Volcanic Eruptions.
Sept. 18	Perigee	... ...	
,, 19	... ...	At Santiago de Cuba	
,, 20	Crosses Equator		
,, 21	New	Canaries, Blidah and in Algiers.	
, 22	Equinox		
,, 30	Apogee		
Oct. 5	Crosses Equator		
,, 6	Full		
,, 16	Perigee		
,, 18	Crosses Equator		
,, 20	New	... ...	Vesuvius active.
,, 28	Apogee		
Nov. 1	Crosses Equator		
,, 4	Full		
,, 10	Perigee		
,, 14	Crosses Equator		
,, 18	New		
,, 25	Apogee		
,, 28	Crosses Equator		
Dec. 4	Full		
,, 6	Perigee		
,, 11	Crosses Equator		
,, 18	New		
,, 22	Apogee		
,, 26	Crosses Equator		

ON EUCALYPTUS KINOS, THEIR VALUE FOR TINCTURES, AND THE NON-GELATINIZATION OF THE PRODUCT OF CERTAIN SPECIES.

By HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N.S. Wales, August 3, 1904.*]

THE greatest objection to the kino of *Pterocarpus marsupium* is the tendency it has to gelatinize when made into tinctures. Many methods have been advanced at one time or another to overcome this difficulty, but in most cases with doubtful success, as at present more than one Pharmaceutical Association is requesting a formula for tincture of kino that will keep. From the results of this investigation it appears that the best way to overcome this difficulty is to discard *Pterocarpus* kino altogether, and to *use those Eucalyptus kinos that do not gelatinize in tinctures.* Pharmacists need not be troubled with gelatinized tincture of kino no matter how long it is kept.

In the Pharmaceutical Journal (1841-2, p. 399) there is a paper by Mr. Redwood which is well worth reading by those interested in this matter. He there discusses the formation and constitution of this gelatinous substance, and calls attention to the statement by Dr. Thomson that the product of *Eucalyptus resinifera*[1] has the property of forming a tincture which gelatinizes on keeping. Dr. Pereira also states that when gelatinized tincture of kino occurs, that probably the Botany Bay kino (inspissated juice of *Eucalyptus resinifera*) had been employed (4th Edition,

[1] *Eucalyptus resinifera,* as we know it to day, has practically a Stringy Bark, and the "Ironbark" kinos (as *E. siderophloia*) consist largely of *Emphloin* and do not dissolve in alcohol.

Vol. II., p. 327). I have mentioned these statements to indicate how easily a whole group of substances may be condemned on the unsatisfactory behaviour of perhaps but one member. What the species of Eucalyptus was from which that kino was obtained it is not now possible to say. The present day *E. resinifera* only exudes kino in very small amount, so that it could not be collected in sufficient quantity to be of any use commercially, even if the kino was of use for tincture, which it is not. It is probable that the "Botany Bay kino" above referred to was the product of several species of Eucalyptus collected indiscriminately, and owing to the facility with which it gelatinized in tinctures, it probably contained a predominance of kinos obtained from such species as *E. pilularis*, *E. piperita*, *E. hæmastoma*, etc., trees which were at that time plentifully distributed throughout the vicinity of Botany Bay. That this is so, is shown from the description given by Dr. Pereira[1] of the kino from Botany Bay that he had met with, which was in irregular odourless masses, many of which were in the form of tears. Some were almost black, and when digested in water, swelled and became soft and gelatinous, like red currant jelly. The kino also acted similarly when digested in rectified spirit. There seems little doubt from the above that that particular sample of kino was of considerable age, and that it was obtained from species allied to the "Stringybarks," or the "Peppermints," because with age all this class of kinos become almost black, and are then but little soluble in either water or alcohol, but swell up like a jelly. The sample could not have been obtained from *E. siderophloia*, which species has been thought to have been the original *E. resinifera*, because the solubility of the "Ironbark" kinos in water is but little impaired by age.

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[1] Pereira, Mat. Med. 4th Ed., Vol. II., pp. 237-8 (1857).

On the other hand the "New Holland kino" mentioned by Dr. Thomson[1] as being procured by wounding the *Eucalyptus resinifera*, gave a brown chocolate powder on which cold water acted but slowly, but boiling water formed a deep cherry-red solution which threw down a brick coloured precipitate on cooling. The solution was coloured *deep green* by sesquichloride of iron. From these reactions it is certain that that sample of kino was not obtained from any species belonging to the "Ironbarks," or the "Stringy-barks," or the "Peppermints." The above statements denote clearly that no care was taken to distinguish between products of separate species.

At the International Exhibition of 1862 a collection of vegetable products was exhibited from Tasmania, and in a series of notes on these by Mr. W. Archer, F.L.S., published in the Technologist, appears the following:—"This gum, which seems to have similar properties to those of the East Indian kino, exudes from woods of all the Tasmanian species of Eucalyptus." That these exudations were at that time, collected without discrimination, is indicated by the above statements.

The evidence which will be submitted later will illustrate how unsatisfactory these Eucalyptus kinos must be when so collected, and it also offers an explanation for the non-agreement in the experiences of various writers, who have described their successes or otherwise with particular methods suggested at various times for the preparation of tincture of kino.

In the journals devoted to pharmacy much information may be found dealing with this subject. It has been supposed that glycerol had the desired effect of preventing gelatinization, and its addition is of course official, but R.

[1] Thomson, Mat. Med. p. 678 (1843).

Rother[1] considers glycerol "as unsatisfactory as all other agents previously tried. The alleged occasional success with sundry corrigents can only be accounted for by the fact that there are numerous varieties of kino, and that one or more of these may not be susceptible of this change." It is very probable that this is so, and it is remarkable that while some Eucalyptus kinos gelatinize very readily, others do not do so even after the lapse of many years.

About seven years ago I made tinctures (1 in 10) of half a dozen Eucalyptus kinos, but omitted the glycerol. These were put up in glass stoppered bottles and kept in the dark continuously. The kinos of *E. amygdalina*, *E. macrorrhyncha* and *E. piperita* readily gelatinized and formed a perfect jelly after a comparatively short time. The kino of *E. corymbosa* has become thick but not even now a jelly, that of *E. punctata* has slightly thickened, but the kino of *E. calophylla* has undergone no alteration after all these years. The evidence thus obtained has been followed up with gratifying results.

The questions naturally arising are, why this variability in gelatinization when the tinctures are made under identical conditions, and what is the cause of the gelatinization? These will be considered together. It may perhaps be generally accepted that the cause of the gelatinization is the same in those Eucalyptus kinos which gelatinize and in the kino of *Pterocarpus marsupium*.

Pereira considered the jelly to consist principally of pectin and tannic acid (page 238) and Dorvault that it was pectic acid, but Mr. Redwood (*loc. cit.*) after experiment, arrived at the conclusion that neither pectin nor pectic acid was present in the jelly, but thought that the change was traceable to "ulmic acid" or "humus."

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[1] American Journal of Pharmacy, 1886, and Pharm. Journ., July 1886, p. 67.

Mr. J. H. Hustwick[1] points out that with one sample of kino he obtained gelatinized and non-gelatinized tinctures by different methods of working. In one case he treated the granular kino with the alcohol without powdering, and consequently an insoluble portion was left which was discarded; this tincture kept well and was as fluid after two years as when made. In the other the kino was powdered and this tincture readily gelatinized. I have referred to this peculiar experience because it bears directly upon what will be shown later.

Mr. Rother (*loc. cit.*) suggests the addition of catechu to the tincture to prevent gelatinization, but from my experiments the addition of a moderate amount of a non-gelatinizable kino to a gelatinizable one does not prevent the ultimate production of a jelly, although it retards it considerably, and in direct ratio to the amount of the former kino or tincture added. (See Table III.)

Mr. G. W. Kennedy[2] advocates the addition of logwood, but it is probable that this acts in the same way as does catechu, and I do not think it would be finally successful unless it was added in large amount.

Mr. G. M. Beringer[3] describes a method for making the tincture with diluted alcohol, but this apparent improvement was probably due to most of the active gelatinizing principle in the kino being left behind in the "dregs" on the filter. Nor will the freshness of the kino help permanently although of some advantage, but fresh or aged the cause of the gelatinization appears to be present in the kino, and will naturally do its work in time. So it is with the Eucalyptus kinos that gelatinize, and Mr. Maiden's qualification[4] for Eucalyptus kinos that will make satis-

[1] Pharm. Journ. [3] 2. 260.
[2] American Journ. of Pharm., Feb. 1880.
[3] American Journ. of Pharm., 1903, p. 378.
[4] Pharm. Journ., Oct. 1889, p. 323.

factory tinctures will unfortunately not now hold, because those Eucalyptus kinos which are, when fresh, completely soluble in cold water as well as in alcohol, are those that gelatinize the most readily. These rapidly gelatinizable kinos are numerous, and are obtained from Eucalypts whose oils contain the terpene phellandrene, such species are *E. pilularis*, *E. piperita*, *E. amygdalina*, (and its allies), *E. hæmastoma*, *E. obliqua*, *E. macrorrhyncha*, *E. Sieberiana*, *E. oreades*, etc. It is a pity that this gelatinization takes place so readily, because these soluble kinos are the most astringent, and when quite fresh are almost as astringent as gallo-tannic acid itself, but owing to the objectionable property of gelatinizing, the whole of the members of this class of Eucalyptus kinos will have to be discarded for tincture making. It should be possible, however, to use them in other directions, but the method by which this could be done is a matter for future determination. Fortunately there are several Eucalyptus kinos which do not gelatinize in tinctures, and these are almost equally astringent with those kinos mentioned above and are readily obtainable.

The kinos of the Eucalypts contain at least three tannins determinable by reagents; two of these gelatinize in tinctures, the other does not. Of the two gelatinizable tannins the one which gives the violet colour and precipitate with ferric chloride gelatinizes much more readily than the one which gives a green colour with ferric chloride.[1] It is possible that the tannins in these kinos may be separated, perhaps through their copper salts.

It was the somewhat regular increment of particular oil constituents in progressive species that enabled the new

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[1] The late Mr. Henry Trimble (the author of "The Tannins") expressed an opinion to the author of this paper, that eventually a new tannin might be isolated from the Eucalypts, and the results here recorded support strongly that supposition.

substances to be most easily isolated. The chemistry of the kinos appears to run in a parallel direction, so that it is possible by following down the species, to find a kino in which a required tannin occurs in a maximum amount.

As two only of these kino tannins appear to gelatinize in tinctures, the cause of the gelatinization may perhaps be indicated. The latest suggestion is that advanced by Mr. E. White[1] where he endeavours to show that the formation of gelatinized tincture of kino is due to the presence of an enzyme. Whether this is so can only be completely solved by its isolation. If an enzyme is the cause then it seems strange that it only acts on certain of these kino tannins, if an oxydase then the product of its action does not form a solid compound with one at least of these tannins. That some action of this sort does take place is suggested by the rapidity with which some of the tannins in Eucalyptus kinos may be made to gelatinize by the addition of a very small amount of formaldehyde, and in a lesser degree by acetaldehyde. The rapidity of the gelatinization brought about by the addition of a few drops of formaldehyde, or of acetaldehyde, can be seen from the tabulated results (Table I.) These results are comparable with those obtained with the tinctures tested by age alone in the ordinary way. The test seems to be a reliable one and by its aid it appears possible to determine whether a kino will gelatinize in tinctures or not. No doubt the test is a severe one and will detect all kinos that might possibly gelatinize.

Although it may not be easy to isolate the unorganised ferment, if such is present, yet, it is not difficult to isolate and grow the organised substance which appears to be present in most Eucalyptus kinos. This substance is easily obtained from those kinos which gelatinize the most readily. It always grows at the bottom of the diluted aqueous kino

[1] Pharm. Journ., May 1903, p. 644, and Nov. 1903, p. 702.

solution and appears to start from the particles of kino which are always left undissolved. Mr. S. J. Johnston, B.A., B.Sc., of the Technological Museum is making an investigation of this organism, and its description will appear later.

The following list gives the general chemical reactions and astringency values of the Eucalyptus kinos dealt with in this paper, and it will be seen that associated kinos behave similarly. In no instance did the time allowed for precipitates to form extend beyond one hour. The method of determining the astringency values was described in the previous paper on the kino glucoside, the strength of the solution being one gram per litre.

The method adopted for taking the colour reaction with ferric chloride was to have a full test tube, standing before a window, and to allow one drop of the reagent to fall through the solution without agitation; the strength of the kino solution for this test was 0·33 gram per litre. The best results were obtained with a solution of this strength. The other tests were made with kino solutions of one gram per litre.

Most Eucalyptus kinos contain mixed tannins and the reactions are, therefore, largely governed by the predominant tannin present. The tannins which give violet and green colorations with ferric chloride gelatinize in tinctures, the former much the more readily, but the one giving the blue coloration does not gelatinize. It is also possible to detect the diminution or otherwise of the individual tannins by the reaction with ferric chloride and by the astringency value and the gelatinization test. The changes that take place in the colour reaction, together with the results of other reagents are not given in the table, as they have little bearing on the results of gelatinization. Those Eucalyptus kinos that give a blue coloration with the ferric salt, a sparce precipitate slow to form with iodine in potassium iodide, and a comparatively small amount of the copper salt insoluble in ammonia, all contain in excess the tannin which does not gelatinize in tinctures.

	Astringency Value.	Coloration at once with Ferric chloride.	Iodine in Potassium Iodide.	Bromine water.	Cupric sulphate and ammonia in excess.	Zinc acetate.
E. Sieberiana ...	777	violet	dense ppt. soon forming	ppt. at once	dense floccu-lent ppt.	ppt at once
E. dives	777	ditto	ditto	ditto	ditto	ditto
E. pilularis ...	838	ditto	ditto	ditto	ditto	ditto
E. corymbosa ...	694	green	ppt. soon forms	ditto	not a large ppt.	ditto
E. trachyphloia ...	729	greenish purple	ditto	ditto	consider-able ppt.	ditto
E. rostrata ...	541	green	precipit. slowly forms	ditto	finely di-vided pre cipitate	ditto
E. rostrata, Bosisto, Victoria	576	green	ditto	ditto	ditto	ditto
E. goniocalyx ...	435	green	ditto	ditto	not large ppt.	ditto
E. Woollsiana ...	235	reddish-brown	ditto	ditto	very slight ppt.	turbidity
E. melliodora ...	247	bright-green	ppt. very slow to form	ditto	no ppt.	ditto
E. populifolia ...	518	purplish grey	ppt. slow to form	ditto	very slight ppt.	ppt. at once
E. Bridgesiana ...	412	greenish grey	ditto	ditto	slight ppt.	ditto
E. hemiphloia ...	200	reddish-brown	ditto	ditto	very slight ppt.	turbidity
E. pendula ...	482	purplish grey	ditto	ditto	fair ppt.	ppt. at once
E. Smithii ...	565	bluish-green	ditto	ditto	slight ppt.	ditto
E. Dawsoni ...	541	purplish grey	ditto	slight ppt.	consider-able ppt.	ditto
E. intertexta ...	518	brownish grey	ppt. very slow to form	ditto	ditto	ditto
E. oleosa	717	violet	consider-able ppt. soon forms	ppt. at once	ditto	ditto
E. calophylla 1897	753	blue	ppt. very slowly forms	ppt. soon forms	slight ppt.	ditto
E. calophylla 1895	729	ditto	ditto	ditto	ditto	ditto
E. eximia... ...	435	ditto	ditto	ditto	ditto	ditto
E. microcorys ...	741	ditto	no ppt.	no ppt.	ditto	ditto
E. maculata ...	612	ditto	turbidity	slight ppt.	small ppt.	ditto
Gallo-tannic acid	1000	ditto	no ppt.	no ppt.	consider-able ppt.	ditto

From the following tables which deal with the results of the gelatinization of the tinctures, it is apparent that some species of Eucalyptus give kinos of great excellence for tincture making. They do not gelatinize even after many years, and the addition of glycerol is not needed. The probable gelatinization of all kinos can also readily be determined by simple tests. The kinos here listed were chosen as being representative of the whole 100 species of Eucalyptus examined. The remainder, not here enumerated, gave the chemical reactions agreeing with these, but so far as this investigation has gone no others were detected giving indications of non-gelatinizable kinos. The list of these is thus restricted to the four following species:—

1. "Tallowwood," *Eucalyptus microcorys*, Eastern Australia.
2. "Red Gum," *Eucalyptus calophylla*, Western Australia.
3. "Mountain Bloodwood," *Eucalyptus eximia*, Blue Mountains, N. S. Wales.
4. "Spotted Gum," *Eucalyptus maculata*, Eastern Australia.

The kinos of *E. eximia* and *E. maculata* (being closely related chemically) give precipitates when diluted with water, which peculiarity might be an objection to their use pharmaceutically. The tincture of *E. calophylla* gives only a slight turbidity when diluted with water, while the tincture of *E. microcorys* remains perfectly clear and transparent on the addition of water.

There seems but little to choose between the kinos of *E. microcorys* and *E. calophylla* for tincture making. The latter, however, can be readily obtained in any quantity. They do not undergo change when kept in the dry state. There seems no reason, apparently, why the kinos of some Eucalyptus species should not eventually replace, for medicinal and official purposes, all other kinos from whatever source obtainable.

TABLE I.

This table shows the comparative rates of gelatinization of tinctures (1 in 10) of the following Eucalyptus kinos with

(*a*) Formaldehyde—commercial formalin of which 20 drops from the same pipette contained ·191 gram HCHO.

(*b*) Acetaldehyde, of which 20 drops contained ·091 gram CH_3CHO.

Experiments were commenced 14th January 1904, when 5 drops of each aldehyde were added to 5 cc. of separate tinctures of each kino, agitated, and stood on one side for 20 hours.

After that time, to those tinctures which had not solidified, 5 drops more of each aldehyde were added to the respective tinctures, and these again stood for 20 hours.

To those tinctures which had not solidified, 5 drops more of aldehyde were again added to the respective tinctures, and observation repeatedly made until 1st July, 1904. 5 cc. of tincture were taken in all cases. Those tinctures which slowly solidified became much thicker previous to forming a jelly. In the table the following may also be noted :—

(*a*) *E. pilularis* being a quite fresh kino did not so readily gelatinize with acetaldehyde as did the kino of *E. dives*.

(*b*) *E. pilularis* after boiling acted similarly to the unboiled kino.

(*c*) *E. Woollsiana*, *E. hemiphloia*, *E. pendula*, and *E. intertexta* did not form homogenous jellies with formaldehyde, but a precipitate separated.

(*d*) *E. rostrata* and *E. calophylla* (2 samples of each) show that the kinos from identical species of Eucalyptus act similarly irrespective of location or date, again illustrating the chemical constancy of Eucalyptus species.

	Formalin 5 drops	Formalin 10 drops	Formalin 15 drops	Acetaldehyde 15 drops
E. Sieberiana, collected May 1899	15/1/04 brown jelly formed	...	...	2/2/04 jelly formed
E. dives, Oct. 1898	,,	...	...	2/3/04 jelly formed
E. pilularis, Jan. 1904	,,	...	...	1/7/04 very thick but not a solid jelly
E. corymbosa, April 1889	15/1/04 no change	16/1/04 light brown jelly form ed	...	1/7/04 had thickened considerably
E. trachyphloia	,,	16/1/04 no change	18/1/04 plum coloured jelly formed	1/7/04 thickened a little
E. rostrata, March 1903	,,	,,	18/1/04 dark salmon coloured jelly formed	1/7/04 still fluid
E. rostrata, Bosisto, Victoria	,,	,,	,,	,,
E. goniocalyx, April 1889	,,	,,	21/1/04 salmon coloured jelly formed	,,
E. Woollsiana, April 1901	,,	,,	10/2/04 partly solid and partly fluid	1/7/04 a homogenous salmon color'd jelly formed
E. melliodora, March 1903	,,	,,	25/1/04 salmon coloured jelly formed	1/7/04 still fluid
E. populifolia, Nov. 1899	,,	,,	18/1/04 salmon coloured jelly formed	,,
E. Bridgesiana, March 1899	,,	,,	22/1/04 salmon coloured jelly formed	1/7/04 thickened a little
E. hemiphloia, Dec. 1900	,,	,,	25/4/04 partly solid and partly fluid	1/7/04 still fluid
E. pendula, Dec. 1900	,,	,,	,,	,,
E. Smithii, Oct. 1900	,,	,,	22/1/04 salmon coloured jelly formed	,,

	Formalin 5 drops	Formalin 10 drops	Formalin 15 drops	Acetaldehyde 15 drops
E. Dawsoni, Oct. 1893	15/1/04 no change	16/1/04 no change	18/1/04 salmon coloured jelly formed	1/7/04 thickened a little
E. intertexta, May 1903	,,	,,	25/4/04 partly solid and partly fluid	1/7/04 partly solid and partly fluid
E. oleosa, May 1903	,,	16/1/04 light brown jelly formed	...	1/7/04 had thickened considerably
E. calophylla, June 1897	,,	16/1/04 no change	1/7/04 as fluid as when put up	1/7/04 as fluid as when put up
E. calophylla, Dec. 1895	,,	,,	1/7/04 no change	1/7/04 no change
E. eximia, Jan. 1898	,,	,,	,,	,,
E. microcorys, April 1896	,,	,,	,,	,,
E. maculata, July 1898	,,	,,	,,	,,
E. pilularis, boiled kino.	15/1/04 brown jelly formed	...	...	1/7/04 thickened but not yet a jelly
Angophora intermedia April 1888	15/1/04 no change	16/1/04 no change	19/1/04 dark brown jelly formed	20/1/04 dark brown jelly formed
Pterocarpus marsupium India	,,	16/1/04 brown jelly formed	...	2/3/04 quite thick 25/4/04 brown jelly formed
Eucalyptus paniculata March 1904	A tincture (1 in 10) was made of this kino by dissolving in a small quantity of water, adding twice the amount of 90% alcohol, and filtering from the small quantity of bark. To 5 cc. of tincture 5 drops of formalin were added. Next day a perfect jelly had formed. The tannin in the "Ironbarks" is thus again shown to be allied to that of the "Peppermints" as *E. dives*, etc.			

Table II.

This table shows the influence a slowly gelatinizable kino, like that of *Eucalyptus Woollsiana*, has upon a rapid gelatinizable one, like that of *Eucalyptus dives*. The mixtures were prepared on the 21st January 1904, and five drops of commercial formalin added to each.

	22/1/04	23/1/04	25/1/04	26/1/04	22/2/04
0·5 cc. of *E. Woollsiana* 4·5 cc. of *E. dives*	slight jelly	solid jelly formed	...	...	purplish-brown jelly
1 cc. of *E. Woollsiana* 4 cc. of *E. dives*	thickened a little	solid jelly formed	...	...	brown jelly
2 cc. of *E. Woollsiana* 3 cc. of *E. dives*	no change	slight jelly	solid jelly formed	...	jelly becoming salmon coloured
3 cc. of *E. Woollsiana* 2 cc. of *E. dives*	...	no change	thickened a little	solid jelly formed	dark salmon coloured jelly
4 cc. of *E. Woollsiana* 1 cc. of *E. dives*	...	...	no change	thickened a little	salmon coloured jelly

NOTE.—The predominant colours of these jellies are those of the jellies of the individual kinos themselves, showing that these colours are not accidental.

TABLE III.

This table shows the preventative action a non-gelatinizable kino like that of *Eucalyptus calophylla*, has when mixed with a gelatinizable one, like that of *Eucalyptus pilularis*. Tinctures of the two kinos were combined in the proportions stated, and five drops of formaldehyde (commercial formalin) added to each mixture. The mixtures were prepared on the 11th February, 1904.

	12/2/04	13/2/04	15/2/04	17/2/04	18/2/04	25/4/04
0·5 cc. of *E. calophylla* 4·5 cc. of *E. pilularis*	thicken'd a little	solid jelly formed				
1 cc. of *E. calophylla* 4 cc. of *E. pilularis*	no change	solid jelly formed				
2 cc. of *E. calophylla* 3 cc. of *E. pilularis*	...	thickened a little	solid jelly formed			
3 cc. of *E. calophylla* 2 cc. of *E. pilularis*	...	no change	no change	slight jelly	solid jelly formed	
4 cc. of *E. calophylla* 1 cc. of *E. pilularis*	...	...	...	no change	no change	slight jelly, solid on April 30

NOTES ON THE THEORY AND PRACTICE OF CONCRETE-IRON CONSTRUCTIONS.

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[With Plates III. - VI.]

[*Read before the Royal Society of N. S. Wales, September 7, 1904.*]

IN presenting the following notes on concrete-iron construction, the author's object is to place before you a digest of the opinions of leading authorities on the subject, moulded together to represent a correct view from the present standpoint of scientific research on this subject. As the constant mentioning of the authorities from whom data have been obtained would become tedious, the author has abstained from quoting them, and it is to be understood that the general term "concrete-iron" includes "concrete-steel," the word iron being used in its generic sense.

"Concrete-iron" is the designation applied to those constructions which consist of Portland cement concrete and iron insertions, both so intimately united that the constructions act as homogeneous bodies when taking up stresses, and at the same time allow the utilisation of each material to its utmost limit. The great success of this combination is due to the following characteristics, five in number, which may be called the fundamental and essential principles :—

1. The thermal coefficients of expansion and contraction of the two materials are nearly equal.

The coefficient of expansion and contraction for cement concrete for each degree Celsius (1° C.) may be taken as 0·0000137, and for iron as 0·00001235. These differences of the coefficients although so small nevertheless set up stresses in the body under great variations of temperature, so that it becomes necessary to ascertain their extent in order to judge if they are of sufficient importance to need further consideration.

The greatest variations of temperature to which under ordinary circumstances an engineering construction would be subject to, do not exceed 100° C. or 180° F. The effect of that variation on a concrete-iron construction 16 inches thick with two layers of round iron half an inch diameter embedded 3 inches apart, would give a maximum compression of 14·25 lbs. per square inch on the concrete, and a maximum tension of 1743 lbs. per square inch on the iron. The opposite effect would be produced by an equal decrease in the temperature. From this it is evident that the stresses so produced are of no real consequence, and therefore unnecessary to take into calculation.

Even under high and rapid variations of temperature no disunion of the concrete and iron materially affecting its carrying capacity takes place, due no doubt to the protection afforded the iron by the concrete. This has been conclusively proved by practical tests, and by the recent experiences in the great Baltimore fire, one of the largest conflagrations of modern times, where the concrete-iron constructions withstood the attack of a fierce fire for hours without sustaining damage affecting their stability.

2. The fact that cement is a preservative of iron against corrosion is so well known that it need not be further dwelt upon.

3. The adhesion of concrete to iron may be very cousiderable, according to the richness of the concrete mixtures, and may in general be taken as equal to the shearing strength of the concrete. The values ranging from 250 to 450 lbs. per square inch. The higher values being obtained from tests with thick iron rods, and

concrete of a high elastic limit, and are independent of whether the iron be smooth or rough.

4. Concrete with iron insertions can undergo elongations which far exceed those of ordinary plain or unarmoured concrete, and generally speaking may be stated to be from 10 to 20 times greater.

Test pieces made to ascertain the elongations of plain and armoured concretes, consisted of prisms of square cross-section of 2·36 inches sides, and 23·6 inches length. Each prism was fixed vertically, well clamped at the lower end—while over the top was fitted a horizontal lever by means of a square eye of the dimensions of the cross-section of the prism. At the end of this lever the loads were applied, and by this method of testing equal bending moments were created in all cross-sections producing elongations on the one side and shortenings on the other. The concrete in all the prisms consisted of 1 of cement to 3 of sand.

The concrete-iron or armoured prisms contained 3 iron rods of 0·167 inch diameter, which latter had an elastic limit of 54,000 ℔s. per square inch. The plain concrete prisms showed just before fracture a shortening of ·0037 inch per lineal foot on the compressive side and an elongation of ·0024 to ·003 inch per lineal foot on the tension side. The concrete-iron prisms showed an elongation of ·024 inch or a ten times greater lengthening than occurred in the plain concrece prisms.

Further tests proved that a prism of concrete composed of 1 part cement, 2 of sand, and 4 of broken stone, 3·9 inch square, 6·56 feet long, with 4 iron rods of ·023 inch diameter inserted, could endure an elongation of ·007 to ·016 inch per lineal foot without fracture, whereas the plain concrete prisms did not elongate more than from ·0018 to ·0036 inch before fracturing.

In order to show that such elongations could be endured by the concrete without affecting its strength materially, a test was made with a piece of concrete cut out of the concrete-iron prism after the removal of the iron, and it withstood when subjected to direct compression a compressive stress of 1646 lbs. per square inch, with a coefficient of elasticity of 2,130,000 lbs. A block of plain concrete similar in aggregates, but which had not previously been used for test purposes, crushed with 1987 lbs. per square inch and showed a coefficient of elasticity of 4,400,000 lbs.

The observations made on a buoy of hollow iron $7\frac{1}{2}$ inches diameter and filled with cement mortar, erected on a rock at Gorlé-Bian in France, supplies a striking example of the ductility of cement mortar or concrete. The waves bent the buoy to a radius of 1·8 feet measured from the axis of the buoy. Upon cutting same open along its axis the cement mortar was found to consist of bent pieces, which were with the exception of a few abrasions, otherwise intact, and whose deformations as regards displacement of the fibres, amounted to 2·4 inches to the foot. From the above data it is evident since the elongations in constructions do never exceed ·0035 inches per lineal foot, that the concrete possesses the power of elongation sufficient for all practical purposes.

5. The combined materials are capable of acting as one body in taking up stresses when subject to bending moments.

In order that this characteristic may be considered in its entirety, it becomes necessary to deal first with some stresses otherwise created, which considerably affect the issue of this statement. The stresses referred to are caused by the alteration of the volume of concrete.

1. By contraction when hardening in air.
2. By expansion when hardening in water.

These alterations of volume are the greater the richer the concrete used, and the amount ranges for pure cements from ·018 to ·024 inches per lineal foot, and for poorer mixtures from ·0036 to ·0006 inch.

Plain concrete bodies expanding and contracting without outside resistance, remain free of internal stresses, but when iron rods are inserted in the concrete and the latter allowed to harden in the air, the rods tend to prevent the contraction of the concrete, causing tensile stresses in the latter and compressive stresses in the iron, the amount depending on the concrete mixture and the sectional area of the iron.

Some concrete-iron prisms of square cross-section with 3·9 inches sides, 6·56 feet long, and with 4 iron rods inserted, each ·023 diameter, and of a concrete proportioned of 1 part cement, 2 of sand and 4 of broken metal were allowed to harden in the air. The shrinkage or contraction amounted to ·0025 inch per lineal foot, which expressed in stresses means that the iron was subjected to a compression of 6,527 ℔s. (per square inch), and the concrete to a tension of 74 ℔s. per square inch. From this it is evident that the two materials through the above causes may become subject to considerable initial stresses which will have the effect of increasing the deformations of the construction when under loading.

To minimise the effect caused by hardening of concrete in the air, it is advisable and even necessary to keep concrete-iron constructions as damp as possible during the earlier stages of hardening, the longer and more thoroughly this is attended to, the better are the results achieved.

When concrete-iron constructions harden in water the opposite effect to hardening in air is produced, viz., compressive stresses occur in the concrete and tensile in the iron, the amount varying according to the aggregate of the concrete, and the percentage of iron used. In this case the initial stresses so produced are of actual benefit to the construction, inasmuch as when the same is subject to loading, the iron being in tension comes at once into action. Further, concrete which has hardened in air will expand when absorbing water, and contract again when drying out. The effects of these hygrometrical alterations on the perfectly hardened concrete are however less than those which result from the gradual hardening of same in air, and the amounts of such volume alterations are inversely proportionate to their coefficients of elasticity.

Reference has been made to the combined materials being capable of acting as one body in taking up the stresses when subject to bending moments. To understand this it is necessary to study the relations between the length alteration and the stresses or in its graphical representation the so-called lines of form-alteration. FOF and HOI represent the lines of form-alteration for the iron and concrete respectively in compression and tension, and OBCGE the line of form-alteration for concrete-iron in tension. The form-alteration of the latter in compression being the same as for the concrete (only with an extended range) has not again been plotted. The ordinates represent the specific stresses and the abscissæ the accompanying shortenings or elongations as the case may be. The compressive stresses are plotted upwards and the tensile downwards, the shortening to the right, the elongations to the left.

The line of form-alteration for iron is straight, showing that the deformations take place proportionately to the stresses (within its elastic limit), while those for the concrete and concrete-iron are curved, denoting that the deformations are not proportionate to the stresses. Thus we have two kinds of elastic bodies before us, viz. the iron with a constant coefficient of elasticity, and the concrete and concrete-iron with variable coefficients under increased loading.

The lines of form-alteration for the concrete and concrete-iron indicate:

1. That the coefficients of elasticity decrease much more rapidly in tension than in compression, under increased loading.
2. That the material in the vicinity of the neutral axis is better utilised than in bodies with a constant coefficient of elasticity.

The leading formulæ for calculating concrete-iron constructions subject to bending moments express the above data of the distribution of the stresses in a more or less simplified manner, as shown by the two types 1 and 2. These formulæ although utilising as far as possible all the scientific data to hand are unable (and it is probably safe to predict will remain so) to give results which will correspond with direct compressive and tensile stresses. Concerning the compressive stresses in concrete-iron constructions, those containing 1½% or more iron (instances where the destruction of the concrete-iron body is dependent on the compressive strength of the concrete) differ in this respect most markedly, from the results obtained from direct compression tests. A poor concrete of 1 part cement, 3 of sand, and 3 of broken metal, at 3 months old, had a compressive strength as a cube under direct compression of 1710 lbs. per square inch, whereas the calculated compressive bending stress of similar concrete in a concrete-iron construction was 2838 lbs. per square inch. Richer concretes show less difference than poorer ones. The question, therefore, arises what circumstances cause these differences. To determine this, it is necessary to compare the two methods of testing. On the one hand a cube is very soon destroyed if the pressure faces are not truly parallel, or if unequal deformations take place on account of unequal application of the force, or unequal texture of the cube, matters which any test in spite of the greatest precautions may more or less be subject to.

On the other hand, in a concrete-iron construction subject to bending moments, there is an even transmission of pressure at an increasing rate from the neutral axis. The elasticity imparted to the construction by the iron rods counteracts the permanent set, and by doing so has an equalising effect on the stresses, thereby preventing unequal deformations, and consequently preventing those secondary shearing stresses which cause destruction of the cubes, when determining their compressive strength.

Since great differences between the direct stresses and calculated stresses of the materials when used in concrete-iron construction do exist, as is evident from the above, it becomes necessary to obtain special data of permissible compressive stresses for concrete-iron constructions with the various percentages of iron and different mixtures of concrete.

Concerning the tensile stresses it is necessary to examine the distribution of the same over the two materials. In order to do this, reference must be made to the line of form-alteration of concrete-iron in tension, viz., the curve OBCGE plotted in the ratio of stress to elongation from results obtained from direct tensile test. The apportioning of the stresses was arrived at by measuring the elongations of the iron under various loadings, calculating the stresses and deducting same from the test load in question, whence the balance would represent the stresses on the concrete. The stresses on the combined material as plotted represent the stresses per square inch, and the stresses in the iron represent the stresses per square inch shortened in the ratio of the areas of the iron to the concrete, the iron being represented by the dotted line of form-alterations FF.

Taking any point on the line of form-alteration of the concrete-iron body, say M, then Mm represents the total elongation and MR the total stress per square inch on the combined material. MP the stress per square inch on the concrete, and PR multiplied by the ratio of the area of the concrete to the iron represents the stress in the iron per square inch. In case the concrete body has hardened in air and thereby become subject to initial internal stresses, viz., tension in the concrete and compression in the iron, these stresses must be added or deducted as the case may be.

The tensile stress on the concrete from that source must be added to the stresses created by the loading, and the distance OA from O represents the intensity of that initial stress (at the beginning of the test). Using now A as the starting point, we must, in order to get the true tensile stresses in the iron, deduct the initial compressive stress on that material from the stresses created by the loading, which is achieved by the deduction of the distance AU, representing the intensity of the initial compressive stress (at the beginning of the test).

To now show the total stresses on the materials, it becomes necessary to move the lines FF and ON to pass severally through points A and U, taking up the positions F′F′ and UV respectively. The total stresses at point M are then represented by MQ in lieu of MP on the concrete, and QS in lieu of PR on the iron.

To illustrate the effect of repeated unloading and reloading, let it be assumed that if the continuous loading was interrupted at point C on the line OBCGE and the load repeatedly unloaded and reloaded then the effect CD, DC′ – C′D′...D^n C^n would represent the lines of form-alteration thus produced. Tests made in that direction brought to light (1) that the concrete, although its elongations amounted to from 10 to 20 times that value which causes fracture in plain concrete bodies, did not fracture and must therefore have taken part in the resistance of the stress. (2) That if the loadings and unloadings be repeated with the same load time after time, the coefficient of form-alteration becomes greater and greater until a certain limit is reached, whence the concrete-iron body acts as a perfectly elastic body, that is, its length alterations become strictly proportionate to the loads, a phenomenon which we are only accustomed to find in such bodies as wrought iron and steel.

Subjecting thereafter the concrete-iron body to greater loads than were applied in the reloading and unloading (above mentioned) then the line of form-alteration will continue in the direction of C'' G E exactly as if the same had been subjected to the greater load from the first. In other words the construction, within its elastic limit, regains by the application of a greater load entirely its former ability of resistance.

The character of the line of form-alteration in tension suggests three distinct stages or periods during testing to destruction. In the earlier stages of loading called the first period, lying between O and B. During that period the elongations in the tension fibres increase slowly until the point B is reached, by which time the concrete has undergone such elongations which would in an unarmoured or plain concrete body have caused fracture.

The stresses in the iron are comparatively small, indicating that the concrete takes up the bulk of the loading, and this is more especially the case where initial stresses are already affecting the two materials, in which case the iron does not take up any tension until such elongations are reached as overcome the initial compressive stresses. The lines of form-alteration indicate that the two materials during this period behave as if they were independent of each other, and that they take up the loads in the proportion of their coefficients of elasticity.

At point B, where there is a decided change in the direction of the line of form-alteration, we enter the second stage or period, during which the stress on the concrete remains with small variations the same throughout, although the concrete-iron body continues to elongate at a much more rapid rate than in the first stage. The coefficient of elasticity of the concrete in tension sinks rapidly, while the diagram of form-alteration of concrete in compression (O H) shows that the coefficient of elasticity in compression experiences but slight alterations in comparison. As soon as these alterations in compression, however, become more conspicuous by increasing loads, or when the elastic limit of the iron has been reached, we enter the third period.

The coefficient of elasticity in tension sinks to nought, indications of the destruction of the body become apparent, and the theory of elasticity can no longer be applied. The end of the second period most probably represents the limit of elasticity of the concrete-iron construction.

The qualification of the concrete to elongate beyond the point B is instilled into the same by the following circumstances, viz.:—

1. Its association with the iron and through it the uniform distribution of the tensile stresses over its sectional area.
2. The decrease of its coefficient of elasticity in tension.
3. The stressless displacement of its molecules.

Concrete-iron bodies of green concrete with a high percentage of iron show when tested that they are frequently quite devoid of that portion of the line of form-alteration known as the first period, and constructions which have already been subjected to repeated loadings are similarly affected, so that if tested later on, it would appear as if such a period had never existed. The carrying capacity of the construction however is thereby not affected. From this it must be deduced that it is inadmissible to draw conclusions as to the carrying capacity of a construction from the elongations at the earlier stages of loading. Regarding the appearance of cracks before period three is reached it is necessary to distinguish as to their causes, whether they are due to changes of temperature ; to too quick drying out ; to weakness of the construction, or to settlement of the supports and distortion of same. The latter are especially a source of danger and difficult to prove, so that it becomes absolutely necessary on that account to pay particular attention to the foundation of the supports.

This outlines the theory of concrete-iron constructions, and although the scientific investigations so far made, permit of a fairly correct view of the theory, there are many points yet which require clearing up. Attention is here directed to the indiscriminate use of formulæ, since each requires data of different permissible stresses for the various mixtures, and the percentages of reinforcement, values which, as already pointed out differ from the results obtained from direct tests of the materials. Should such information be available from abroad, care should be exercised in its use as local conditions and materials considerably affect their values, rendering local investigations absolutely necessary. The theory which appears a most simple one when first entering into the subject becomes the more complex the deeper the same is studied as in trying to solve one point, other points come to light which also require investigating.

The theory of concrete-iron having been dealt with a few notes on its application may be of interest. The earliest scientific application of concrete-iron was in the manufacture of plates with free ends, these being the most simple constructions subject to bending stresses. A plate thus supported becomes, when loaded, subject to compressive stresses in the upper fibres, and tensile in the lower. In order to augment the tensile strength of the concrete, iron was inserted near the underside of the plate in the direction of the span. This iron took the shape of round bars in the first instance, that being the easiest form procurable, and having been found later on to be also the most advantageous shape to use, it has become the standard section of the leading systems of concrete-iron. More frequently in practice the ends of the plates are more or less fixed to the supports or the plates are continuous over the supports, in which cases, tensile stresses occur at or near the upper side of the plates over the point of support, as well as on the lower side at and near the middle of the span, so that it becomes necessary to place iron in those sectional areas subject to tension.

As the rectangular section of a plate does not permit of the iron being utilised to the best advantage, the application of this form of construction becomes for economic reasons limited to small spans. For larger spans, and where heavy loads come into play a more favourable type of cross-section was substituted, which dissected, consists of adjoining T girders.

This type in its most economic form is designated the plate-beam construction, on account of the webs being spaced so far apart that the flanges between same act as plates continuous over the web. The continuous plates being armoured with iron insertions as above mentioned. The webs also have iron insertions embedded according to their having free ends, fixed ends, or being continuous over supports. Further, the webs require vertical or oblique irons, otherwise termed "stirrups" or "struts," to assist the concrete to take up the shearing stresses produced in a loaded beam, and which in most cases exceeds the shearing resistance of the comparatively small concrete section of the web.

Plate-beam constructions may present the following features, viz.—1. A space may be covered by a plate-beam consisting of main beams and plates only.

2. It may be advisable to place the main beams so far apart that cross beams are necessary to lessen the spans of the plates.

3. In conjunction with this latter arrangement another series of beams parallel to the main beams may be employed so that the whole area becomes subdivided into squares, the plate portion of which being supported on all four sides, acts similarly to buckled plates.

Columns of concrete-iron constructed to support the plate beams, have the advantage over ordinary iron columns that they allow a better connection between column and beam. They are made in all shapes, solid or hollow, and are fortified by vertical irons placed near the outer surfaces, which irons are connected together by horizontal cross-ties to form a skeleton framing which hoops the concrete and prevents it from buckling and bulging. The concrete-iron plate-beam constructions in conjunction with columns are especially suited for heavily loaded floors of wide spans and have on that account found a very extensive application in warehouses, hotels, stores and industrial establishments. The whole of the concrete is built *in situ* and forms a well connected monolithic body, which considerably increases the stability of the buildings.

These constructions being of greater bulk and dead weight than those of iron, makes them less sensitive to vibrations from fast running machines, or blows from falling bodies, and observations show that the maximum oscillation of a concrete-iron beam and the duration of such oscillation is considerably less than that of an equally strong steel girder. This property is of great importance in dealing with constructions of large spans, subject to heavy and rapid moving loads as in the case of bridges.

Many bridges with one or more openings up to 70 feet span have been carried out for road and railway purposes, and the experience gained therewith has been highly satisfactory. Within certain limits, according to circumstances, plate-beam bridges are more advantageous than arch bridges, but in spans of considerable size the arch bridges are more economical. Arches similar to plates and beams require to be strengthened in those areas subject to bending moments by means of iron insertions. Arches of parabolic shape, carrying an equally distributed load, need only be reinforced with iron near the intrados; but to carry varying loads it becomes necessary to reinforce the arch near the extrados as well as the intrados. These iron insertions while effecting a great increase in the factor of safety, and elasticity, give important economic advantages.

In constructions of circular shape subject to equally distributed internal pressures, as occurs in pipes, reservoirs, etc., filled with water, concentric iron insertions are necessary, but when they are subject to unequal external pressures as in the case of pipes under earth pressure, it is necessary to use either eccentric iron insertions, extending from the outer surface at the horizontal diameter to the inner surface at the vertical diameter, or else to use concentric rings near the inner and outer surfaces respectively.

It has been already stated that round iron bars have become the standard section of the leading systems of concrete iron. Other shaped irons have here and there been substituted for the round bars, such as I irons, X iron, twisted iron, and many other sections, for each of which is claimed an increase of strength, either by adhesion or mechanical means.

The mechanical means to assist the adhesion of the concrete to the iron becomes unnecessary in all such concrete-iron constructions, which, besides strength, take due consideration of the preservation of the iron, by using such concrete mixtures, which experience has proved to be water-tight. The mixtures usually adopted are one part cement, two parts of sand, with aggregate not exceeding three parts of gravel or small broken stone, which when used in a plastic state, can be relied upon to surround the iron so thoroughly and closely that the preservation of the iron is ensured, besides creating sufficient adhesion for all practical purposes, as has been demonstrated by exhaustive tests and experience.

Concrete-iron constructions built with poorer mixtures may be cheaper in the first place, but such saving is obtained by sacrificing thereby the perfect preservation of the iron, one of the most important factors of such combination, besides reducing the adhesion between the two materials, so that mechanical means must be resorted to, to make up for the loss. The form of such mechanical means may take numerous shapes, and has on that account been taken advantage of to form distinctive features for various systems advocated by competing firms as offering special advantages.

The above description outlines the most general application of concrete-iron, and as all other applications embody more or less the principles enumerated, only two specific types will be further noticed, viz.:—1. Its use in the manufacture of piles, sheet piles, etc., which present a novel feature, inasmuch as that they can be driven similarly to those of timber. 2. Its use in the manufacture of pipes for water supply purposes, and as such subject to internal stresses.

The new Woolloomooloo baths lately erected, have an enclosure consisting of concrete-iron piles and sheet piles, the main piles are 22 inches × 15 inches and 15 inches × 12 inches, and the sheet piles 14 inches × 6 inches, both up to 25 feet 6 inches in length. They were driven with a $2\frac{1}{2}$ ton monkey, with a drop as much as 7 feet, in places through quarry refuse, without sustaining any damage. A retaining wall has lately been built along the Darling Harbour foreshore, consisting of concrete-iron sheet piles 27 feet long and 18 inches wide, ranging from 9 inches to 18 inches in thickness, according to the strength required to stand the earth pressure. They were potted in a rock trench, and held back at the top by tie-rods.

The use of concrete-iron pipes for water supply purposes was first attempted about 14 years ago, and its success has led to its extended adoption in Europe and other places, as it has many points in its favour when compared with cast-iron. Concrete-iron pipes are manufactured to withstand any internal pressures required, and as such are of two distinct types:—

1. The ordinary pipe, where the imperviousness necessary depends solely on the concrete.
2. The pipe which has embedded in the concrete a thin metal core to prevent percolation.

Dealing with the first type, viz., the pipes solely depending on the concrete for its imperviousness; it has been found that although they may exude or sweat when first put into use under high pressures, they soon "take up." Observations made on a pipe line of 4,920 feet long, on pipes 5 feet 9 inches diameter laid in connection with the Paris Water Supply, designed for a head of water of 44 feet 6 inches, showed when tested to be water-tight with a head of 24 feet. Under a pressure of 36 feet 5 inches wet spots appeared, and under a pressure of 44 feet 6 inches a general wetness showed, which, however, gradually "took up" within two to three months.

A concrete-iron pipe 9·84 feet long, 1 foot 8 inches diameter, and $1\frac{2}{3}$ inch thick, taken from a pipe line, having been three years in use, under a working pressure of 59 feet, showed no wet spots until subjected to a head of water of 125 feet. Upon being re-tested later on, it withstood a pressure of 130 feet head for one month without sweating, and percolation only commenced under a head of 197 feet. Numerous instances of the extensive use of concrete-iron pipes could be mentioned, among which are a length of four miles of 2 feet $7\frac{1}{4}$ inches diameter pipes, $1\frac{1}{2}$ inch thick, working under a head of 23 feet, for the City of Venice; $18\frac{1}{2}$ miles of 2 feet diameter pipes in Algeria, under a head of from 56 feet to 78 feet, with thickness varying from 1·6 inch to 1·8 inch; $3\frac{3}{4}$ miles of 2 feet diameter pipes at Valence, under a head of 65 feet of water; 38 miles of 2 feet diameter pipes in Tunis, etc.

In New South Wales concrete-iron pipes to withstand internal pressures have so far only been manufactured in connection with their application as bridge cylinders. The cylinders were designed to withstand an internal pressure of 50 feet head of water, and have been successfully sunk in many places with and without the airlock. They are manufactured in 3 feet 6 inches to 6 feet diameters, and contain within their thickness longitudinal steel bar connections, which are coupled—in jointing the cylinders—by means of fishplates and wedges.

Regarding local tests of the impermeability of pipes under high internal pressures, the author made a series of tests with the ordinary concrete-iron pipes, which had been manufactured for use as culverts, stormwater channels, etc., and not designed to withstand internal pressures, and found that they withstood pressures up to 110 feet head of water before sweating or cracking. The pipes tested varied from 12 inches to 30 inches in diameter, and from $1\frac{1}{8}$ inches to $1\frac{3}{4}$ inches in thickness. As these tests were made primarily with the object of ascertaining the bursting strength of the pipe, and extended in each case only over a short period, the tests cannot be regarded as a true gauge for imperviousness to sweating, for to ascertain that it would have been necessary to extend the period of the test pressure over a considerable time. With regard to the second type mentioned, these can be made to withstand any internal pressures required similarly to steel pipes.

Before concluding this portion of the paper it is advisable to draw attention to the necessity which has arisen in Europe and America to issue regulations in order to fix a standard of the materials to be used, the stresses admissible and the method of carrying out and testing these constructions in order to safeguard the public against their indiscriminate use by those not qualified to design or construct. This step became necessary on account of the many accidents in connection with these constructions.

* * *

Particulars of a test of a plate-beam construction made on a large scale in this State being available, and this form of construction coming more and more into general use, a description of the construction and the test of same should be of interest. By instructions of the Engineer-in-Chief for Existing Lines, N. S. Wales Railways, a concrete-iron plate-beam construction was built in order to ascertain its strength and carrying capacity. The site chosen in the Newcastle Railway yard had an old concrete floor, and as the foundation soil in that locality was rather uncertain, it was deemed advisable not to disturb the same, but to build the construction on this floor. In order to distribute the pressure of the piers over as large an area as possible, four steel joists 12 inches × 6 inches × 12 feet long were used for each pier to rest upon. The piers 5 feet $8\frac{1}{2}$ inches long × 1 foot 10 inches thick × 2 feet 11 inches high to the top of plate were built of ordinary bluestone concrete a few days before the plate-beams, and had dovetailed recesses left in them for the beams and the plate to rest in. Two types of plate-beams were employed, with the object of ascertaining and comparing their values, the plate being made continuous across the two. Both beams were 23 feet 6 inches span between piers, or 27 feet 2 inches over all, 1 foot 10 inches deep at the centre, and 1 foot $4\frac{1}{2}$ inches at the supports to the under side of the plate. The latter was $2\frac{1}{2}$ inches thick, making total depth of 2 feet 1 inch and 1 foot 7 inches respectively at the centre and ends. Beam A was 10 inches wide, reinforced with five round iron bars placed about $1\frac{1}{16}$ inches above the under side. Three of these bars (one $\frac{7}{8}$ inches and two $\frac{3}{4}$ inches) extended along the lower side throughout into the recesses. The remainder, viz., two $\frac{7}{8}$ inch bars, extended only for a certain distance along the lower side, thence upwards toward the upper surface and then along the latter into the support.

Each bar was in one length from support to support and bent over at the ends. Additional bars $\frac{5}{8}$ inch diameter, and 5 feet 6 inches long were inserted near the top surface one at each support. Beam G was 7 inches wide reinforced with six round iron bars. One $\frac{7}{8}$ inch diameter and two $\frac{3}{4}$ inch diameter bars were situated $1\frac{1}{16}$ inch above the lower surface of the beam and extended along same into the piers. The other three $\frac{3}{4}$ inch bars placed $2\frac{3}{8}$ inch above the lower surface of the beam extended only a certain distance along such, thence upward toward the upper surface and along the latter into the piers. These bars were also continuous throughout their lengths and were bent over at their ends. Additional bars $\frac{3}{8}$ inch diameter and 5 feet 6 inches long were inserted near the top surface two at each support. The weld of the main iron bars being situated at the centre of the spans, four additional bars 5 feet long by $\frac{3}{8}$ inch diameter were inserted at these places to provide against risk of bad welding. The arrangement of the main bars as shown provides for the ends of the beams being partially fixed. Three-eighth inches diameter iron stirrups or struts were placed at varying distances along the length of each beam in order to assist to take up the shearing stresses. The plate which was $2\frac{1}{2}$ inches thick and 4 feet $1\frac{1}{4}$ inch wide contained $\frac{3}{8}$ inch diameter iron bars alternately near the lower and the upper surface.

After the piers were built the centreings for the beams and plate were fixed, and the iron rods placed in the positions shown and described, and carefully held there during the process of encasing them with the concrete. The concrete which consisted of 1 part "Union Brand" tested Portland cement, 1 part Nepean sand, 2 parts $\frac{3}{4}$ inch bluestone shivers, containing all the small screenings and dust from the crusher, or subdivided 1 cask of cement, 4 cubic feet of sand, 4·62 cubic feet of dust, 6·38 cubic feet of shivers, bulked when mixed and wetted of one half of a cubic yard. It was well worked into place in a plastic state. The iron bars were of Lithgow manufacture and withstood a breaking strain of from 24 to 26 tons per square inch, with an elastic limit of two-thirds the breaking strength.

The test took place in July 1903, being seven weeks after its construction. Levers were fixed at three points on each beam, and also on the plate, viz., at $\frac{1}{4}$ centre, and $\frac{3}{4}$ span, in order to measure the deflections. The points of the levers were steel shod and rested on cement pats attached to the beams and plate, whilst the other ends moved against graduated scales. Verniers were also attached to the side of the beams to ascertain if any movements took place sideways under the loading.

The method of loading was as follows:—A timber frame with open vertical joints was formed around the test object into which dry sand was filled level to the top. On the sand was laid a course of bricks and on these a platform of rolled joists 12 inches × 6 inches × 12 feet long. Under the projecting ends of the joists timber structures were built allowing a $\frac{1}{2}$ inch clearance being maintained by adjustable blocks throughout the testing. This platform of rolled joists was necessary in order to get sufficient width on which to stack the bricks, and served in conjunction with the timber structure to ensure safety to those loading up and reading the deflections.

The test which extended over a period of 24 hours was commenced one day and completed the next. The loading, beside the sand filling, layer of bricks and steel joists consisted of bricks, and reference to the drawings and photographs will show the method of loading adopted. The sand, steel joists, and a quantity of bricks amounting in all to a weight of 33·43 tons, was placed on the test object on the first day and left on all night, an interval of 18 hours. This load which amounted to more than twice the working load for which the construction was designed, caused at the end of that time deflections from $\frac{1}{5}$th to $\frac{1}{4}$ of an inch. Next day the loading was continued, and the deflections taken with each increase of 5 tons.

As previously mentioned the old concrete floor supporting the piers rested on very uncertain grounds, and in spite of the precautions taken to transmit the pressure by means of these steel joists over a larger area, the floor cracked and settled, and consequently increased the readings of the deflections. As these settlements could not be measured and eliminated, the deflection readings are inclusive of the settlements. Besides, these settlements not taking place evenly, a twisting of the construction took place, all of which circumstances, to a certain extent must have affected the carrying capacity of the construction. With 55·89 tons, a slight crack appeared on the side of beam G, about 15 inches from the centre of the span, the crack starting at a point 3 inches above the underside of the beam, and extending upwards about 4 inches. With 59·99 tons a small hair crack on the side of beam A appeared similar to that in beam G. That these cracks were not caused by constructional weakness affecting the carrying capacity of the beams is proved, in that they did not increase under subsequent loading. What caused their appearance may be briefly stated as being the effect of the concentration of the iron for economic reasons as near the underside of the beam as practicable, thereby depriving those areas in which the cracks appeared of the qualification of elongating to such an extent as the sectional areas surrounding the iron were able to accomplish.

With 64·98 tons small cracks, hardly perceptible, started simultaneously at the edges of the underside of both beams, and extended under increased loading until with 74·96 tons they became clearly visible across the whole underside, and also extended up the sides of the beams.

The object of the test having been attained and the deflection apparatus removed, it was decided in order to ascertain how much the construction, so damaged, would be able to support before collapsing, to continue with the loading. This was carried on until the supply of bricks was exhausted, by which time the load amounted to 142·10 tons. During this loading the cracks had extended from the underside of the beams upward to near the underside of the plate, and had opened out considerably. The beams had deflected 3½ inches, causing a tilting of the piers, and a concentration of the compressive stresses on the inside edges, effecting great cracking and crushing at those points.

Referring now to the test of the structure and accepting 60 tons as the load when the cracks appeared on the underside of the beams, or 30 tons on each. The bending moment caused by the deadload, and load of 30 tons on beam A at point of crack = 2,560,000 inch ℔s. The distance of the centre of compression from the centre of tension = leverage = 21 inches. The sectional area of the iron = 2·68 square inches, and the tensile strain on the iron = 45,200 ℔s. or over 20 tons per square inch. The compression on the concrete = 1,360 ℔s. per square inch. On beam G, the bending moment caused by the dead load, and loads of 30 tons at point of crack = 2,450,000 inch ℔s. The distance of the centre of compression from the centre of tension = leverage = 20·5 inches. The sectional area of the iron available = 2·65 square inches, and the tensile strain on the iron = 42,400 ℔s. per square inch, or over 19 tons. The compression on the concrete = 1,330 ℔s. per square inch.

Referring now to the beams, when loaded with the 142 tons, of which 120 tons may be taken as resting on the beams, or 60 tons on each. The cracking of the beams extended up to the underside of the plate, and consequently the leverage, or distance between the centre of compression and centre of tension = $22\frac{2}{3}$ inches, and for beam A the strain on the iron per square inch = 81,000 ℔s. The compression on the concrete = 3,510 ℔s. per square inch. On beam G the tensile strain on the iron is 78,900 ℔s. and the compression on the concrete is 3,400 ℔s. per square inch.

As such abnormal strains could not have taken place it must be inferred that the equally distributed loading arched itself as the deflections increased, and the results obtained by such loading can only be relied upon whilst the beam showed only small deflections, viz., to the time when the cracks appeared. Judging from tests made with concentrated loads on other objects, the breaking down ought to have occurred with under 100 tons loading.

In conclusion the author desires to thank Mr. James Fraser, Engineer-in-Chief for Existing Lines, and Mr. W. H. Davidson, Divisional Engineer, under whose supervision this test was carried out, for their courtesy in supplying the necessary information to enable him to place before you the particulars of this test.

CURRENT PAPERS, No. 8.

By H. A. Lenehan, F.R.A.S., Acting Government Astronomer.

[With Diagrams.]

[*Read before the Royal Society of N. S. Wales, August 3, 1904.*]

Two years have nearly elapsed since Mr. Russell read his last Ocean Current paper before this Society, and owing to his recent illness it has fallen to my lot to present this pamphlet to you, which makes No. 8 of the Series.

For a long time past, since 1888, papers have been supplied to masters of ships trading to this port, but owing to the new Federal Postal Regulations (which came into force in the latter part of 1902) doing away with the frank post on State Government documents, it was thought advisable to discontinue spreading the forms broadcast owing to the expenditure that would be incurred in postage. Now only ship masters who make written or personal application for the forms receive them. Under the present system it was only natural that the numbers received monthly would greatly diminish; the change was not at once noticeable, but after June 1903, there was a pronounced falling off. Whereas, during the years 1899 to 1903 (inclusive), the average papers received from January to July was 76—during 1904 the total reached for the same period was only 31—nearly a 60% decrease. Perhaps at some future time the distribution will again be taken up with renewed vigor. Paper No. 8 contains 181 records, a greater number than any previous paper published by the Sydney Observatory; the nearest approach was No. 3 paper with 167.

Several very valuable papers are here recorded. No. 976 I consider the most interesting. Cast adrift within a few miles of the Californian coast of North America, perhaps just outside the influence of the coastal inset, it has travelled a distance of 11,350 miles—nearly semi-circumnavigating the globe—before reaching its terminal point on the island of Boillon in the Java Sea. It is the first record received of the drift in that part of the North Pacific Ocean. I presume that when the paper was put overboard, July 19th, 1901, winds were blowing off the land and so drove it into the great North Pacific Drift. It was carried to the south and thence along to the westward in latitudes between 0° and 20° north, when it probably got into the North Equatorial Current. From thence it has passed through Malacca Straits to the spot where it was discovered. The distance travelled creates a record for the whole of the papers since the collection commenced.

No. 936 is another interesting paper with both a long and rapid drift. It was put off a few degrees south of the Equator in Long. 88° 47′ E. and threaded its way through Torres Strait to the Solomon Islands. The locality it passed through is a veritable network of reefs and islands. The drift was 4,830 miles at a daily rate of 21·6 miles, the fastest in this pamphlet.

Current Paper No. 966 in the Indian Ocean has not followed a usual course. Previous papers put off near it have either drifted west to Africa or east to Java or Siam. This one has drifted almost due northerly to the east coast of India.

Three papers, Nos. 985, 1,005, and 1,086, put over south of Canary Islands, Bay of Biscay, and west of the Island of St. Helena, respectively, have found their way to the West Indies, the drift furthest north being the slowest, and the one south of the Equator the fastest.

Six papers in the Indian Ocean have been found on the coast of Africa, five of which have followed well known courses, but one, No. 928 has had rather a peculiar drift. From previous experiences I would have imagined this paper to have made its way to the coast of Cape Colony, but owing to some reasons for which I cannot put forward a lucid explanation, it was found at Mombasa. I think in all likelihood it must have commenced with a north-easterly drift and so got into the same current as shown by papers Nos. 1,001 and 1,003.

There are several very important ones in the Southern Ocean, some of which reached the Australian coast, one made its way to north of New Zealand near Kaipara Heads, while yet another was found at Aneiteum, New Hebrides. Of these papers the fastest drift was No. 1,008 at 9·7 miles per day and the slowest No. 1,075 at a daily rate of 1·4 miles.

Now coming to the currents with short drifts; we find some very peculiar anomalies. Referring to the charts you will see that the drift in the Great Australian Bight is to the eastward, yet three papers Nos. 957, 967, and 1007, have a very conceivable westerly set. On the west coast five papers have been recovered, two with routes north of east, and three south of east.

The New Zealand coast has not been neglected. More than 20 papers have come from there, of which 17 have been plotted on the charts. The general trend of papers put off in the low latitudes has been northerly, but two are here shown as southerly drifts. It was only in following out a fundamental rule in plotting the courses, *i.e.*, plot the shortest route—that such a course has been followed, for I am most certain that the papers did not arrive at their destination in the manner marked. In all probability they first went to the north, passed around the Three Kings and thence down the east coast of New Zealand. Two papers, Nos. 1,103 and 1,098 partly bear out the theory of a drift along the east coast of that colony. Of these papers the most rapid was a short drift in the Foveaux Strait. Shipmasters trading to the south New Zealand ports know with what strength the current at certain makings of the tides passes through these straits, and so it is not at all surprising that we find a drift of nearly 17½ miles per day. The paper was only six days on its journey of 104 miles, and if it was not found the day it came ashore, the rate of drift must have been considerably more.

The next section is on the eastern seaboard of Australia, and again we see that papers are found north from where they are put over, although the drift of the current is south. The rates of drift are so small that I think that they must invariably reach their destination by a more circuitous route. One paper cast overboard off the north coast of New South Wales ultimately reached New Caledonia, but of this I am unable to state the rate of drift owing to the writer not saying when he found it. Here I may mention that several papers have been received, but owing to negligence, most likely unintentional, on the part of the finder not giving any information as to where, when, and by whom found, we are unable to make any use of them.

LIFE BUOY DRIFT.

The following letter dated March 13th, 1901, which did not appear in the last pamphlet was received from the Department of Navigation:—

"I have the honour by direction of the Superintendent to report for your information that a life buoy marked "Rio, Napier," was picked up yesterday on the Manning Bar. The log book of the vessel has been inspected, and it appears that the buoy referred to was thrown overboard on the 15th of January, 1901, in Lat. 33° 10′ S., Long. 159° 20′ E. It will be remembered that the chief officer of this vessel fell overboard on the voyage from New Zealand, and it appears that this life buoy was thrown to his assistance. This communication is made as the Superintendent thought it might be an item of interest to you."

(Signed) Norman C. Lockhardt, Secretary."

This life buoy was found on the Manning River Bar, Lat. 31° 55′ S., Long. 152° 33′ E., so that it also appears to have drifted in the adverse direction to the southerly set of the current. It traversed a distance in a direct line of 397 miles in 56 days, at a daily rate of 7·1 miles.

In conclusion, I wish to thank the captains of ships who have contributed to this paper by casting adrift the ocean current forms, for without their coöperation it would be almost impossible to obtain the information as to the direction of the principal ocean drifts, and to the officer of the Observatory, Mr. W. C. Graham, for his services in compiling these records.

List of current papers arranged in months in which they were found:—

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	No	bse	rvat	ions			Wor	k be	gan	3	7	11	21
1897	5	7	4	5	10	7	9	9	3	8	9	6	82
1898	6	7	6	2	10	7	5	9	4	16	8	12	92
1899	11	11	11	6	13	9	10	15	7	16	11	10	130
1900	14	20	11	12	8	10	9	7	9	17	10	8	135
1901	13	13	14	11	10	13	6	9	9	14	11	15	138
1902	12	15	15	17	9	12	9	8	12	8	13	11	141
1903	15	12	8	7	7	11	6	6	6	6	6	14	104
1904	5	6	9	2	5	3	1	...	...	...	...	...	31
Total	81	91	78	62	72	72	55	63	50	88	75	87	874
Average	10·1	11·4	9·8	7·7	9·0	9·0	6·9	7·9	6·3	9·8	8·3	9·7	97·1

List of current papers that made a rapid daily drift, taken from current pamphlet No. 8 :—

No. of Pamphlet.	List number of Paper.	Miles per day.	Locality of Current.
8	936	21·6	Indian Ocean
	944	20·0	Gulf of Aden
	946	12·2	Indian Ocean
	976	11·5	Pacific Ocean
	988	16·2	East Indies
	989	12·7	East Coast
	995	11·4	South Indian Ocean
	1021	15·4	China Sea
	1045	17·3	South New Zealand
	1086	11·5	Atlantic Ocean
	1089	11·1	South Coast

Long drifts of current papers, selected from the eight pamphlets published by the Sydney Observatory :—

Current pamphlet No. 1 (July 1883 to June 1894; 43 current papers) Vol. xxviii., p. 245.

Current pamphlet No. 2 (June 1894 to August 1896; 157 current papers) Vol. xxx., p. 202.

Current pamphlet No. 3 (August 1896 to November 1893; 167 current papers) Vol. xxxii., p. 230.

Current pamphlet No. 4 (November 1898 to November 1899; 124 current papers) Vol. xxxiii., p. 145.

Current pamphlet No. 5 (November 1899 to October 1900; 106 current papers) Vol. xxxv., p. 30.

Current pamphlet No. 6 (October 1900 to November 1901; 154 current papers) Vol. xxxv., p. 336.

Current pamphlet No. 7 (November 1901 to October 1902; 164 current papers) Vol. xxxvi., p. 201.

	No. of paper in list.	Distance travelled in miles.	Rate per day in miles.
Current pamphlet No. 8 (September 1902 to July 1904; 181 current papers)	936	4,830	21·6
	969	3,050	8·4
	976	11,350	11·5
	985	3,090	10·2
	995	5,100	11·4
	1003	3,930	3·7
	1005	4,100	7·0
	1008	4,480	9·7
	1075	4,380	1·4
	1082	5,250	4·0
	1083	5,675	6·9
	1086	4,820	11·5

Ref. No.	Date when put into the sea.	Name of Ship.	Name of Commander.	Thrown Over. Lat. ° ′	Thrown Over. Long ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No.
927	Jan. 13-03	S.S. 'Aberdeen'	A. Robb	37 22 S.	112 0 E.	32 36 S.	115 38 E.	Oct. 13-03	West Coast ...	273	340	1·2	927
928	Dec. 8-99	S.S. 'Afric'	— Alford...	29 40 ,,	57 5 ,,	4 10 ,,	39 40 ,,	Sept. 17-02	Indian Ocean ...	1013	2100	2·1	928
929	Sept. 17-99	R.M.S. 'Alameda'	Van Otterendorp ...	0 25 N.	166 47 W.	1 10 ,,	174 50 ,,	July 17-02	Pacific Ocean ...	1033	1275	1·2	929
930	Nov. 6-01	R.M.S. 'Aorangi'	C. W. Hay	18 32 S.	162 19 E.	17 14 ,,	146 2 ,,	Jan. 18-03	S. Pacific Ocean	138	1080	2·5	930
931	Sept. 2-02	,, ...	,, ...	41 53 N	131 50 W.	45 47 N.	124 0 W.	Jan. 25-03	N. Pacific Ocean	145	385	2·7	931
932	Nov. 8-02	,, ...	,, ...	23 43 S.	165 57 E.	24 55 S.	153 18 E.	May 14-03	East Coast ...	187	805	4·3	932
933	June 18-03	,, ...	,, ...	23 34 ,,	166 50 ,,	21 30 ,,	168 20 ,,	Oct. 3-03	S. Pacific Ocean	107	158	1·5	933
934	Sept. 9-03	,, ...	,, ...	22 3 ,,	170 33 ,,	21 0 ,,	165 40 ,,	Oct. 27-03	,, ,,	48	320	6·7	934
935	Oct. 12-03	,, ...	,, ...	20 0 ,,	175 25 ,,	20 30 ,,	164 55 ,,	Dec. 31-03	,, ,,	80	690	8·6	935
936	July 1-01	R.M.S. 'Arcadia'	C. C. Loggin	3 33 ,,	88 47 ,,	8 0 ,,	157 40 ,,	Feb. 10-02	Indian Ocean ...	224	4830	21·6	936
937	Feb. 1-02	,, ...	F. C. A. Lyon	35 29 ,,	131 40 ,,	37 55 ,,	140 22 ,,	... ...	South Coast ...	...	506	...	937
938	June 15-02	,, ...	,, ...	38 22 ,,	148 14 ,,	30 53 ,,	153 0 ,,	Dec. 17-02	East Coast ...	185	600	3·2	938
939	Sept. 24-02	,, ...	,, ...	31 48 ,,	115 13 ,,	31 19 ,,	115 35 ,,	Feb. 28-03	West Coast ...	157	35	0·2	939
940	Sept. 25-02	,, ...	,, ...	34 40 ,,	115 27 ,,	34 28 ,,	115 43 ,,	July 29-03	S. West Coast ...	307	19	0·1	940
941	Oct. 19-02	,, ...	,, ...	38 25 ,,	148 5 ,,	38 23 ,,	147 13 ,,	Nov. 16-02	South Coast ...	27	39	1·4	941
942	Oct. 22-02	,, ...	,, ...	37 3 ,,	139 23 ,,	37 7 ,,	139 50 ,,	Nov. 20-02	,, ,,	29	27	0·9	942
943	Dec. 14-02	,, ...	,, ...	42 12 N.	9 36 W.	42 36 N.	9 15 W.	Jan. 5-03	Coast of Spain ...	22	35	1·6	943
944	March 3-03	,, ...	,, ...	11 53 ,,	51 23 E.	13 20 ,,	45 38 E.	Mar. 23-03	Gulf of Aden ...	20	400	20·0	944
945	May 25-03	,, ...	,, ...	36 32 S	138 52 ,,	37 5 S.	139 45 ,,	July 4-03	South Coast ...	40	58	1 5	945
946	July 6-03	,, ...	,, ...	9 41 N.	66 40 ,,	8 2 N.	93 28 ,,	Dec. 2-03	Indian Ocean ...	149	1822	12·0	946
947	Oct. 10-97	M.M.S.S. 'Armand Behic'	M. Richard	37 58 S.	140 20 ,,	37 52 S.	140 21 ,,	April 7-01	South Coast ...	1284	8	...	947
948	Oct. 8-02	,, ...	M. le Coispellier ...	32 10 ,,	115 21 ,;	31 18 ,,	115 27 ,,	Nov. 30-02	S. West Coast	53	50	0·9	948
949	Jan. 7-03	,, ...	,, ...	37 20 ,,	125 26 ,,	32 15 ,,	126 12 ,,	June 4-03	South Coast ...	148	308	2·1	949
950	Jan. 23-03	,, ...	,, ...	37 8 ,,	150 19 ,,	36 23 ,,	150 5 ,,	Feb. 5-03	S. East Coast ...	13	45	3·5	950
951	Jan. 25-03	,, ...	,, ...	38 38 ,,	140 9 ,,	37 2 ,,	139 43 ,,	Feb. 27-03	South Coast ...	33	120	3·6	951
952	Sept. 9-02	R.M.S. 'Austral'	Colin Nicholson ...	38 2 ,,	140 22 ,,	37 57 ,,	140 28 ,,	... ...	,, ,,	...	7	...	952
953	Aug. 13-02	R.M.S. 'Australia'	F. Cole	37 17 ,,	135 38 ,,	35 47 ,,	139 13 ,,	Sept. 29-02	,, ,,	47	230	4·9	953
954	Mar. 19-03	,, ...	,, ...	39 16 ,,	149 14 ,,	34 3 ,,	151 11 ,,	June 8-03	East Coast ...	81	375	4·6	954
955	Oct. 25-03	,, ...	,, ...	38 21 ,,	141 10 ,,	35 7 ,,	137 24 ,,	Dec. 9-03	South Coast ...	45	275	6·1	955
956	Oct. 28-03	,, ...	,, ...	37 33 ,,	150 4 ,,	37 25 ,,	150 3 ,,	Dec. 15-03	S. East Coast ...	48	8	0·2	956
957	Feb. 14-04	,, ...	,, ...	38 4 ,,	140 27 ,,	35 36 ,,	138 6 ,,	May 27-04	South Coast ...	103	210	2·0	957
958	July 15-02	M.M. 'Australien'	M. Verron	35 18 ,,	117 6 ,	33 50 ,,	121 55 ,,	June 29-04	S. West Coast ...	717	233	0·3	958
959	Jan. 23-03	,, ...	,, ...	34 50 ,,	115 49 ,,	34 22 ,,	115 12 ,,	Feb. 21-03	,, ,,	29	44	1·5	959
960	Feb. 14-00	G.M.S. 'Barbarossa' ...	A. Richter	30 33 ,,	114 6 ,,	28 45 ,,	113 55 ,,	Mar. 16-04	,, ,,	1491	110	0·1	960
961	May 24-02	Ship 'Ben Dearg'	... ...	32 34 ,,	161 43 ,,	29 11 ,,	153 27 ,,	Mar. 14-04	East Coast ...	659	535	0·8	961
962	Nov. 9-01	R.M.S. 'Britannia'... ...	F. H. Seymour	35 39 ,,	130 43 ,,	37 55 ,,	140 22 ,,	... ...	South Coast ...	...	560	...	962

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963	April 11-02	R.M.S. 'Britannia'	F. H. Seymour... ...	35 33 S.	131 50 E.	35 42 S.	137 8 E.	Nov. 21-02	South Coast ...	224	300	1·3	963
964	Jan. 14-03	,, ...	,, ...	38 37 ,,	139 52 ,,	37 0 ,,	139 42 ,,	Jan. 28-03	,, ,,	14	90	6·4	964
965	July 6-03	,, ...	,, ...	36 42 ,,	139 6 ,,	37 2 ,,	139 45 ,,	Feb. 25-04	,, ,,	234	41	0·2	965
966	Aug. 12-03	,, ...	,, ...	5 37 ,,	80 17 ,,	16 10 N.	81 11 ,,	Feb. 26-04	Indian Ocean ...	198	1500	7·6	966
967	Nov. 6-03	,, ...	,, ...	35 29 ,,	124 2 ,,	34 38 S.	118 49 ,,	May 15-04	S. West Coast ...	191	300	1·6	967
968	June 6-02	R.M.S. 'China'	Thos. S. Angus	35 28 ,,	131 39 ,,	35 38 ,,	139 5 ,,	Nov. 7-02	South Coast ..	154	450	2·9	968
969	Aug. 21-02	,, ...	,, ...	11 23 ,,	94 30 ,,	16 50 ,,	49 30 ,,	Aug. 21-03	Indian Ocean ...	365	3050	8·4	969
970	Sept. 3-02	,, ...	,, ...	38 41 ,,	149 55 ,,	35 17 ,,	150 35 ,,	Nov. 10-02	East Coast ...	68	235	3·5	970
971	Sept. 21-02	,, ...	,, ...	38 15 ,,	148 32 ,,	37 35 ,,	149 50 ,,	Oct. 31-02	S. East Coast ...	40	81	2·0	971
972	Mar. 29-03	,, ...	,, ...	38 30 ,,	141 41 ,,	38 20 ,,	142 0 ,,	May 12-03	South Coast ...	44	20	0·5	972
973	Sept. 10-03	R.M.S. 'Damascus' ...	— McKilliam	42 40 ,,	133 53 ,,	38 44 ,,	143 10 ,,	Jan. 8-03	,, ,	120	535	4·5	973
974	Feb. 10-03	,, ...	,, ...	37 55 ,,	137 27 ,,	36 20 ,,	139 41 ,,	June 14-03	,, ,,	124	168	1·4	974
975	Feb. 11-03	,, ...	,, ...	38 40 ,,	142 35 ,,	38 26 ,,	144 9 ,,	Mar. 6-03	,, ,,	25	90	3·6	975
976	June 19-01	R.M.S. 'Colombia ...	P. J. Donovan	33 35 N.	120 25 W.	2 48 ,,	107 35 ,,	Mar. 5-04	Pacific Ocean ...	989	11350	11·5	976
977	Nov. 2-02	S.S. 'Dovenby'	N. Fegan...	45 28 S.	123 0 E.	35 20 ,,	150 33 ,,	Mar 27-04	Southern Ocean	511	1730	3·4	977
978	May 21-02	S.S. 'Eastern'	Winthorp Ellis... ...	12 15 N.	120 55 ,,	12 0 ,,	120 25 ,,	... ...	Oceania	...	38	...	978
979	Oct. 18-02	, ...	,, ...	19 12 S.	147 13 ,,	19 20 ,,	147 28 ,,	Nov. 1-02	East Coast ...	14	18	1·3	979
980	Oct. 19-02	,, ...	,, ...	22 53 ,,	151 42 ,,	22 47 ,,	150 50 ,,	Mar. 17-03	,, ,,	149	56	0·4	980
981	Jan. 31-03	,, ...	,, ...	24 6 ,,	152 36 ,,	23 44 S.	151 20 ,,	Feb. 15-03	,, ,,	15	83	5·5	981
982	Nov. 14-03	,, ...	,, ...	8 24 N.	121 48 ,,	3 10 N	125 30 ,,	April 25-04	Oceania	163	450	2·8	982
983	Oct. 22-03	S.S. 'Gulf of Bothnia' ...	R. Hay	34 8 S.	26 0 ,,	34 2 S.	22 18 ,,	Nov. 14-03	Cape Good Hope	23	215	9·3	983
984	May 6-02	S.S. 'Gulf of Siam'... ...	A. Warden	47 50 N	8 36 W	46 5 N.	1 22 W.	April 1-03	Coast of France	330	350	1·1	984
985	Feb. 10-03	,, ...	,, ...	25 14 ,,	16 18 ,,	18 8 ,,	63 10 ,,	Dec. 9-03	North Atlantic...	303	3090	10·2	985
986	March 1-03	,, ...	,, ...	35 25 S	21 15 E.	34 35 S.	20 16 E.	Mar. 12-03	Cape Good Hope	11	75	6·8	986
987	Oct. 21-03	S.S. 'Guthrie'	A. E. Dabelle	25 19 ,,	153 24 ,,	25 0 ,,	153 24 ,,	Dec. 5-02	East Coast ...	45	20	0·4	987
988	Dec. 6-03	,, ...	,, ...	5 34 ,,	130 28 ,,	6 20 ,,	134 25 ,,	Dec. 23-03	East Indies ...	17	275	26·2	988
989	Jan. 26-04	,, ...	,, ...	22 9 ,,	154 37 ,,	35 12 ,,	150 40 ,,	April 2-04	East Coast ...	67	850	12·7	989
990	Feb. 4-04	,, ...	,, ...	39 9 ,,	145 50 ,,	38 47 ,,	146 11 ,,	Mar. 6-04	South Coast ...	30	27	0·9	990
991	May 18-04	,, ...	,, ...	28 56 ,,	153 43 ,,	28 43 ,,	153 38 ,,	June 5-04	East Coast ...	18	14	0·8	991
992	June 3 04	,, ...	,, ...	27 2 ,,	153 30 ,,	27 15 ,,	153 25 ,,	July 4-04	,, ,,	31	14	0·5	992
993	Feb. 5-03	S.S. 'Hauroto'	W. J. Newton	30 26 ,,	156 17 ,,	31 16 ,,	152 58 ,,	Feb. 2-04	,, ,,	362	205	0·6	993
994	June 14-03	,, ...	,, ...	14 22 ,,	174 15 W.	10 21 ,,	161 39 ,,	Dec. 9-03	Oceania	177	1880	10·6	994
995	Aug. 23-01	R.M.S. 'Himalaya' ...	W. Broun	15 0 ,,	98 41 E.	34 50 ,,	20 0 ,,	Nov. 12-02	S. Indian Ocean	446	5100	11·4	995
996	Jan. 31-02	,, ...	,, ...	35 34 ,,	132 2 ,,	35 37 ,,	138 29 ,,	Oct. 26-02	South Coast ...	268	200	0·8	996
997	Sept. 12-02	,, ...	,, ...	35 32 ,,	132 9 ,,	31 56 ,,	132 38 ,,	Feb. 15-03	,, ,,	156	210	1·3	997
998	May 19-03	,, ...	,, ...	3 14 N.	83 26 ,,	7 50 N.	98 26 ,,	Sept. 10-03	Indian Ocean ...	114	830	7·3	998

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999	Mar. 27-03	R.M.S. 'Himalaya' ...	W. Broun ...	8 20 N.	72 37 E.	8 20 N.	73 2 E.	Mar. 31-03	Indian Ocean ...	4	29	7·3	999
1000	Aug. 14-03	,, ...	,, ...	35 36 S.	131 7 ,,	34 59 S.	136 11 ,,	Nov. 1-03	South Coast ...	79	291	3·7	1000
1001	April 21-99	R.M S. 'India' ...	W. D. G. Worcester ...	13 54 ,,	96 37 ,,	5 40 ,,	53 42 ,,	Oct. 14-02	Indian Ocean ...	906	2975	3·3	1001
1002	Aug. 19-00	,, ...	,, ...	35 24 ,,	118 14 ,,	32 20 ,,	125 40 ,,	Jan. 26-03	South Coast ...	890	510	0·6	1002
1003	Aug. 25-00	,, ...	,, ...	11 17 ,,	96 20 ,,	4 6 ,,	39 45 ,,	Aug. 7-03	Indian Ocean ...	1077	3930	3·7	1003
1004	March 4-01	,, ...	,, ...	16 7 N	60 37 ,,	7 40 N.	81 43 ,,	Jan. 12-03	Arabian Sea ...	680	1700	2·5	1004
1005	April 4-01	,, ...	,, ...	46 50 ,,	6 58 W.	21 35 ,,	74 0 W.	Nov. 10-02	North Atlantic...	585	4100	7·0	1005
1006	Feb. 14-02	,, ...	,, ...	35 24 ,,	123 29 E.	32 18 S.	126 0 E.	May 10-03	South Coast ...	450	265	0·6	1006
1007	Feb. 15-02	,, ...	,, ...	35 40 ,,	130 33 ,,	32 15 ,,	127 28 ,,	Aug. 23-03	,, ,,	554	420	0·8	1007
1008	Oct. 22-01	S.S. 'Indraghiri' ...	G. W. Harwood ...	44 7 ,,	37 10 ,,	34 22 ,,	119 33 ,,	Jan. 25-25	Southern Ocean	460	4480	9·7	1008
1009	July 30-01	S.S. 'Kadina' ...	— Rose	37 55 ,,	137 26 ,,	38 30 ,,	145 12 ,,	Feb. 8-04	South Coast ...	923	470	0·5	1009
1010	Mar. 29-01	N.Y.K. 'Kasuga Maru' ...	E. W. Haswell ...	29 51 ,,	153 20 ,,	21 55 ,,	166 40 ,,	... ...	South Pacific ...	...	975	...	1010
1011	Aug. 8-02	N.Y.L. 'Kumano Maru' ...	,, ...	29 32 ,,	153 32 ,,	28 57 ,,	153 32 ,,	June 2-03	East Coast ...	298	37	0·1	1011
1012	Aug. 10-02	,, ...	,, ...	23 33 ,,	152 29 ,,	24 2 ,,	151 46 ,,	April 6-03	,, ,,	239	55	0·2	1012
1013	Oct. 11-02	,, ...	,, ...	6 10 ,,	131 41 ,,	3 40 ,,	128 40 ,,	Nov. 26-02	Oceania	46	270	5·9	1013
1014	Nov. 10-02	,, ...	,, ...	20 42 ,,	149 5 ,,	20 55 ,,	149 8 ,,	Dec. 15-02	East Coast ...	35	14	0·4	1014
1015	Jan. 25-03	,, ...	,, ...	38 22 ,,	148 13 ,,	32 51 ,,	151 53 ,,	March 7-04	,, ,,	407	470	1·2	1015
1016	... ...	,, ...	,, ...	33 31 ,,	151 33 ,,	34 13 ,,	151 2 ,,	April 21-03	,, ,,	...	50	...	1016
1017	April 9-03	,, ...	,, ...	17 20 ,,	141 7 ,,	16 54 ,,	145 56 ,,	April 13-03	,, ,,	4	31	7·8	1017
1018	April 14-03	,, ...	,, ...	29 39 ,,	153 33 ,,	31 6 ,,	153 5 ,,	April 23-03	,, ,,	9	91	10·1	1018
1019	June 25-03	,, ...	,, ...	1 53 N	125 13 ,,	1 30 N.	124 50 ,,	Feb. 15-04	East Indies ...	235	37	1·6	1019
1020	Sept. 13-03	,, ...	,, ...	16 40 ,,	118 32 ,,	4 45 S.	120 14 ,,	Mar. 24-04	China Sea ...	193	1580	8·2	1020
1021	Nov. 1-03	,, ...	,, ...	18 56 ,,	117 0 ,,	7 25 N.	100 25 ,,	Jan. 27-04	,, ,,	87	1350	15·4	1021
1022	Aug. 2-01	S.S. 'Manapouri' ...	Geo. Crawshaw ...	28 47 S.	162 25 ,,	29 4 S.	153 27 ,,	Jan. 27-03	East Coast ..	178	550	3·1	1022
1023	Nov. 12-01	,, ...	,, ...	29 39 ,,	179 20 ,,	13 52 ,,	144 30 ,,	May 11-03	N. Queensl. Coast	545	2500	4·6	1023
1024	Dec. 6-01	,, ...	,, ...	20 37 ,,	173 19 ,,	27 14 ,,	153 25 ,,	Feb. 6-03	East Coast ...	427	1330	3·1	1024
1025	March 3-02	,, ...	,, ...	32 51 ,,	177 18 ,,	19 5 ,,	178 12 ,,	Dec. 3-02	South Pacific ...	266	856	3·2	1025
1026	May 9-02	,, ...	,, ...	31 5 ,,	178 37 ,,	26 37 ,,	153 26 ,,	Sept. 30 03	East Coast ...	509	1560	3·1	1026
1027	June 5-02	,, ...	,, ...	32 56 ,,	153 58 ,,	20 40 ,,	174 30 W.	Jan. 5-04	Oceania	579	2145	3·7	1027
1028	June 9-02	,, ...	,, ...	23 22 ,,	171 17 ,,	17 47 ,,	146 10 E.	Feb. 28-03	N. East Coast ...	264	1675	6·7	1028
1029	April 29-03	S.S. 'Mapourika' ...	,, ...	21 50 ,,	158 0 W.	18 35 ,,	179 55 ,,	Nov. 17-03	Oceania	202	1450	7·1	1029
1030	May 27-03	,, ...	,, ...	20 32 ,,	179 50 E.	19 0 ,,	178 28 ,,	June 22-03	,, ,,	21	133	5·1	1030
1031	Aug. 5-02	S.S. 'Medic' ...	W. S. Atkin ...	35 58 ,,	119 10 ,,	31 47 ,,	128 48 ,,	... ...	S. West Coast ...	...	630	...	1031
1032	July 28-02	R.M.S. 'Miowera' ...	F. A. Hemming...	4 6 N.	167 1 ,,	7 31 N.	119 6 ,,	June 3-03	Oceania	311	275	0·9	1032
1033	Jan. 30-03	R.M.S. 'Moana' ...	M. Carey... ...	25 48 S.	157 32 ,,	26 22 S.	153 4 ,,	June 4-03	N. East Coast ...	124	280	2·3	1033
1034	Sept. 24-02	S.S. 'Mokoia' ...	J. Gibb	40 2 ,,	172 2 ,,	38 23 ,,	174 41 ,,	Nov. 17-02	N. Zealand Coast	54	170	3·1	1034

Ref. No.	Date when put into the sea.	Name of Ship.	Name of Commander.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No.
1035	Nov. 17-02	S.S. 'Mokoia'	J. Gibb	46 12 S.	166 25 E.	46 28 S.	168 17 E.	Dec. 1-02	N. Zealand Coast	14	90	6·4	1035
1036	Nov. 23-02	,, ...	,, ...	39 33 ,,	169 58 ,,	36 30 ,,	174 12 ,,	Jan. 25-03	,, ,,	63	290	4·6	1036
1037	Feb. 9-03	,, ...	,, ...	37 12 ,,	162 12 ,,	46 26 ,,	168 16 ,,	Jan. 10-04	, ,,	335	565	1·7	1037
1038	June 1-02	S.S. 'Mona'	C. McArthur	45 49 ,,	161 48 ,,	35 52 ,,	173 42 ,,	Dec. 14-02	,, ,,	196	822	4·2	1038
1039	Nov. 19-01	R.M.S. 'Monowai'	R. Neville	45 36 ,,	162 44 ,,	37 53 ,,	174 49 ,,	Nov. 14-02	,, ,,	360	750	2·1	1039
1040	July 29-02	,, ...	,, ...	45 51 ,,	163 19 ,,	30 18 ,,	173 45 ,,	Dec. 1-02	,, ,,	124	630	5·1	1040
1041	Oct. 9-02	,, ...	,, ...	44 13 ,,	153 14 ,,	36 43 ,,	174 20 ,,	June 10-04	,, ,,	610	1180	1·9	1041
1042	Nov. 5-02	,, ...	,, ...	39 49 ,,	171 7 ,,	40 57 ,,	174 57 ,,	Dec. 5-02	,, ,,	30	212	7·1	1042
1043	Jan. 13-03	,, ...	,, ...	38 53 ,,	167 37 ,,	35 31 ,,	173 21 ,,	June 22-03	,, ,,	150	375	2·5	1043
1044	May 24-03	,, ...	,, ...	39 43 ,,	170 43 ,,	46 27 ,,	168 17 ,,	Mar. 22-04	,, ,,	302	610	2·0	1044
1045	Dec. 14-03	,, ...	,, ...	46 12 ,,	166 15 ,,	46 38 ,,	168 20 ,,	Dec. 20-03	,, ,,	6	104	17·3	1045
1046	Aug. 12-02	S.S. 'Moonta'	C. Ulbrick	23 5 ,,	113 27 ,,	22 37 ,,	113 42 ,,	... ...	West Coast ...	...	40	...	1046
1047	June 27-02	R.M.S. 'Moravian'	A. Simpson	37 36 ,,	135 8 ,,	38 3 ,,	141 0 ,,	Oct. 6-02	South Coast ...	101	325	3·2	1047
1048	Oct. 4-02	S.S. 'Narrung'	A. W. Bond	41 55 ,,	115 0 ,,	38 2 ,,	140 33 ,,	July 6-03	,, ,,	275	1370	5·0	1048
1049	Sept. 9-03	R.M.S. 'Omrah'	F. S. Symons	38 15 ,,	140 37 ,,	38 2 ,,	140 48 ,,	Sept. 20-03	,, ,,	11	15	1·4	1049
1050	Sept. 30-03	,, ...	,, ...	37 38 ,,	140 3 ,,	37 32 ,,	140 8 ,,	Oct. 2-03	,, ,,	2	7	3·5	1050
1051	Dec. 28-01	R.M.S. 'Orizaba'	R. Archer	35 17 ,,	126 30 ,,	34 51 ,,	135 45 ,,	July 10-03	,, ,,	559	530	0·9	1051
1052	Aug. 9-02	,, ...	,, ...	35 33 ,,	125 12 ,,	36 36 ,,	138 7 ,,	Jan. 4-04	,, ,,	513	675	1·3	1052
1053	June 2-96	R.M.S. 'Ormuz'	F. M. Tuke	37 36 ,,	149 58 ,	37 38 ,,	149 56 ,,	July 2-02	S. East Coast ...	2585	3	...	1053
1054	Nov. 13-02	R.M S. 'Oroya'	R. Fletcher	31 37 ,,	115 7 ,,	31 20 ,,	115 35 ,,	Mar. 8-03	West Coast ..	115	32	0·3	1054
1055	Nov. 19-02	,, ...	,, ...	39 1 ,,	146 50 ,,	37 52 ,,	148 3 ,,	Dec. 18-02	South Coast ...	29	135	4·7	1055
1056	Nov. 20-02	,, ...	,, ...	38 5 ,,	149 5 ,,	37 16 ,,	150 5 ,,	Dec. 21-02	S. East Coast ...	31	85	2·7	1056
1057	Nov. 21-02	,, ...	,, ...	35 40 ,,	150 15 ,,	35 10 ,,	150 40 ,,	Dec. 9-02	East Coast ...	18	38	2·1	1057
1058	Dec. 13-02	,, ...	,, ...	35 27 ,,	127 7 ,,	32 6 ,,	133 37 ,,	Sept. 8-03	South Coast ...	273	422	1·5	1058
1059	March 8-03	,, ...	,, ...	35 24 ,,	124 10 ,,	37 19 ,,	139 50 ,,	Nov. 4-03	,, ,,	241	880	3·7	1059
1060	Sept. 22-02	R.M.S. 'Oruba'	W. H. Burgoin... ...	32 10 ,,	115 25 ,,	31 48 ,,	115 40 ,,	May 30-03	,, ,,	250	26	0·1	1060
1061	Dec. 14-03	,, ...	,, ...	34 55 ,,	123 58 ,,	33 36 ,,	123 40 ,,	Jan. 8-03	,, ,,	25	77	3·1	1061
1062	Jan. 20-03	,, ...	,, ...	0 41 N.	84 13 ,,	7 51 N.	98 33 ,,	Dec. 20-03	Indian Ocean ...	334	670	2·0	1062
1063	Nov. 21-03	M.M. 'Pacifique'	M. Couret	28 4 S.	158 31 ,,	34 40 S.	150 53 ,,	Mar. 18-01	East Coast ...	117	595	5·1	1063
1064	Jan. 21-03	,, ...	,, ...	30 49 ,,	154 38 ,,	31 15 ,,	153 0 ,,	Feb. 2-03	,, ,,	12	100	8·3	1064
1065	Jan. 25-03	,, ...	,, ...	31 23 ,,	155 40 ,,	33 21 ,,	151 32 ,,	June 9-03	,, ,,	135	267	2·0	1065
1066	Nov. 28-03	,, ...	,, ...	24 58 ,,	163 22 ,,	26 27 ,,	153 8 ,,	May 2-04	,, ,,	156	650	4·2	1066
1067	Sept. 29-96	Ship 'Patriarch'	Mark Beach	40 8 ,,	72 48 ,,	34 0 ,,	25 42 ,,	Nov. 30-92	Southern Ocean	2252	2610	1·2	1067
1068	Sept. 2-02	S.S. 'Persic'	F. H. Armstrong ...	0 5 ,,	10 10 W.	5 18 N.	3 55 W.	... ...	W. African Coast	...	570	...	1068
1069	Feb. 23-03	,, ...	,, ...	35 19 ,,	129 6 E.	35 57 S.	139 25 E.	Aug. 29-03	South Coast ...	187	620	3·3	1069
1070	... ...	,, ...	,, ...	35 30 ,,	127 39 ,,	34 0 ,,	123 3 ,,	Nov. 27-03	,, ,,	...	270	...	1070

Ref. No	Date when put into the sea.	Name of Ship.	Name of Commander.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No.
1071	May 28-00	M.M. 'Polynesien'	A. Chevalier	29 7 S.	154 51 E.	19 43 S.	147 53 E.	Oct. 17-03	East Coast ...	1237	740	0·6	1071
1072	March 2-03	"	"	26 21 "	159 17 "	19 24 "	147 28 "	Oct. 31-03	" "	243	880	3·6	1072
1073	March 7-03	"	"	25 23 "	160 19 "	30 2 "	153 15 "	Dec. 12-03	" "	230	520	1·9	1073
1074	Nov. 4-02	S.S. 'Port Denison' ...	W. Johnson	28 5 N.	92 8 W.	29 15 N.	94 48 W.	Sept. 23-03	Gulf of Mexico...	323	177	0·5	1074
1075	Oct. 12-01	S.S. 'Port Hunter'... ...	S. M. Orr...	46 0 S.	92 20 E.	34 50 S.	173 13 E.	Mar. 9-03	Southern Ocean	3069	4280	1·4	1075
1076	April 14-02	R.M.S. 'Rome'	E. Street...	35 6 "	138 6 "	34 17 "	138 2 "	May 14 03	South Coast ...	395	56	0·1	1076
1077	May 12-02	"	"	32 42 "	115 6 "	32 43 "	116 18 "	May 12-04	S. West Coast ...	731	70	0·1	1077
1078	May 13-02	"	"	30 6 "	113 34 "	31 23 "	115 28 "	... ...	West Coast ...	...	138	...	1078
1079	Jan. 28-03	"	J. Paine	37 11 "	139 29 "	36 28 "	139 35 "	Feb. 27-03	South Coast ...	30	40	1·3	1079
1080	Feb. 1-03	"	"	35 15 "	118 25 "	34 58 "	117 56 "	Feb. 12-03	" "	11	33	3·0	1080
1081	May 6-03	"	R. A. Peters	29 26 "	113 0 "	32 10 "	115 40 "	July 20-03	West Coast ...	75	425	5·7	1081
1082	June 30-00	S.S. 'Star of Victoria' ...	J. M. Hart	42 45 "	42 33 "	38 17 "	141 40 "	Jan. 23-04	Southern Ocean	1302	5250	4·0	1082
1083	July 4-01	S.S. 'Star of New Zealand'	"	45 43 "	72 30 "	20 8 "	169 48 "	Sept. 29-03	S. Pacific Ocean	817	5675	6·9	1083
1084	Nov. 13-01	"	"	36 38 N.	11 56 W.	28 29 N	13 40 W.	May 10-02	North Atlantic...	178	492	2·2	1084
1085	Aug. 29-02	G.M.S. 'Stuttgart'... ...	P. Grosch	28 42 S.	112 15 E.	29 2 S	114 41 E.	Oct. 19-02	West Coast ...	51	150	2·9	1085
1086	Feb. 15-02	S.S. 'Sussex'	B. Hayward	16 6 "	3 46 "	13 15 N	59 33 W.	April 11-03	Atlantic Ocean ..	420	4820	11·5	1086
1087	June 5-02	"	"	35 15 "	114 18 "	34 37 S.	115 50 E.	April 15-03	S. West Coast ...	311	95	0·3	1087
1088	Mar. 27-01	R.M.S. 'Victoria'	E. Crewe	31 22 "	114 56 "	28 42 "	114 30 "	June 13-03	West Coast ...	808	170	0·2	1088
1089	Aug. 10-02	M.M. 'Ville de la Ciotat'...	A. Fiaschi	35 22 "	118 30 "	34 22 "	119 30 "	Aug. 19-02	South Coast ...	9	100	11·1	1089
1090	Mar. 23-03	"	"	38 10 "	138 1 "	38 24 "	142 17 "	May 25-03	" "	64	230	3·6	1090
1091	Sept. 8-03	"	"	35 36 "	133 13 "	34 30 "	136 0 "	Dec. 6-03	" "	89	165	1·9	1091
1092	Oct. 16-03	"	"	37 27 "	139 42 "	37 53 "	140 21 "	Mar. 6-04	" "	142	44	0·3	1092
1093	Jan. 29-04	"	"	38 34 "	141 55 "	38 16 "	141 20 "	Feb. 11-04	" "	13	29	2·2	1093
1094	Aug. 19-01	S.S. 'Waihora'	— McDonald	37 10 "	161 35 "	20 20 "	166 45 "	Jan. 9-03	Tasman Sea ...	508	1075	2·1	1094
1095	Sept. 11-02	"	E. Stott	45 10 "	160 4 "	36 42 "	174 19 "	Aug. 19-03	" "	342	880	2·6	1095
1096	Dec. 30-02	S.S. 'Waikare'	Geo. Crawshaw... ...	33 58 "	151 53 "	32 49 "	152 0 "	Jan. 10-03	East Coast ...	11	68	6·2	1096
1097	Jan. 7-03	"	"	40 26 "	172 36 "	41 21 "	174 47 "	Jan. 17-03	N. Zealand Coast	10	135	13·5	1097
1098	Feb. 13-03	"	"	33 48 "	154 8 "	37 58 "	177 18 "	Dec. 20-03	Tasman Sea ...	310	1390	4·5	1098
1099	Feb. 22-03	"	"	36 41 "	171 30 "	35 4 "	173 12 "	July 26-93	N. Zealand Coast	154	133	0·9	1099
1100	Mar. 13-03	"	"	33 35 "	153 44 "	31 55 "	152 44 "	... ...	East Coast ...	...	115	...	1100
1101	Mar. 20-03	"	"	34 28 "	162 23 "	35 45 "	173 34 "	Nov. 1-03	Tasman Sea ..	226	645	2·9	1101
1102	May 18-03	"	"	34 17 "	171 42 "	34 54 "	173 7 "	July 6-03	N. Zealand Coast	49	90	1·8	1102
1103	July 1-03	"	"	34 10 "	165 11 "	36 6 "	175 28 "	Dec. 1-03	Tasman Sea ...	167	510	3·1	1103
1104	May 5-03	R.M.S. 'Warrimoo' ...	R. Neville	38 58 "	168 51 "	35 49 "	173 37 "	Aug. 8-03	" "	95	315	3·3	1104
1105	May 14-03	"	"	43 21 "	148 25 "	42 11 "	148 22 "	June 15-03	Tasmanian Coast	32	62	1·9	1105
1106	June 27-03	"	"	44 51 "	161 39 "	46 3 "	170 15 "	Dec. 6-03	Tasman Sea ...	162	460	2·8	1106
1107	Aug. 28-03	"	"	42 17 "	152 50 "	30 22 "	153 9 "	May 11-04	East Coast ...	262	665	2·5	1107

FURTHER EXPERIMENTS ON THE STRENGTH AND ELASTICITY OF REINFORCED CONCRETE.

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[*Read before the Royal Society of N. S. Wales, September 7, 1904.*]

THE following paper consists of an investigation on the strength and elasticity of Portland cement mortar and concrete when reinforced with steel rods, and is a continuation of the work contained in a paper by the writer read before the Society on December 3rd, 1902.[1] All the specimens dealt with in this paper were kept in air until tested, whereas those referred to in the above paper were kept in water.

Tension Tests.—The experiments made to determine the behaviour of reinforced concrete in tension were conducted in a similar manner to those described in the paper above referred to. The specimens, clips for holding them during the test, and the method of determining the extensions produced under the various loads were also, except when otherwise mentioned, the same in every respect.[2]

The strength of reinforced concrete or mortar when subjected to tensile stress is governed by the adhesive strength of the mortar to the metal reinforcement. In all the experiments made the specimen fractured at the change of section, close to the heads of the specimen held by the clips, the concrete sliding longitudinally by overcoming the adhesion to the metal rods. If a sufficient adhesion area could have been provided between the section where

[1] Journ. Roy. Soc. N.S. Wales, Vol. XXXVI., page 290.

[2] Figs. 1, 2, and 3.

fracture occurred, and the extremity of the head of the specimen, considerably greater stresses would have been sustained, and fracture could not then occur until the elastic limit of the metal reinforcement was reached. The stresses developed in the metal rods varied considerably, but assuming the extensions of the concrete, within the 4 inches length upon which measurements were taken, to be the same as the metal embedded in it, (which was not true in many of these tests), the stresses may be calculated as follows:—

Let P = the total pull on the metal reinforcement.

ρ = the intensity of stress on the metal.

E = the coefficient of elasticity of the metal. In this case Bessemer steel = 30,000,000 lbs. per square inch.

λ = the extension per inch.

a = the area of the reinforcement in square inches.

$$\text{Then } \rho = \frac{P}{a} = \lambda E$$

In I. a. 1, Table I., 5,000 lbs. pull produced an extension = 0·000131 inch per inch. The breaking load 5696 lbs. produced λ = 0·00015 inch, a = 0·1963 sq. inches.

$\therefore \rho$ = 4500 lbs. per sq. inch and P = 883 lbs.

$\therefore$ 5696 − 883 = 4813 lbs. sustained by the concrete, or about 300 lbs. per square inch.

In I. a. 3, Table I. λ = 0·00014 inch, a = 9815 sq. inches.

$\therefore \rho$ = 4200 lbs. per sq. inch, and P = 4122 lbs. The breaking load was 8256 lbs., and the load sustained by the concrete 4134 lbs. or 258 lbs. per square inch.

The rods used to reinforce the tension were in every case of Bessemer steel, having an elastic limit of 42,000 lbs. per square inch and a coefficient of elasticity of 30,000,000 lbs. per square inch.

The adhesive resistance was always much below the elastic limit of the material, as it was impossible to provide the necessary adhesion area between the fractures and the extremity of the head of the specimen.

If l = the length of the rod required to provide an area sufficient to develop the elastic limit of the material.
c = circumference of the rod.
ρ_s = the adhesive strength per square inch.
f = the elastic limit of the material per square inch.

Then:
$$l = \frac{fa}{c\rho_s}$$

If the diameter of the steel rod is $\frac{1}{2}$ inch and circumference = 1·57 inch
$$l = \frac{42000 \times 0{\cdot}1963}{1{\cdot}57\rho_s} = \frac{5251}{\rho_s}$$

The value of ρ_s varies with the age of the mortar or concrete, and with the quantity of water used in mixing.

It will be seen that it varies considerably in the various tests recorded in Tables I. and II.

If $\rho_s = 100$, then $l = 52{\cdot}251$ inch.

With a length of 7 inches which represents the distance from the fracture to the extremity of the head in a large number of tests, the adhesive resistance would have to be 750 lbs. per square inch to develop the strength of the metal at the elastic limit.

In I. b. 1 to I. f. 6 the same shackles were used to hold the heads, but the specimen was made longer and reduced to 4 × 3 and 3 × 3 for the middle 4 inches, as shown in the sketch on Table I. b. 1, with a view to provide a larger adhesive resistance and develop a greater tensile strength. The largest stress sustained was in I. b. 5, which gave 1611 pounds per square inch, although the mortar was only 42 days old. The strength of this mortar was certainly not greater than 250 lbs. per square inch, so that a resistance of at least 1361 lbs. per square inch, was contributed by the five steel bars $\frac{3}{8}$ of an inch in diameter, or the stress in the bars was 22190 lbs. per square inch. The extension recorded for a load of 14000 lbs. was 0·001563 inch, so that the metal must have slipped in the mortar, as the elastic extension of the rods was only 0·0007396 inches. Similar slipping occurred in I. b. 4 and I. b. 5, and to a smaller extent in I. b. 2. In like manner, in Table II., slipping occurred in II. d. 3, II. e. 1, II. e. 2, II. f. 1, II. f. 3 and in some others. And in general whenever the extension recorded in column 5 exceeds that of the elastic extension of the steel rods for the actual stress upon the rods, the difference is due to slipping, or in other words the partial failure of the adhesion of the mortar or concrete to the rods.

In fig. I. a. the resistance of the reinforcement is denoted by straight lines 1 f., 2 f. and 3 f., on the assumption that no slipping occurred. The diagrams 1, 2 and 3 are at first curved and afterwards become straight lines. For any given extension within the elastic limit of the steel, the intercept between the straight line representing the steel and the curve representing the reinforced specimen, is the total resistance contributed by the mortar or concrete.

A further test was made in which the length of the head measured from the extremity of the parallel portion was 14 inches, instead of 7 as in the other tests, thus providing a greater adhesion area. The concrete consisted of 1 of cement, 2 of sand, 3 of $\frac{3}{4}$ inch shivers, reinforced with 5 steel rods $\frac{1}{2}$ inches in diameter. At 99 days the total load sustained was 16500 lbs., or 1030 lbs. per square inch. Taking the strength of the concrete at 300 lbs. the rods contributed 730 lbs. per square inch, sustaining a total pull of 11680 lbs. or 11918 lbs. per square inch. The extensions were, however, in excess of that due to the steel for the stress developed, and at fracture the extension was 0·001855 inch per inch, whereas if slipping had not occurred the extension would have been only ·0003972 inch per inch.

Tables I. and II. give the coefficient of elasticity for various stresses, and the curves Figs. I. a. and I. b., Figs. II. a. to II. f. show the total loads applied and the extensions produced by them. The decrease in the coefficient of elasticity, as the intensity of stress increases, is characteristic of reinforced concrete, and is clearly indicated by the tables and curves. The coefficient of elasticity is the tangent of the slope of the curve for the stress in question. The column $E = \frac{\text{Total Unit Stress}}{\text{Total Unit strain}}$ necessarily differs from the coefficient of elasticity, and it is given in order to supply data for calculations on the transverse strength of beams. The adhesion per square inch is calculated by measuring the area of the surface of the rods, after the fracture of the test piece, between the fracture and the extremity of the head, and dividing this area into the total pull sustained by the rods. The total pull on the rods is easily found from the extension of the test piece, and the coefficient of elasticity of the metal provided slipping has not occurred, or it can be found by subtracting the pull on the unreinforced material from the total load applied. Values of the adhesive strength are given in Tables I. and II. approximately as the actual tensile strength of the concrete itself in the reinforced test piece is only approximately known.

Compression Tests.—The results of a considerable number of tests of mortar prisms 12 inches long by 6 inches by 6 inches of various proportions of cement to sand are recorded in a previous paper.[1]

Table III. and Fig. III. a. give the results of testing similar prisms of mortar, but at ages of from 720 to 729 days. The results do not differ to any extent from those recorded on pages 306-7,[1] and show the diminution of the

[1] Journ. Roy. Soc. N.S. Wales, Vol. xxxvi., page 295.

coefficient of elasticity with increasing stress, although the actual values obtained in any particular case is necessarily somewhat irregular.

Table IV. a. and Fig. IV. a., Fig. IV. α., and Fig. IV. β. give similar results for concrete prisms 12 inches long by 6 by 6 inches in cross-section. In IV. β, and Fig. IV. β, the loads were carried to 1240 lbs. per square inch, then gradually reduced to the initial stress of 200 lbs. per square inch, producing a permanent deformation of 0·00088 inch on 8 inches; the load was afterwards reapplied and continued until fracture took place. Table IV.b. and Fig. IV.b., Fig. IV. c., Fig. IV. d., Fig. IV. e., Fig. IV. f., and Fig. IV. h., give the results of testing prisms of concrete 24 inches long by 6 by 6 inches in cross-section. This series of tests consists of plain concrete prisms of various proportions of cement, sand and stone, also when reinforced with longitudinal rods bound together at intervals with soft iron wire and when reinforced with iron grills. The effect of loading and unloading is also dealt with.

Remarks—On the strength of concrete prisms reinforced with longitudinal rods bound together with cross ties:—

Length of prism 24 inches.

Cross section $6 \times 6 = 36$ square inches.

Strength of concrete prism 1 : 2 : 2 IV. b. 1, age 84 days = 1836 lbs. per square inch.

Strength of concrete reinforced with 4 iron rods $\frac{3}{8}$ inch diameter with cross ties of wire $\frac{3}{16}$ inch diameter—average age 64 days = 2248 lbs. per square inch.

Difference due to reinforcement = 588 lbs. per square inch.

Area of 4 rods $\frac{3}{8}$ inch diameter = 0·4416 square inch.

Resistance at elastic limit = 16780 lbs.

Resistance per square inch of prism $= \frac{16780}{36} = 466$ lbs. per square inch.

Hence the longitudinal rods contributed rather more than would be represented by the elastic limit of the material, the difference is probably due to the ties.

Strength of concrete prisms 1 : 2 : 3 IV. b_2 to IV. b_4, age 79 days (mean) = 1468 lbs. per square inch.

Total strength of prisim reinforced with 4 iron bars $\frac{3}{8}$ inch diameter (mean) = 2086 lbs. per square inch.

Difference due to reinforcement = 618 lbs. per square inch.

Here also the increase is greater than that of the 4 rods at their elastic limit.

The experiments on the concrete of similar composition but of different ages is shown in this table and in IV. d. 1, 2, 3, and IV. e. 1 and 2 the effects of repeated loading and unloading are shown.

The strength of the concrete prisms IV. f. 1 and 2, consisting of cement, sand, and $\frac{3}{4}$ inch basalt shivers in the proportion of 1 : 2 : 2 having 4 rods $\frac{1}{2}$ inch diameter and 2 and 5 cross ties respectively gave a mean value of 2666 lbs. per square inch. The mean resistance of two similar prisms not reinforced IV. d. 1 and 2 was 2007 lbs. per square inch, but the age was 32 days greater, the difference 659 lbs. per square inch is therefore below the amount contributed by the reinforcement. The actual resistance of the four $\frac{1}{2}$ inch rods at their elastic limit is about 827 lbs. per square inch, and the cross ties must have contributed something.

The mean strength of the prisms IV. f. 2 and 3, similar in every respect to the foregoing but with 4 rods $\frac{3}{8}$ inch diameter, and 10 and 15 cross ties respectively, was 2619 lbs. per square inch, or a difference due to reinforcement of 612 lbs. per square inch. Here the 4 rods $\frac{3}{8}$ inch diameter would contribute about 466 lbs. per square inch, leaving a difference of 146 lbs. per square inch to be supplied by the cross ties.

The mean strength of the reinforced prisms IV. g. 1 and 2, 182 days old was 1803 lbs. per square inch, and of similar prisms unreinforced, but 21 days older, 1555 lbs. per square inch; IV. d. 3 and IV. e. 1 giving a difference of 248 lbs. per square inch only, which is only about half as much as the actual resistance of the reinforcement.

The mean resistance of the reinforced prisms IV. g. 3 and 4, 173 days old, similar to IV. g. 1 and 2, but with 10 and 15 cross ties respectively, was 1985 lbs. per square inch, which compared with similar unreinforced prisms 30 days older shows a difference of 430 lbs. per square inch, due to the reinforcement, but although this would account for the resistance contributed by the rods, it is below what might have been expected from the rods and cross ties combined.

The prisms IV. h. 1 and 2 are reinforced with 7 grills, each consisting of 8 bars $\frac{3}{16}$ inch in diameter arranged transversely. These prisms gave a mean strength of 2398 lbs. per square inch at 106 days, or an excess of 391 lbs. per square inch over similar prisms not reinforced but 192 days old, so that the value of this kind of reinforcement appears to be not as good as the longitudinal rods and cross ties of the same volume.

Concrete reinforced by longitudinal rods.—Tables IV. m. and IV. k. and Figs. IV. m. and IV. k. give the results of testing concrete prisms octagonal in cross section, having an area of 29·75 square inches. The lengths of these prisms were 24 and 12 inches respectively. The object of these tests was to ascertain the effect of reinforcing with soft wire spirals with and without longitudinal rods of steel.

M. Considère has pointed out that when concrete prisms reinforced with longitudinal rods are allowed to set in water the rods are extended, due to the swelling of the concrete, and when allowed to set in air they are compressed.

The expression

$$\rho_s = E_s \lambda_s$$

is true only when λ_s includes the initial strain due to shrinkage as well as that due to the applied load. The initial stress upon the longitudinal rods in a concrete prism set in air may be very near to the intensity of stress at the elastic limit of the metal, and thus the rods begin to deform plastically with very moderate intensities of stress and contribute very little to the strength of the prism. The strength in any case cannot differ much from that due to the sum of the resistances of the concrete to crushing, and to the resistance of the rods up to the elastic limit of the metal.

If A = the area of cross section of prism.
a = the area of rods.
c = the compressive strength of the concrete.
w = the total load carried.

Then,

$$w = c\left(A + \frac{E_s}{E_c}a\right)$$

In IV. m. 1, the shortening of the prism per inch with a stress of 1806 ℔s. per square inch was 0·000725 inch, corresponding with a stress of 21750 ℔s. per square inch. If we add to this stress, the initial stress due to shrinkage, say 7,000 ℔s. square inch, we have 28750 ℔s. per square inch as the total intensity of stress on the rods when the prism is under a stress of 1806 ℔s. per square inch. At 2409 ℔s. per square inch, when the prism fractured, the stress on the rods would be much greater, so that there is very small margin remaining which is available in the case of a reinforced prism.

Concrete reinforced with transverse rods or grills.—The tendency to shear along oblique planes is resisted by rods whether they are arranged parallel with or at right angles to the direction of pressure, in consequence of the equality of the intensities of shearing stresses on planes at right angles to each other, so that transverse rods behave in a manner very similar to longitudinal rods.

Concrete prisms reinforced by means of spirals of soft iron or steel wire.—M. Considère has shown that a prism of sand reinforced by a continuous shell offers 2·4 times the resistance of the sand when reinforced by longitudinal rods of the same weight as the shell, and he infers that spirals or hoops are 2·4 times as effective as the same weight of metal arranged as longitudinal rods in a concrete prism. The spirals are in tension from the swelling of the concrete which is much smaller than the longitudinal shortening of the rods, and concrete reinforced by spirals can sustain great deformations without injury to either metal or concrete. The compressive resistance of a concrete prism reinforced with spirals and longitudinal rods is the sum of the resistances due to:—

1. The compressive resistance of the plain concrete without reinforcement.
2. The compressive resistance of the longitudinal rods up to their elastic limit.
3. The compressive resistance which would have been produced by imaginary longitudinal rods at the elastic limit of the material used in the spirals, the volume of the imaginary rods being 2·4 times that of the spiral.

Remarks—On the compressive strength of reinforced concrete prisms, octagonal in cross section:—

Area 29·75 square inches, Fig. IV. m., length = 12 inches.

No. 1. Compressive strength of concrete, prism not reinforced = 2409 lbs. per square inch.

No. 2. Reinforced with a spiral 5 inch in diameter of wire 0·2 inch in diameter = 4220 lbs. per square inch.

Increase due to spiral = 1811 lbs. per square inch.

Ratio of area of metal to concrete = ·022

$$·022 \times 39000 = 858 \text{ lbs. per square inch.}$$

$$\text{Ratio } \frac{1811}{858} = 2·1$$

The efficiency of the spiral over an equal volume of metal arranged as longitudinal rods = 2·1 times as great.

No. 3. Total compressive strength = 4517 lbs. per sq. inch.
Resistance of spiral from last test = 1811 ,, ,,
Resistance of concrete ... ... = 2109 ,, ,,
Increase in strength due to 6 Bessemer steel rods $\frac{1}{2}$ inch in diameter = 297 lbs. per square inch.
Area of rods = 6 × 0·196 = 1·176.
Limit of elasticity of metal = 37770 lbs. per square inch.
Resistance of the rods if unstrained before testing =

$$\frac{1·175 \times 37770}{29·5} = 1490 \text{ lbs. per square inch.}$$

Hence these rods did not contribute their full resistance in consequence of the initial compression due to shrinkage of the concrete.

No. 4. The total strength of concrete prism reinforced = 3158 lbs. per square inch.
Increase due to spiral = 749 lbs. per square inch.
Here the ratio $\frac{749}{858} = 0·87$. Whereas a similar test, No. 2, gave a ratio of 2·1.

No. 5. The total strength of the reinforced prism = 5421 lbs. per square inch.
Increase due to reinforcement = 3012 lbs. per square inch.
Assuming that the spiral contributed 1811 lbs. as in No. 2, the increase due to rods = 1201 lbs. per square inch.

10 Bessemer steel rods $\frac{3}{8}$ inch diameter having an elastic limit of 37770 lbs. per square inch $= \frac{1·104 \times 37770}{29·75} =$ 1400 lbs. per square inch.

In this case the rods appear to have contributed nearly their full amount, assuming the spirals contributed the same amount as in No. 2 tests.

Concrete prisms 24 inches long, Fig. IV. k.

No. 1. Compressive strength of concrete prism, not reinforced = 2786 lbs. per square inch.

No. 2. Reinforced with spiral 5 inch diameter of wire 0·2 inch diameter = 4098 lbs. per square inch.

Increase due to spiral = 1312 lbs. per square inch.

Ratio of area of metal to concrete = ·022

$$\cdot 022 \times 39000 = 858 \text{ lbs. per square inch.}$$

$$\text{Ratio } \frac{1312}{858} = 1\cdot 53$$

No. 4. Total strength of prism = 5270 lbs. per square inch.

Increase due to spiral and concrete from No. 2 test = 4098 lbs. per square inch.

Difference due to 6 rods of Bessemer steel $\frac{1}{2}$ inch in diameter = 1172 lbs. per square inch.

Area of rods = 6 × 0·196 = 1·176 square inch.

$$\text{Resistance} = \frac{1\cdot 176 \times 37770}{29\cdot 5} = 1490 \text{ lbs. per square inch.}$$

Hence the rods contributed about 80% of their resistance.

No. 5. Total strength of prism = 4214 lbs. per square inch.

Resistance due to concrete and spiral from No. 2 test = 4098 lbs. per square inch.

Difference due to rods = 116 lbs. per square inch.

The 10 rods $\frac{3}{8}$ inch diameter should have contributed 1400 lbs. per square inch, so that the longitudinal rods in this case did not contribute their proper proportion, due probably to initial stresses in consequence of shrinkage of concrete.

The experiments recorded in Tables IV. m. and IV. k. show that prisms of concrete reinforced with spirals of soft steel or iron possess considerable ductility and sustain large deformations before fracture. Moreover, cracks appear on the outer face long before actual fracture, thus giving warning of approaching danger.

The experiments also suggest that in order to obtain the maximum strength for the minimum cost in reinforced concrete columns, such as would be most suitable for fire proof buildings, the reinforcing should consist of soft iron or steel spirals having a longitudinal pitch of about $\frac{1}{8}$ of the diameter, with longitudinal steel rods arranged on the inner side of the spirals, around the circumference of, say Bessemer or other steel having a high elastic limit. It has been shown by Considère that such a combination is approximately equal in resistance to riveted steel of the same weight. It has been suggested to submit such columns to a test load sufficient to crush the outer shell of concrete, and after the test to put on a concrete coating in which asbestos is substituted for the sand.

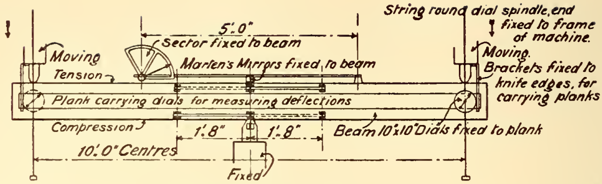
Coefficient of elasticity.—The curves Fig. IV. m. and Fig. IV. k. show that the coefficient decreases rapidly with the increase in the stress, when the loads are gradually increased to tbe breaking point, but if the loads are removed and reapplied the effect of the load first applied is to increase the coefficient for the second load. 4 Fig. IV. m., 5 Fig. IV. m., and 5 Fig. IV. k. illustrate this point. The application of the first pressure on a hooped concrete prism raises the elastic limit. The coefficient of elasticity obtained by repeated loading and unloading does not diminish to the same extent as when the loads are gradually increased to the breaking point.

Transverse strength.—The experiments on the transverse strength were made on mortar beams consisting of 1 of cement to 3 of river sand. These beams were 4 by 4 inches in cross section, tested on a span of 40 inches; two beams were reinforced with three rods $\frac{1}{2}$ inch in diameter and two were plain. The results obtained are recorded in Tables V. a. V. b., and in the diagrams Figs. V. a. and V. b. These tests are a continuation of the work described in a previous paper,[1] their chief interest being the age at which they were tested, as they show the same general characteristics as similar beams described in the paper referred to, but which were tested at a lesser age.

Experiments were also made on concrete beams, consisting of 1 of cement, 2 of sand, and 3 of broken basalt $\frac{3}{4}$ inch gauge. These beams were 10 by 10 inches in cross section, and were tested, except in the case of No. 1, on a span of 120 inches. Beams Nos. 1, 2, 3 and 4, were reinforced on the tension side by three steel rods $\frac{7}{8}$ inch in diameter, beams Nos. 7 and 8 were not reinforced. In the testing of these beams it was attempted to measure the strains produced by the various loads applied, in causing deflection, in shortening it on the compression side at the extreme fibres, and at positions $1\frac{1}{4}$ inch from the top and bottom of the beam. The apparatus used consisted of the Martens' mirror extensometers, used with four telescopes and scales, also some accurately made sectors and dials. The method of applying these instruments to the beam is illustrated in Figs. 7, 8, and 9, and the results obtained are recorded in the following diagrams.

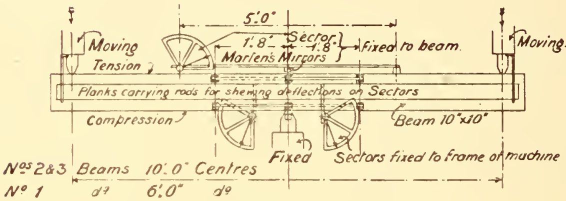
Fig. VI. a. shows the loads and the extensions produced by them between the centre of the beam and 20 inches on either side of the centre. The extensions are measured $1\frac{1}{4}$ inch from the top of the beam, and at the top of the beam, which was the extreme fibre on the tension side. Fig. VI. b. shows the loads and corresponding shortenings measured in a similar manner. Fig. VI. c. shows the loads and the extensions measured at the top of the beam (extreme fibre), and Fig. VI. d. shows the loads and corres-

[1] Journ. Roy. Soc. N.S.Wales, Vol. xxxvi., 1902, p. 298.



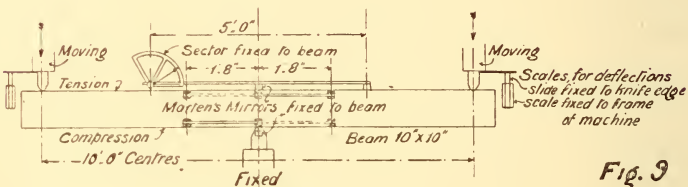
BEAMS Nos 4 & 8

Fig. 7



BEAMS Nos 1, 2 & 3.

Fig. 8



BEAM No 7.

Fig. 9

ponding deflections. It will be observed that the loads and deformations in Nos. 2, 3, and 4 are very similar, and it was considered that the mean obtained would be more useful. This has been done in Fig. V. f. and Table V. The curves Fig. VI. a. and Fig. VI. c. all show very rapid increases in extension for the gradually increasing loads applied, and corresponding diminution in the coefficient of elasticity of the reinforced concrete in tension. The other diagrams show the same peculiarities, but to a lesser extent. In the curves of loads and deflections, Fig. VI. d. No. 2 a, show very small deflections up to a load of 3 tons, the deflections then increase more rapidly up to the breaking point. This change in the diagram is characteristic, and is seen more or less well defined in all load deflection curves with reinforced concrete beams. The curves after passing this point become much straighter and resemble those obtained in direct tension tests.

Comparing Fig. VI. d. with Fig. VI. e. it will be seen how greatly the reinforced beam differs from the plain beam, in the increased loads it is able to carry, and the enormous increase in the deflections sustained before fracture compared with a plain beam.

The experiments show that the extensions increase in a reinforced beam from the point where the maximum tensile strength of the plain concrete has been attained, to the point where fracture occurs, where it may be ten times as great as in a plain concrete beam. The tensile coefficient of elasticity in a reinforced beam becomes less in proportion to the greater extension, since the tensile strength of the concrete remains constant during the period included, between the point where the fracture would occur in a plain beam, to the actual fracture in the reinforced beam.

The equations for calculating the position of the neutral axis and the moment of resistance for a reinforced concrete beam may be found in the following manner (Figs. 10, 11, and 12):—

Let $h\,x$ = the distance from the compression face to the neutral axis of the beam.

$h\,u$ = the distance from the compression face to the centre of gravity of the reinforcement.

$h\,(1-x)$ = the distance from the neutral axis to the tension face.

h = the total depth of the beam.

$E_s\ E_c\ E_t$ = the coefficient of elasticity of the metal reinforcement, the concrete in compression, and the concrete in tension respectively.

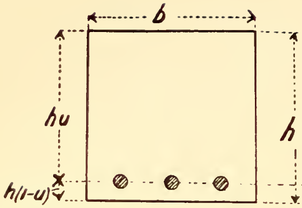


Fig. 10

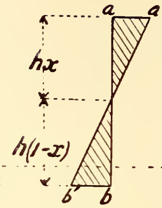


Fig. 11

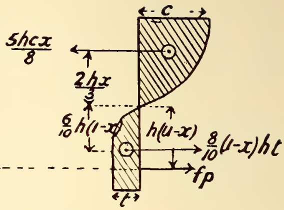


Fig. 12

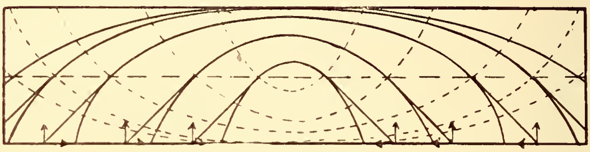


Fig. 13

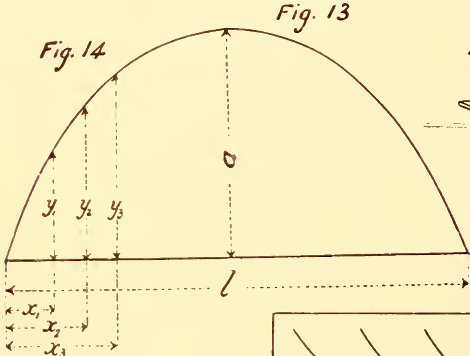


Fig. 14

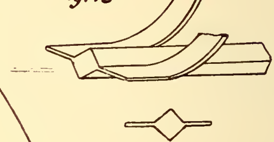


Fig. 15

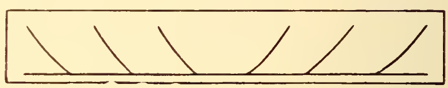


Fig 17

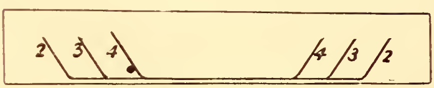


Fig. 16

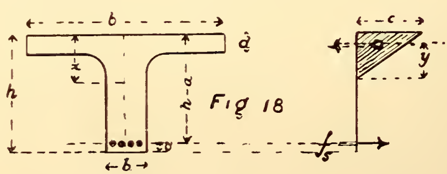


Fig 18

c = the compressive strength in the extreme outer fibre of the concrete.

t = the tensile stress in the extreme outer fibre of the concrete.

f = the stress in the metal reinforcement which should not exceed the elastic limit of the metal.

p = the ratio of the area of the reinforcement to the area of that of the beam, thus, if a = the total area of the metal $p = \frac{a}{b\,h}$ where b = the breadth of the beam.

We assume that a plain section before flexure remains plain during flexure, or if $a\,b$, Fig. 11, represents a line perpendicular to the neutral axis of the beam before flexure, then $a'\,b'$ represents the position of the line after flexure. This is a usual assumption, but it is not strictly true, as can be proved by measuring the strains on the faces of a beam with delicate extensometers, such as Martens' mirror apparatus; but the assumption is sufficiently approximate in this case, having in view the unavoidable variation in the physical properties of concrete. The form of the stress strain curves obtained by testing beams and prisms in cross breaking, tension and compression are shown on the numerous diagrams in the paper, from which it will be seen that the area of the curves (Fig. 12) above and below the neutral axis are approximately:—

$$\frac{5}{8}\,h\,x\,c \text{ and } \frac{8}{10}\,h\,(1-x)\,t \text{ respectively.}$$

It is also clear that:—

$$\frac{c}{t} = \frac{E_c}{E_t}\left(\frac{x}{1-x}\right) \quad (1)$$

$$\frac{f}{t} = \frac{E_s}{E_t}\left(\frac{u-x}{1-x}\right) \quad (2)$$

Equating the tensile and compressive forces:—

$$\frac{5}{8}\,x_c = \frac{8}{10}\,(1-x)t + Pf \ldots (2)$$

Substitute for c and f from (1) and (2) we have:—

$$\frac{5}{8}\frac{E_c x^2 t}{E_t(1-x)} = \frac{8}{10}(1-x)t + Pt\frac{E_s(u-x)}{E_t(1-x)}$$

$$\frac{5}{8}\frac{E_c}{E_t}x^2 = \frac{8}{10}(1-x)^2 + P\frac{E_s}{E_t}(u-x) \ldots(4)$$

From which quadratic equation x may be found.

Take moments about the point of application of the resultant of the compressive stresses we have the moment of resistance of a unit section:—

$$\frac{M}{bh^2} = \frac{8t}{10}(1-x)\left\{\frac{6}{10}(1-x) + \frac{2}{3}x\right\} + fp\left(\frac{3u-x}{3}\right)$$

$$,, = \frac{8}{150}t(9-8x-x^2) + fp\left(\frac{3u-x}{3}\right)$$

To find the moments of resistance for any intensity of stress in the concrete we must substitute in equation (4) the values of E_s and E_t for the particular stresses c and t and find x which should be substituted in equation (5) to find M. When a crack has developed on the tension face of the concrete $t = 0$ and equation (4) becomes:—

$$\frac{5}{8}x^2 = p\frac{E_s}{E_c}(-x) \ldots(6)$$

Equation (5) becomes:—

$$\frac{M}{bh^2} = fp\left(\frac{3u-x}{3}\right)$$

Equation (6) may be solved for x thus:—

$$x = \frac{2}{5}\sqrt{\frac{10\,p\,E_s\,u}{E_c} + \frac{4\,p^2\,E_s^2}{E_c^2}} - \frac{4}{5}p\frac{E_s}{E_c} \ldots(8)$$

If we apply these results to the concrete beams Nos. 2, 3, and 4, recorded in Table V. and Fig. V. we have the following data:—

$$\frac{E_s}{E_c} = 12, \quad M = 0{\cdot}9, \quad P = 0{\cdot}018$$

Tests made on the steel rods used in the reinforcement gave the following results:—

$E_s = 31{,}000{,}000$ lbs. per square inch.

Limit $E = f = 42{,}000$ lbs. per square inch.
Ultimate strength = 29 tons per square inch.
Elongation on 10 inches = 25%
Contraction of area = 69%

The equations become then :—

$$x = \frac{2}{5}\sqrt{108\,p + 576\,p^2} - 9{\cdot}6\,p$$

$$\frac{M}{bh^2} = \frac{42000}{3}(2{\cdot}7 - x)\,p.$$

$$,, \quad = 14000\,(2{\cdot}7 - x)\,p.$$

$$c = \frac{8\,pf}{5\,x} = 67200\,\frac{p}{x}$$

From which we obtain :—

$$x = 0{\cdot}41, \quad \frac{M}{bh^2} = 576{\cdot}828$$

$c = 2950$ pounds per square inch.

It is assumed that the extension of the steel rods is the same as the concrete in which it is embedded, and that consequently there is no slip, and that a stress of 42,000 lbs. per square inch was developed in the steel rods at the moment of fracture. If the length of the beam is insufficient to provide the necessary adhesion area to develop this stress, the beam will fail with a smaller load. The average load causing a crack in the three beams was 8·8 tons, and the bending moment consequently 591·360 inch tons.

$$\therefore \frac{M}{bh^2} = 591{\cdot}360$$

The mean extension per inch obtained from the mirror extensometers showed that the elastic limit of the steel was just reached at the moment of fracture. The moment of resistance obtained in the foregoing calculations is sufficiently near the mean result obtained in the testing of the three beams to prove the accuracy of the method adopted in the calculations.

The diagram Figs. 12 a_1 and 12 a_2, shows the values of $\frac{M}{bh^2}$, x and c for the concrete used in the three beams, but with different values of p. In 12 a_2 the values of $f =$ 42000 ℔s., $u = 0{\cdot}9$ and $\frac{E_s}{E_c} = 12$ have been substituted in the equation given in Fig. 12 a_1.

This subject has been investigated in Europe and America by various experimenters. The elaborate work of M. Considère[1] and Professor Hatt[2] may be specially mentioned. The equations obtained by these authorities are very similar to those given by the writer, and are expressed as follows for the sake of comparison :

Considère obtains :—

$$c = \frac{E_c}{E_s} f \left(\frac{x}{u - x} \right) \ldots(1)$$

$$t\,(1 - x) + fp = \frac{E_c\, f}{2\, E_s} \left(\frac{x^2}{u - x} \right) \ldots(2)$$

$$M = bh^2 \left\{ \frac{t\,(1 - x)\,(3 + x)}{6} + fp \left(\frac{3\,u - x}{3} \right) \right\} (3)$$

Using the same data as before and applying the equations to the beam tested we obtain :—

$x = 0{\cdot}441$

$c = 2750$ ℔s. per square inch.

$\frac{M}{bh^2} = 568{\cdot}512.$

Professor Hatt obtains :—

$$\frac{M}{bh^2} = \frac{5\,cx^2}{12} + pf\,(u - x) \ldots(1)$$

$$\frac{2}{3}\,cx = pf \ldots(2)$$

$$p\,\frac{E_s}{E_c}\,(u - x) = \frac{2}{3}\,x^2 \ldots(3)$$

(3) can be simplified by solving for x thus[3]:—

$$x = \sqrt{\frac{3\,p\,E_s\,u}{2\,E_c}} - \frac{3\,p\,E_s}{4\,E_c} \ldots(4)$$

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[1] Experimental researches on reinforced concrete by Armand Considère, Ingenieur en Chef des Ponts et Chausées, Paris.

[2] See Engineering News, July 1902.

[3] B. R. Leffler, Engineering News, Vol. L., No. 15, page 320.

(1) may be simplified thus:—

$$\frac{M}{bh^2} = pf\left(u - \frac{3x}{8}\right) \ldots(5)$$

Using the same data as before and applying the results in a similar manner we obtain:—

$$x = 0{\cdot}4$$

$$c = 2835 \text{ lbs. per square inch.}$$

$$\frac{M}{bh^2} = 567$$

Professor Hatt, however, uses data which differs considerably from that obtained by the writer, and if these had been inserted in his equations the results would not be the same. For instance, he gives $\frac{E_s}{E_c} = 7{\cdot}5$ instead of 12.

Professor Hatt has given equations for the determination of x, M and c for loads less than those which produce a crack on the tension side, and points out very clearly the necessity of using the correct values of the coefficients of elasticity for the particular stresses developed in tension and compression in a reinforced beam. The real difficulty in obtaining correct results for steel-concrete work consists in knowing accurately the strength and coefficients of elasticity of the various materials employed under the conditions existing.

SHEARING STRESSES IN STEEL-CONCRETE BEAMS AND THE METHODS EMPLOYED TO RESIST THEM.

When a steel-concrete beam reinforced in a horizontal plane only is subjected to a uniformly distributed load, it tends to fail near the ends by cracking on the tension side in a direction inclined towards the centre of the beam, following the full lines in Fig. 13. The inclination of the cracks is 45°. To prevent this cracking, the beam should be reinforced in a vertical plane by means of bars arranged vertically or inclined at 45° sloping away from the centre of the beam.

The cracking is more likely to occur with distributed loads than with a load concentrated at the centre as in testing, and it is more likely to occur in deep beams than in shallow beams, as in both cases the shearing forces are greater. In a steel-concrete beam properly designed, a crack should appear on the tension face before the elastic limit of the steel reinforcement is reached. Before a crack has developed, the internal stresses will follow the curved lines shown in the figure in which the full lines denote compression and the thin lines tension; these lines intersect the neutral axis at an angle of 45 degrees and equilibrium is established among the internal stresses, and no reinforcement is needed. When a crack has developed, the thick curved lines should be eliminated below their intersection with the neutral axis, and tangents to the curve at the points where they intersect the neutral axis continued to their intersection with the horizontal reinforcement at the under side of the beam, show the altered directions of the lines denoting the internal stresses. These inclined lines may be resolved horizontally and vertically at the points where they intersect the horizontal reinforcement, into horizontal and vertical components of equal intensity; the former are resisted by the horizontal reinforcement, the latter must be resisted by vertical stirrups or preferably by inclined bars, the sectional area and spacing of which should be made proportional to the shearing stresses developed.

If the beam is subjected to a uniformly distributed load, the distribution of bending moments along the beam is represented by a parabola, fig. 14, the equation being:—

$$y = \frac{w}{2}(lx - x^2)$$

Where y = the bending moment at any distance x measured from the origin.

$w =$ the uniform load per unit of length.
$l =$ the span.

If $a =$ the area of the horizontal reinforcement in square inches required at the centre of the beam :—

Then a is proportional to the central bending moment when $x = \frac{l}{2}$ *i.e.*, $\frac{wl^2}{8}$ and we may write the equation in terms of a thus:—

$$y = \frac{4a}{l}(lx - x^2)$$

For any length of beam denoted by $x_2 - x_1$, the area required to resist the shearing stresses arranged in a vertical plane is :—

$$y_2 - y_1 = \frac{4a}{l}\left\{(x_2 - x_1) - \left(\frac{x_2^2 - x_1^2}{l}\right)\right\}$$

and the area of rods arranged to slope at an angle of 45° away from the beam, is clearly the value of $(y_2 - y_1)$ Sec. 45° for the length of beam included between $(x_2 - x_1)$.

If we make the distance between the ordinates of the parabola $= 1$, the equation may be written :—

$$y_2 - y_1 = \frac{4a}{l}\left\{1 - \left(\frac{x_2 + x_1}{l}\right)\right\}$$

The shearing stress between one foot from the ends and the ends of the span is :—

$$y_2 - y_1 = \frac{4a}{l}\left(1 - \frac{1}{l}\right) = \frac{4a}{l^2}(l - 1)$$

and the area of rods inclined at 45° is $= \frac{4a}{l^2}(l - 1)$ Sec. 45°

Between 2 feet and 1 foot :—

$$y_2 - y_1 = \frac{4a}{l}\left(1 - \frac{3}{l}\right) = \frac{4a}{l^2}(l - 3)$$

the area of rods inclined at 45° is :—

$$\text{Area} = \frac{4a}{l^2}(l - 3) \text{ Sec. } 45^\circ$$

It should be clearly understood that the actual stress upon the inclined rod is the difference between the total stress given by the above equations and the shearing resistance of the concrete. Hence generally no reinforcement will be needed near the centre where the small shearing stress may be left to the concrete.

As an example we may find the area of the reinforcement to resist the shearing stresses in a concrete beam 10 inches by 10 inches cross section, reinforced horizontally by 3 rods $\frac{7}{8}$ inch in diameter if the span is 10 feet and the load uniformly distributed.

The area of 3 rods $\frac{7}{8}$ inches diameter $= 3 \times 0{\cdot}6 = 1{\cdot}8$ square inches. For the first foot from the ends the area required if arranged vertically is

$$\frac{4 \times 1{\cdot}8}{10}\left(1 - \frac{1}{10}\right) = 0{\cdot}648 \text{ square inches.}$$

and if inclined at 45° :—

$$0{\cdot}648 \times 1{\cdot}414 = {\cdot}0916 \text{ square inches.}$$

For the portion included between $x_2 = 2$ and $x_1 = 1$:—

$$\frac{4 \times 1{\cdot}8}{10}\left(1 - \frac{3}{10}\right) = 0{\cdot}504 \text{ square inch vertically}$$

$$= 0{\cdot}504 \times 1{\cdot}414 = 0{\cdot}713 \text{ square inch inclined at } 45^\circ$$

For the portion included between $x_2 = 3$ and $x_1 = 2$:—

$$\frac{4 \times 1{\cdot}8}{10}\left(1 + \frac{5}{10}\right) = 0{\cdot}36 \text{ square inch vertically}$$

$$= 0{\cdot}36 \times 1{\cdot}414 = 0{\cdot}509 \text{ square inch inclined at } 45^\circ$$

For the portion included between $x_2 = 4$ and $x_1 = 3$:—

$$\frac{4 \times 1{\cdot}8}{10}\left(1 + \frac{7}{10}\right) = 0{\cdot}216 \text{ square inch vertically}$$

$$= 0{\cdot}216 \times 1{\cdot}414 = 0{\cdot}305 \text{ square inch inclined at } 45^\circ$$

We may provide steel stirrups having the area calculated above, or inclined bars having an area equal to the vertical stirrup multiplied by 1·414. The bars arranged to take the shearing stresses should be rigidly connected to the horizontal reinforcement in all cases. Mr. Julius Kahn accomplishes this condition by the use of bars of the form shown in Fig. 15.

Mr. A. L. Johnson has proposed and largely used corrugated bars, consisting of rolled steel bars having a ribbed surface, to reinforce concrete beams which exceed a span of 15 feet; for spans between 8 and 15 feet expanded metal is used to reinforce the concrete. Both the corrugated bars and the expanded metal furnish a mechanical bond, quite independent of the bond due to adhesion between the steel and the concrete. M. Considère has shown that the adhesive resistance tends to yield to a soliciting force, and there can be no doubt that some structures are exposed to vibrations and shocks which must tend to break the ordinary adhesion bond between steel and concrete.

Fig. 16 shows the arrangement of corrugated bars in Johnson's reinforcement for deep beams.

Fig. 17 shows the arrangement of the Kahn bars in a similar beam, in which the reinforcement is inclined to the vertical, with varying upward curvature approximating to the lines of principal tensile stress:—

In the Prussian regulations, just published, for reinforced concrete in building construction, the following is worthy of notice in regard to working stresses:—

In the members subjected to bending, the compressive stress in the concrete shall not exceed one-fifth of its ultimate resistance; the tensile and compressive stresses in the steel shall not exceed 17,000 pounds per square inch.

The following loads shall be provided for:—

a. For structural parts subjected to moderate impact the sum of the live and dead loads.

b. For parts subject to higher impact or widely varying loads; the dead load added to one and one half times the live load.

c. For parts subject to heavy shocks; the dead load added to twice the live load.

In columns the concrete shall not be stressed above one-tenth of its breaking strength, and in computing the steel reinforcing for column flexure a factor of safety of five shall be provided.

The shearing stress in the concrete shall not exceed 64 pounds per square inch.

If greater shearing resistance is shown, the shearing stress shall not exceed one-fifth of the ultimate resistance.

The adhesive stresses shall not exceed the allowable shearing stress.

The coefficient of elasticity of the steel shall be taken as fifteen times that of the concrete, unless another ratio be shown.

For the computation of columns for flexure Euler's formula shall be used when the height exceeds eighteen times the least diameter.

The equation for locating the neutral axis in a rectangular beam when expressed by the symbols adopted in this paper for the sake of comparison is :—

$$x = \frac{E_s\, p}{E_c} \left\{ \sqrt{1 - \frac{2\, u\, E_c}{p\, E_s}} - 1 \right\}$$

For obtaining the maximum intensity of stress on the extreme fibres in compression :—

$$c = \frac{2\, M}{b h^2 x} \left(u - \frac{x}{3} \right)$$

and for the maximum intensity of stress in the metal reinforcement :—

$$f = \frac{M}{p\, b\, h^2 \left(u - \frac{x}{3} \right)}$$

For tee-formed sections, such as shown in Fig. 18, the equations remain the same if the neutral axis lies in the flange or at the junction of the flange with the web.

If the neutral axis passes through the web, the slight compressive stresses in the web may be neglected, and we have approximately

$$x = \frac{(h - a)\, n\, f_s + \frac{1}{2}\, bd^2}{b\, d + n\, f_s}$$

$$y = x - \frac{d}{2} + \frac{d^2}{6\,(2\,x - d)}$$

The maximum stress in the steel is :—

$$\rho_s = \frac{M}{f_s\,(h - a - x + y)}$$

The maximum stress in the concrete is :—

$$c = \rho_s \frac{x}{n(h - a - x)}$$

Here $n = \frac{E_s}{E_c} = 12$, say $f_s =$ the total area of the rods equal say 7·5 square inches.

Let $h = 36$ inches, $b = 57$ inches, $a = 3$ inches, $d = 5·5$ inches, $b = 12$ inches.

Applying the foregoing equations we obtain :—

$$x = 9·5 \text{ and } y = 7.$$

If $M = 2008000$ inch-pounds corresponding with a distributed load of 35700 pounds on a span of 37·5 feet we should have :—

$$\rho_s = 9000 \text{ pounds per square inch.}$$

$$c = 303 \text{ pounds per square inch.}$$

A beam similar to Fig. 18 and having approximately the dimensions assumed, was made by the Ferro-concrete Company of Cincinnati, U.S.A., and tested by Mr. Gustave W. Drach,[1] with a load of 35,700 lbs. distributed over a span of 37·5 feet, and gave a central deflection of only one-eighth of an inch. The load was allowed to remain on the beam for 24 hours.

The author wishes to thank Messrs. Gummow and Forrest, Steel Concrete Engineers, for their kindness in making all the concrete specimens referred to in the tests given in this paper. He also wishes to acknowledge the

[1] The Engineering Record, Vol. L., No. 3, page 90.

valuable assistance rendered by Mr. A. J. Gibson, Assoc. M. Inst. C.E., Mr. R. Hawken, B.E., B.A., Mr. A. Boyd, B E., B.Sc., Mr. P. L. Weston, B.E., B Sc., and Mr. J. M. C. Corlette, B.E., in connection with the testing and recording of the results obtained. In a future paper the author proposes to give the results obtained in testing reinforced concrete beams under a constant bending moment, also an experimental determination of the position of the neutral axis and the deformations above and below it.

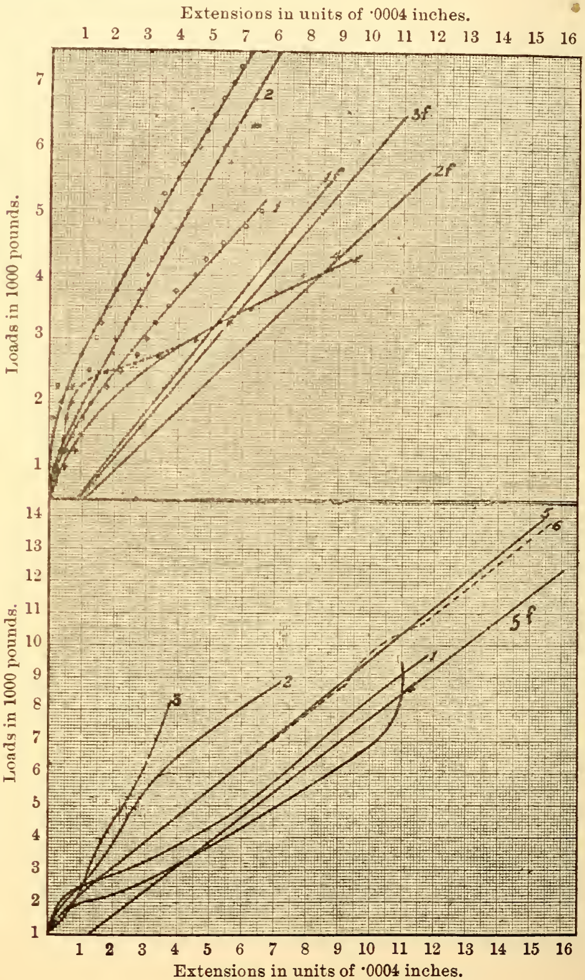
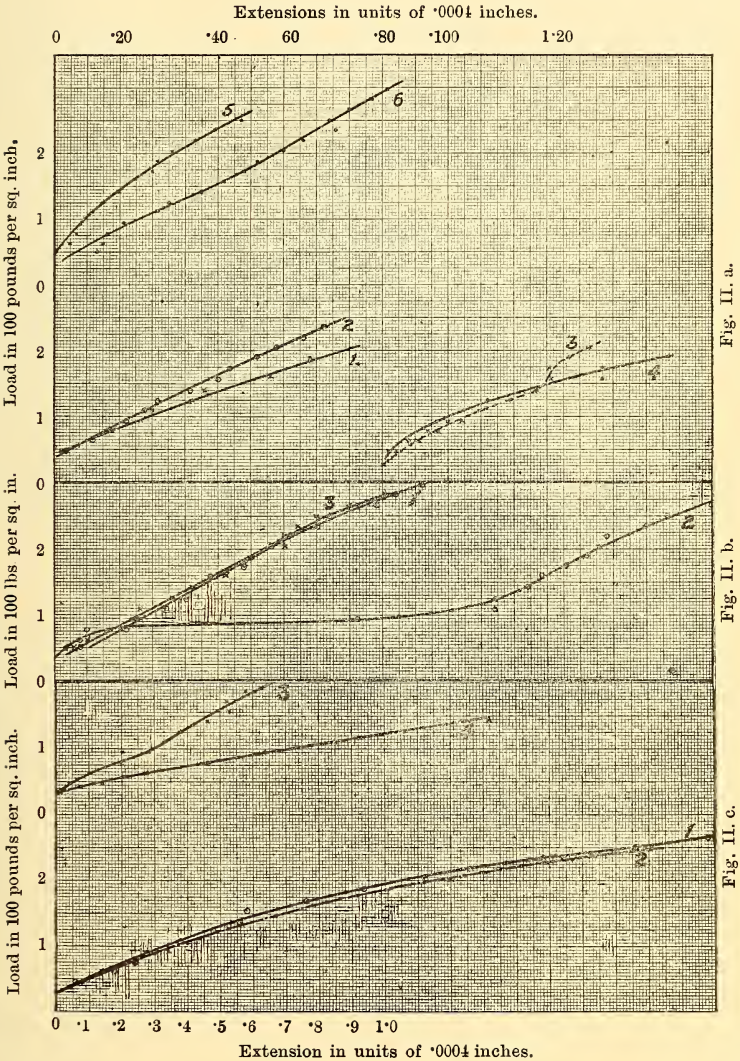


Fig. I. a.

Fig I. b.


Extensions in units of ·0004 inches.
0 ·20 ·40 60 ·80 ·100 1·20
Load in 100 pounds per sq. inch.
Load in 100 lbs per sq. in.
Load in 100 pounds per sq. inch.
Fig. II. a.
Fig. II. b.
Fig. II. c.
0 ·1 ·2 ·3 ·4 ·5 ·6 ·7 ·8 ·9 1·0
Extension in units of ·0004 inches.

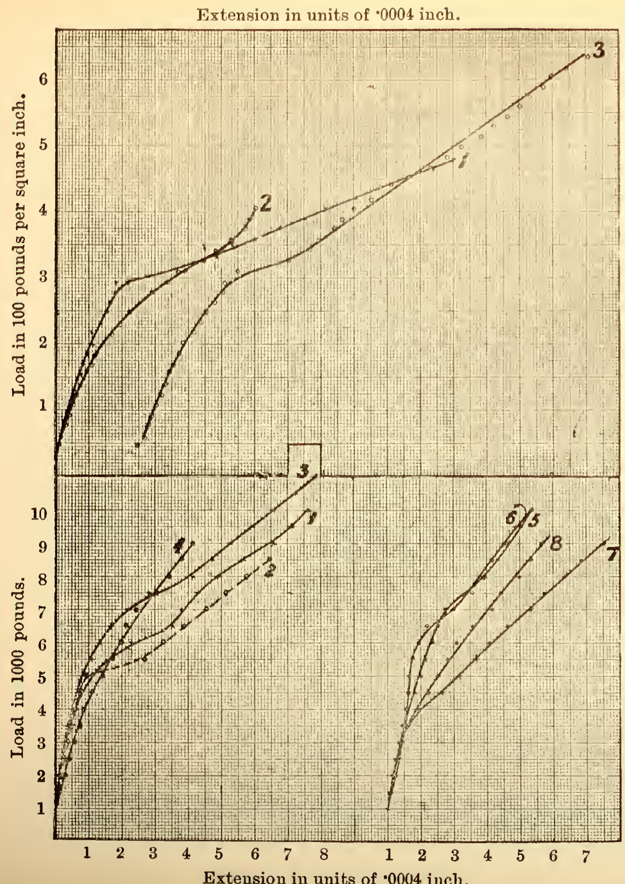


Fig. II. d.

Fig. II. f.

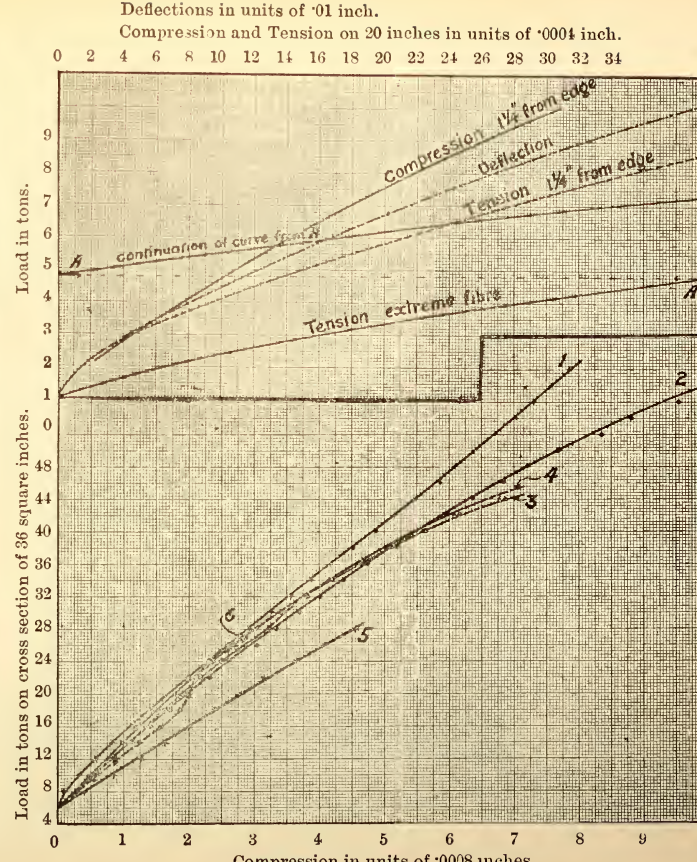


Fig. V. f.

Fig. III. a.

Fig. IV. b.

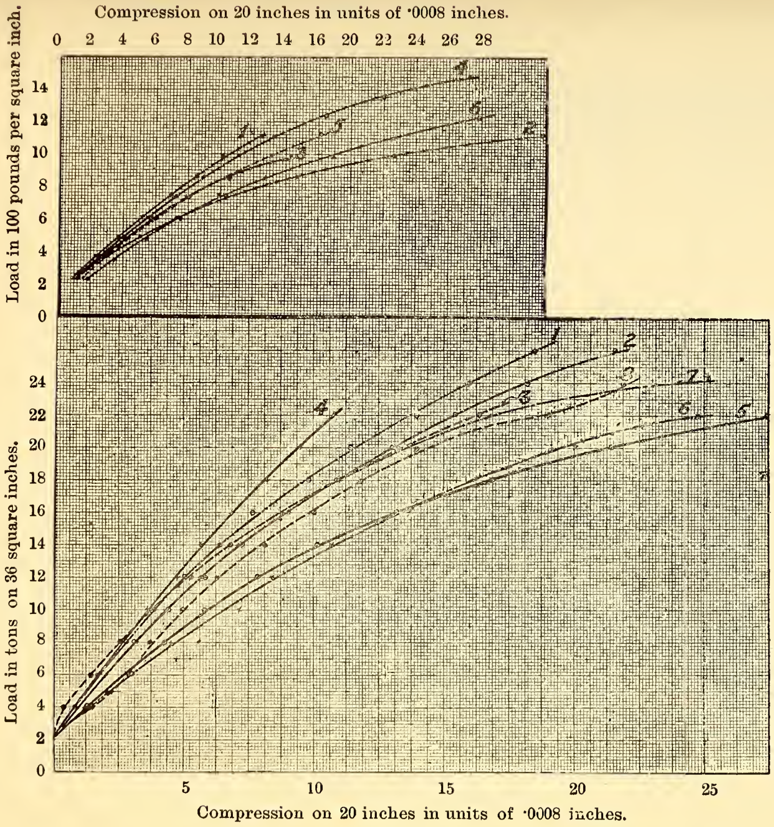


Fig. IV. c.

Fig. IV. d.

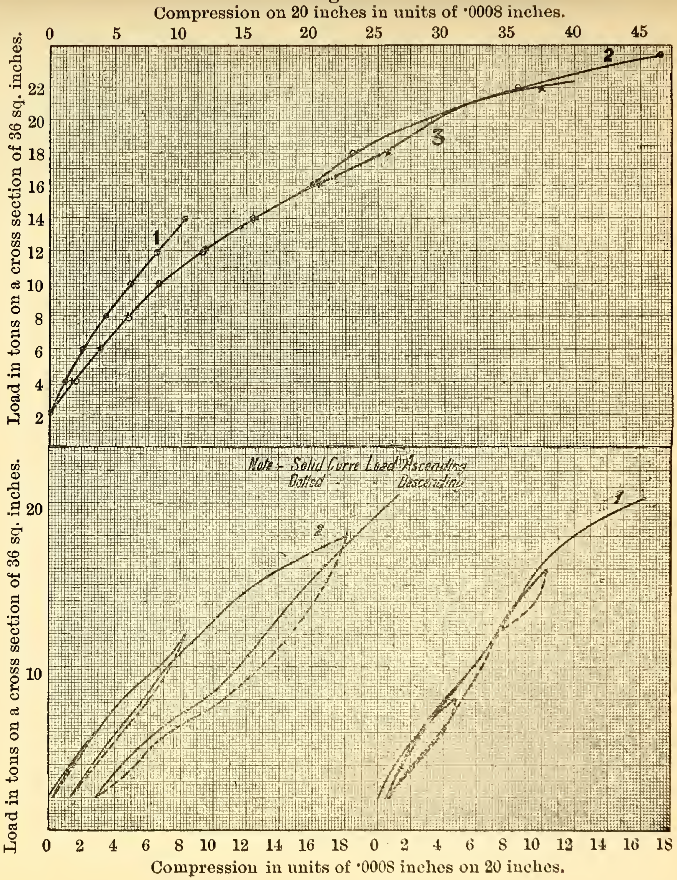


Fig. IV. e.

Fig. IV. f.

Fig. IV. g.

Fig. IV. e.

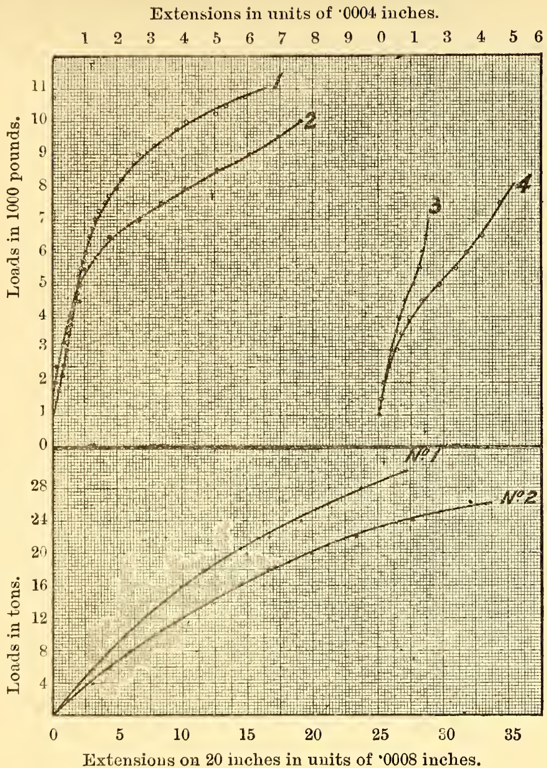
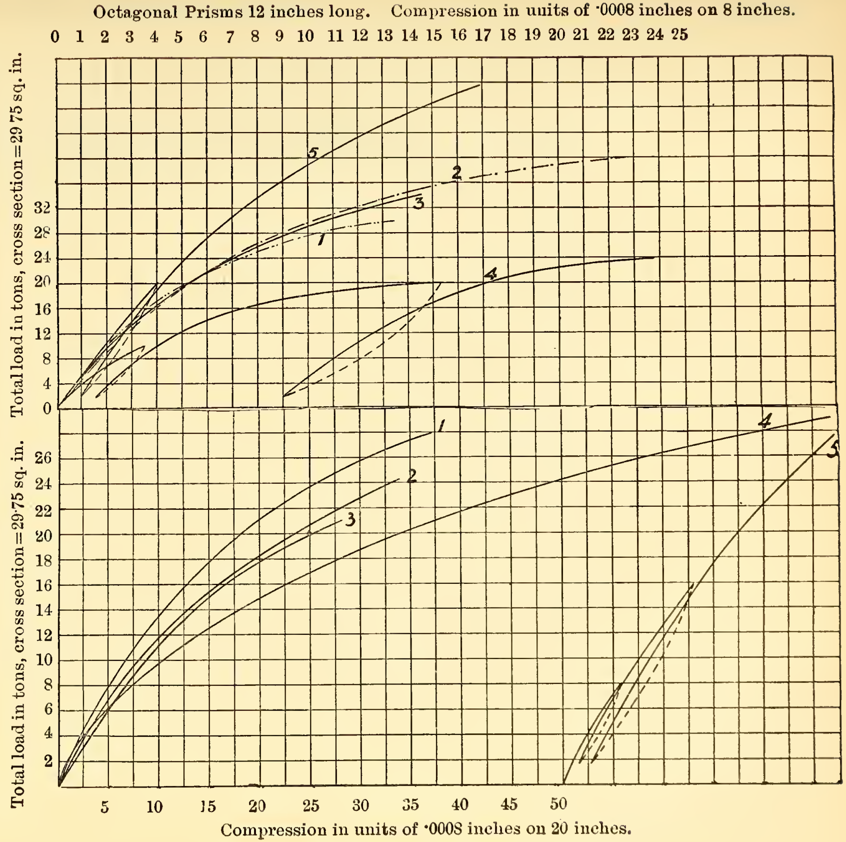


Fig. IV. h.

Fig. IV. m.

Octagonal Prisms 12 inches long.



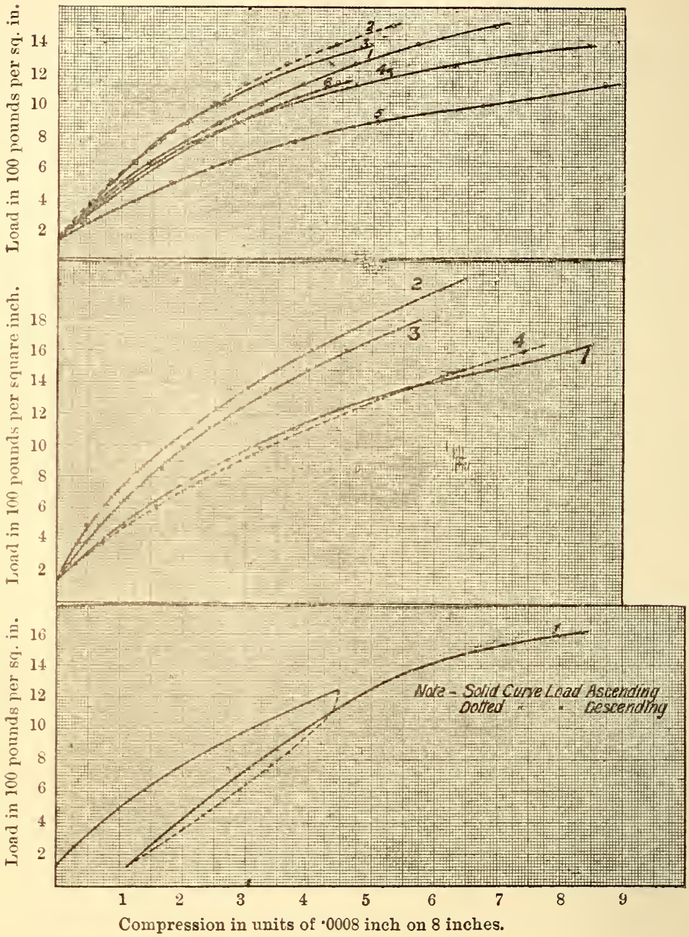

Load in 100 pounds per sq. in.
Load in 100 pounds per square inch.
Load in 100 pounds per sq. in.
Note - Solid Curve Load Ascending
Dotted " " Descending
Compression in units of ·0008 inch on 8 inches.

Fig. IV. β

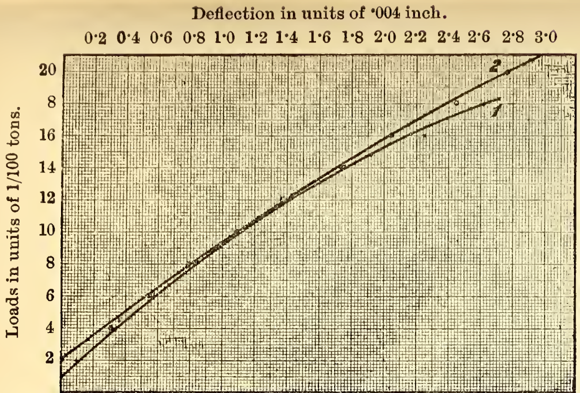


Fig. V. a.

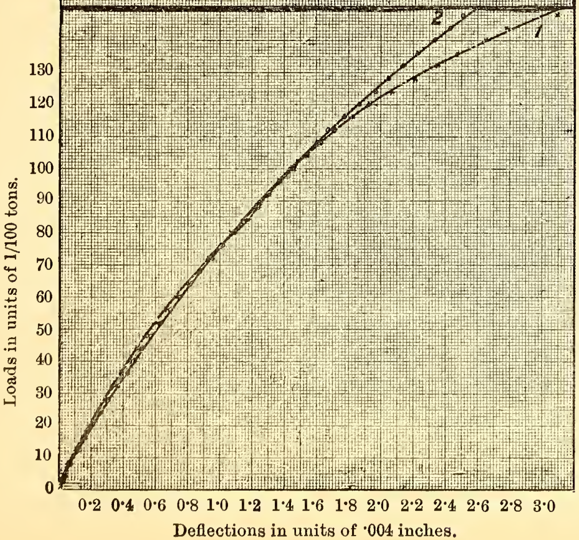


Fig. V. b.

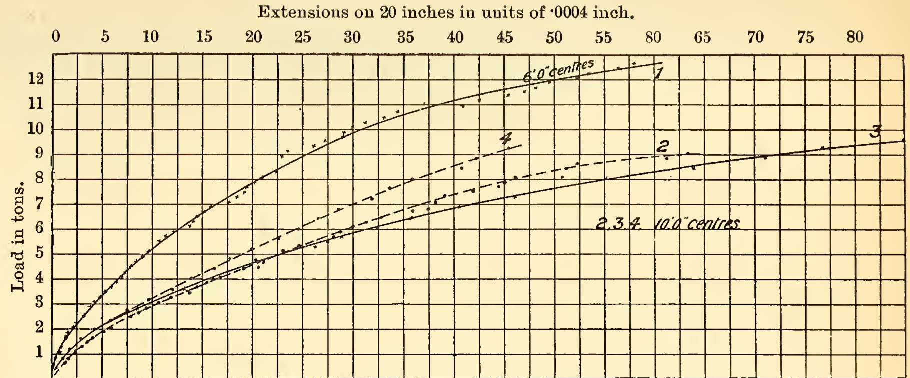


Fig. VI. a.

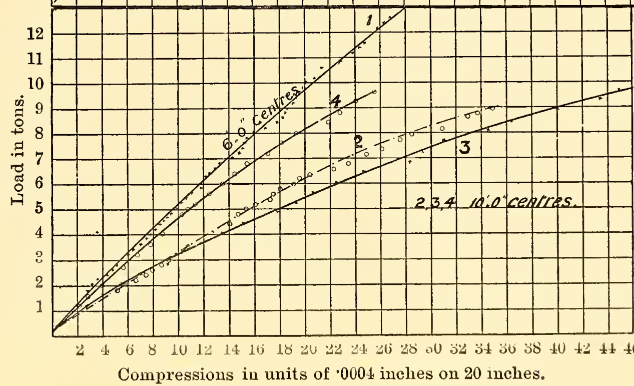


Fig. VI. b.

Fig. VI. c.

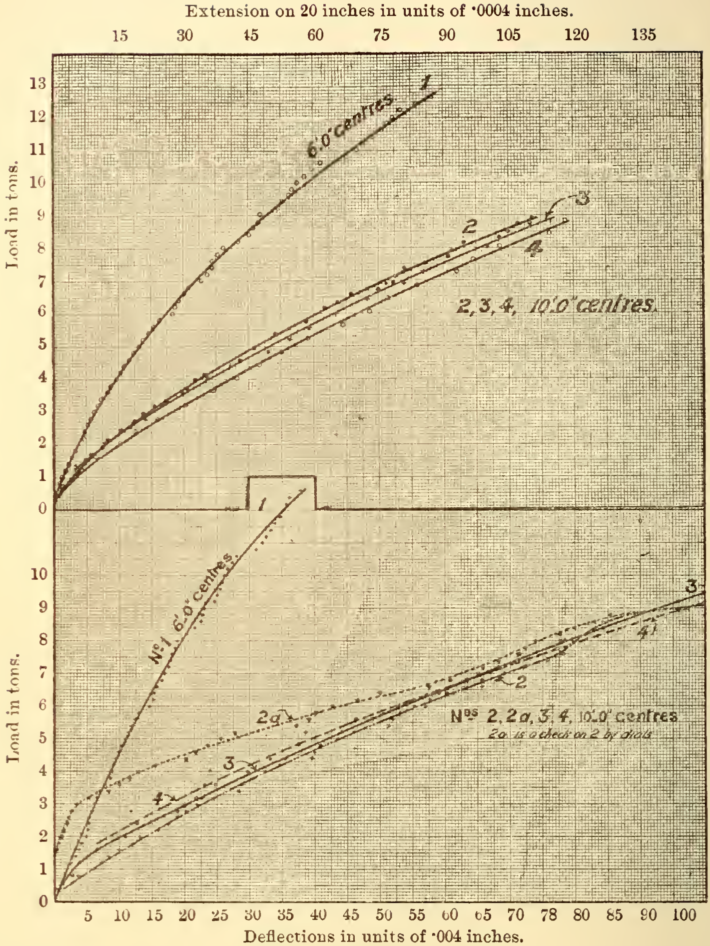


Fig. VI. d.

Fig. 12 a₁.

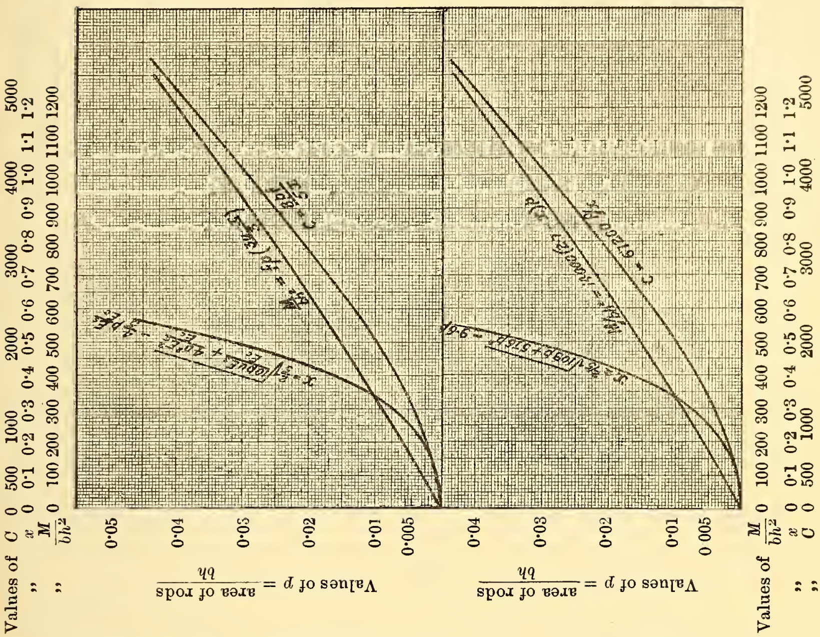


Fig. 12 a₂.

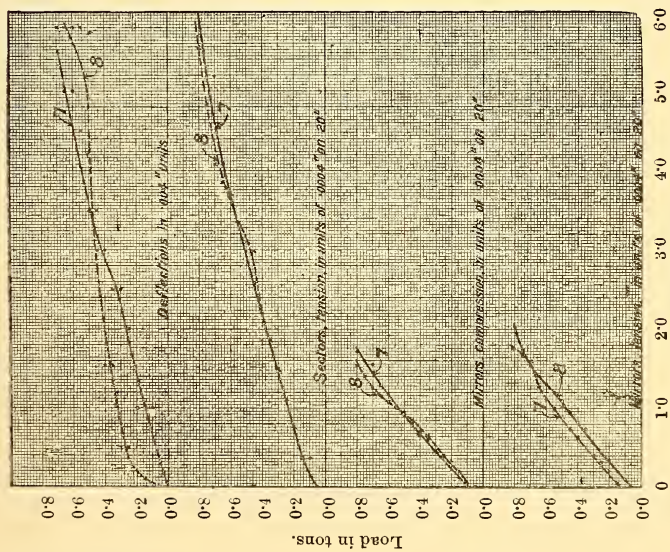


Fig. VI. e.

TABLE I.—TENSILE TESTS, MORTAR BRIQUETTES.

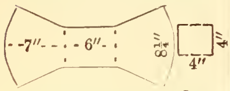
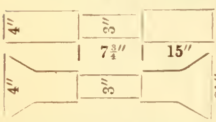
Description	Age in Days	Total Load in thousand pounds	Tensile Stress in pounds per square inch	Extension in ·0004 inch on 4 inch	Coefficient of Elasticity in millions of pounds per square inch	$E = \frac{\text{Total unit Stress}}{\text{Total unit Strain}}$ 500 lbs initial load always subtracted	Breaking Load in pounds per square inch	Reference to Curves	Adhesion pounds per square inch of surface of rods approximate
1	2	3	4	5	6	7 × 10^6	8	9	10
1 cement to 3 sand; 1	764	1	63	·06	4·528	5·330	356	I.a. 1	88
½ in. bar.		2	125	·25	2·388	3·760			
Section 4 x 4 inches.		3	188	·60	1·862	2·618			
		4	250	·90	1·758	2·433			
		5	313	1·31	1·620	2·153			
1 cement to 3 sand; 4	765	1	63	·04	5·390	8·000	491	I.a. 2	94
½ in. bars.		3	188	·40	2·921	3·925			
Section 4 x 4 inches.		5	313	·85	2·845	3·320			
		6	375	1·07	2·845	3·215			
1 cement to 3 sand; 5	760	2	125	·08	4·740	11·750	516	I.a. 3	82
½ in. bars.		4	250	·46	2·791	4·783			
Section 4 x 4 inches.		6	375	·92	2·720	3·740			
		8	500	1·36	2·720	3·450			
1 cement to 4 sand; no	943	1	63	·10	3·360	3·200	266	I.a. 4	...
bars.		2	125	·14	1·596	6·714			
Section 4 x 4 inches.		3	188	·90	·979	1·744			
		4	250	1·58	·750	1·390			
1 cement to 3 sand; 5	30	2	167	·40	·907	3·125	833	I.b. 1	190
⅜ in. bars.		4	334	4·33	·450	·675			
Section 4 x 3 inches.		6	501	7·35	·690	·627			
		8	668	9·80	·684	·638			
1 cement to 3 sand; 5	32	2	205	·55	1·220	2·800	922	I.b. 2	176
⅜ in. bars.		5	513	2·68	1·727	1·725			
Section 3¼ x 3 inches.		8	820	5·88	·720	1·308			
1 cement to 3 sand, 5	34	2	208	·86	1·710	1·814	881	I.b. 3	163
⅜ in. bars.		4	417	1·66	2·030	1·211			
Reinforced with 4⅜		6	625	2·87	2·170	2·000			
inch bars at end.		8	834	3·71	2·820	2·108			
Section 3·2 x 3 inches									
1 cement to 3 sand; 5	36	2	208	·95	·465	1·642	993	I.b. 4	190
⅜ in. bars.		5	520	7·05	·673	·665			
Section 3·2 x 3 inches		8	834	10·84	3·260	·720			
1 cement to 3 sand; 5	42	2	222	·61	1·060	2·721	1611	I.b. 5	...
⅜ in. bars, stiffened		6	667	5·62	·905	1·222			
at ends.		10	1111	10·60	·905	1·000			
Section 3 x 3 inches.		14	1555	15·63	·905	·958			
1 cement to 3 sand; 5	40	2	222	·57	1.060	3·350	1583	I.b. 6	...
⅜ in. bars.		6	667	5·75	·850	1·105			
Section 3 x 3 inches.		10	1111	10·59	·800	1·018			
		14	1555	15·33	·836	·992			

TABLE II.—TENSILE TESTS CONCRETE BRIQUETTES.

Section 4 inch by 4 inch, unless stated otherwise.

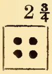
Composition.	Age in Days	Total Load in thousand pounds	Tensile Stress, pounds per square inch	Extension in ·0004 inch on 4 inches	Coefficient of Elasticity in millions of pounds per square inch	$E = \frac{\text{Total Unit Stress}}{\text{Total Unit Strain}}$ ×10⁶	Breaking Load in pounds per square inch	Reference to Curves	Adhesion, pounds per square inch
1	2	3	4	5	6	7	8	9	10
1 cement, 2 sand,	59	1	63	·02	2·500	16·000	203	IIa. 1	
2 ¾ in. shivers		2	125	·42	1·740	2·215			
		3	188	·78	1·550	2·000			
Ditto	59	1	63	·12	2·840	2·667	250	IIa. 2	
		2	125	·32	2·500	2·939			
		3	188	·62	2·236	2·533			
Ditto	242	1	63	·10	2·950	3·200	219	IIa. 3	
		2	125	·39	2·290	2·410			
		3	188	·67	3·300	2·344			
Ditto	244	1	63	·08	3·750	4·000	203	IIa. 4	
		2	125	·32	1·670	2·937			
		3	188	·87	1·140	1·805			
1 cement, 2 sand	239	1	63	·05	5·680	6·400	259	IIa. 5	
3 ¾ shivers		2	125	·15	4·115	6·265			
		3	188	·32	3·170	4·909			
		4	250	·57	2·695	3·841			
Ditto	240	1	63	·13	3·065	2·830	266	IIa. 6	
		2	125	·35	3·270	2·686			
		3	188	·62	2·765	2·532			
		4	250	·82	2·855	2·606			
1 cement, 2 sand,	61	1	63	·10	2·720	3·200	297	IIb. 1	
3 ¾ in. shivers		2	125	·40	2·670	2·350			
		3	188	·60	2·640	2·818			
		4	250	·84	2·110	2·606			
Ditto	60	1	63	·08	4·220	4·000	278	IIb. 2	
		1	94	·10	·279	6·300			
		2	125	1·34	1·410	·702			
		3	188	1·62	2·400	·969			
		4	250	1·86	2·125	1·178			
Ditto	59	1	63	·10	2·600	3·200	278	IIb. 3	
		2	125	·36	2·680	2·611			
		3	188	·70	2·540	2·244			
		4	250	·90	2·220	2·433			
1 cement, 3 grit	57	2	125	·48	1·590	1·957	278	IIc. 1	
with dust		3	219	1·58	·771	1·197			
Ditto	58	2	125	·88	1·250	1·070	273	IIc. 2	
		3	219	1·34	·736	1·403			
Ditto	238	1	63	·10	2·315	3·200	209	IIc. 3	
		2	125	·38	2·895	1·670			
		3	188	·58	2·660	2·706			
Ditto	239	1	63	·28	1·157	1·143	145	IIc. 4	
		2	125	1·06	·800	·887			
1 cement, 2 sand,	48	2	125	·22	3·720	4·273	500	IId. 1	100
2 ¾ in. shivers,		4	250	·56	2·600	3·910			
4 ½ in. bars		5	313	1·50	·468	1·890			
		7	438	3 92	·500	1·036			

TABLE II.—Continued.

Composition.	Age in Days	Total Load in thousand pounds	Tensile Stress, pounds per square inch	Extension in ·0004 inch on 4 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain $\times 10^6$	Breaking Load in pounds per square inch	Reference to Curves	Adhesion, pounds per square inch
1	2	3	4	5	6	7	8	9	10
1 cement, 2 sand,	48	2	125	·26	3·060	3·615	422	IId. 2	44
3 ¾ in. shivers,		4	250	·90	1·190	2·433			
4 ½ in. bars		5	313	1·56	·770	1·807			
		6	375	2·30	1·260	1·500			
Ditto	46	2	125	1·28	2·890	·734	656	IId. 3	165
		4	250	1·82	1·408	1·200			
		6	375	3·48	·676	·903			
		7	438	4·30	·845	·946			
		10	626	6·20	·884	·960			
1 cement, 2 sand,	82	2	125	·27	2·980	3·481	694	IIe, 1	162
2 ¾ in. shivers,		6	375	1·07	2·160	3·214			
4 ½ in. bars		8	500	1·86	·728	2·521			
		10	625	4·12	·356	1·444			
1 cement, 2 sand,	121	2	125	·19	2·400	4·949	688	IIe. 2	159
2 ¾ in. shivers,		6	375	1·12	·800	3·070			
4 ½ in. bars		8	500	4·12	·346	1·137			
		10	626	7·67	·410	·776			
1 cement. 2 sand,	237	2	125	·17	2·315	5·530	419	IIe. 3	18
2 ¾ in. shivers,		4	250	·57	2·500	3·840			
4 ½ in. bars		6	375	1·33	2·720	2·585			
1 cement, 2 sand,	230	2	125	·22	2·315	4·275	531	IIe. 4	109
3 ¾ in. shivers,		4	250	·95	·962	2·305			
4 ½ in. bars		6	375	2·78	·736	1·238			
		8	500	3·72	·388	1·261			
1 cement, 2 sand,	123	2	125	·00	4·460	...	656	IIf. 1	147
2 ¾ in. shivers,		5	313	·91	·781	3·090			
4 ½ in. bars		7	438	3·80	·725	1·071			
		10	626	7·10	·625	·837			
1 cement, 2 sand,	124	2	125	·16	3·300	5·876	563	IIf. 2	117
2 ¾ in. shivers,		5	313	·92	·350	3·065			
4 ½ in. bars		7	438	4·54	·530	3·960			
1 cement, 2 sand,	128	2	125	·06	4·460	15·660	720	IIf. 3	177
3 ¾ in. shivers,		6	375	1·37	·880	2·510			
4 ½ in. bars		11	688	7·89	·500	·754			
1 cement, 2 sand.	127	2	125	·31	2·500	3·032	588	IIf. 4	132
3 ¾ in. shivers,		6	375	2·00	1·025	1·720			
4 ½ in. bars		9	563	4·15	·771	1·282			
1 cement, 2 sand,	128	2	125	·15	3·125	6·268	625	IIf. 5	145
3 ¾ in. shivers,		5	313	1·03	2·083	2·736			
4 ½ in. bars		7	438	1·76	·745	2·311			
		10	625	4·37	1·180	1·361			
1 cement, 2 sand,	127	2	125	·21	2·238	4·478	651	IIf. 6	143
3 ¾ in. shivers,		5	313	·69	3·900	4·007			
4 ½ in. bars		7	438	2·17	·550	1·865			
		10	626	4·32	·694	1·366			
1 cement, 2 sand,	236	2	125	·20	2·170	4·700	589	IIf. 7	114
2 ¾ in. shivers,		5	313	2·17	·500	1·299			
4 ½ in. bars		8	500	5·37	·539	·873			
1 cement, 2 sand,	231	2	125	·18	2·170	5·221	594	IIf. 8	114
5 ¾ in. shivers,		5	313	1·52	·868	1·855			
4 ½ in. bars		8	500	4·00	·718	1·172			

TABLE III.—COMPRESSION TESTS OF MORTAR PRISMS.

Length 12 inches; Cross Section 6 x 6 inches.

Composition.	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 8 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain	Breaking Load in pounds per square inch	Number on Curve	Remarks
					×10⁶			
1	2	3	4	5	6	7	8	9
1 cement to 2 sand	720	373	·31	5·300	8·481	5109	IIIa. 1	cracked at
		1120	1·99	4·110	5·125			170,000
		2240	4·86	3·830	4·382			pounds
		3360	7·58	4·220	4·287			
1 cement to 2 sand	721	373	·59	5·410	4·457	4617	IIIa. 2	cracked at
		1120	2·32	4·010	4·352			134,000
		2240	5·61	3·120	3·798			pounds
		3360	9·56	1·950	3·400			
1 cement to 3 sand	725	373	·48	4·980	5·479	3204	IIIa. 3	cracked at
		1120	2·08	4·360	4·855			108,000
		2240	5·62	2·410	3·790			pounds
1 cement to 3 sand	726	373	·58	4·840	4·532	2868	IIIa. 4	cracked at
		1120	2·18	4·050	4·632			89,600
		2240	5·60	2·499	3·801			pounds
1 cement to 4 sand	727	373	·85	3·260	3·093	2364	IIIa. 5	cracked at
		871	2·37	3·060				78,500
		1120	3·15	2·950	3·205			pounds
		1493	4·57	2·770	3·028			
1 cement to 4 sand	729	373	·55	4·150	4·780	2209		cracked at
		871	1·85	5·720				72,000
		1120	2·04	7·001	4·951			pounds
		1493	2·96	3·830	4·672			

TABLE IVa.—COMPRESSION TESTS OF CONCRETE PRISMS.

Length 12 inches; Cross Section 6 inches x 6 inches.

Composition.	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 8 inches	Coefficient of Elasticity in millions of pounds per square inch	$E = \frac{\text{Total Unit Stress}}{\text{Total Unit Strain}}$ $\times 10^6$	Breaking Load in pounds per square inch	Reference to Curve
1	2	3	4	5	6	7	8
1 cement, 2 fine Nepean	75	373	·62	3·380	4·241	1773	IV. a 1
sand, 2 of ¾ in. Nepean		1120	3·22	1·650	3·137		
shivers		1493	6·94	963	1·992		
Ditto	70	373	·52	4·167	5·057	1618	IV. a 2
		747	1·58	3·222	4·031		
		1493	5·30	2·624	2·609		
1 cement, 2 fine Nepean	72	373	·56	3·936	4·696	1599	IV. a 3
sand, 3 of ¾ in. Nepean		747	1·76	3·146	3·618		
shivers		1120	3·22	1·874	3·137		
Ditto	82	373	·64	3·299	4·109	1625	IV. a 4
		747	1·58	2·000	4·031		
		1120	4·72	1·019	2·138		
1 cement, 3 Nepean grit	78	373	1·24	2·000	2·120	1362	IV. a 5
with dust		747	3·76	1·111	1·693		
		1120	8·70	1·516	1·264		
Ditto	69	373	·74	3·070	3·553	1649	IV. a 6
		747	2·20	2·000	2·895		
		1120	4·42	1·275	1·161		
1 cement, 2 sand, 2 ¾ inch	243	373	·69	3·400	3·811	1618	IV. *a* 1
shivers		1120	3·80	1·740	2·657		
		1493	6·98	1·137	1·983		
Ditto	244	373	·35	6·250	7·513	2638	IV. *a* 2
		1120	2·14	3·000	4·721		
		1493	3·55	2·130	3·897		
		1865	5·35	1·945	3·280		
Ditto	244	373	·46	4·765	5·718	2311	IV. *a* 3
		1120	2·43	2·780	4·157		
		1493	3·96	2·980	3·493		
1 cement, 2 sand, with	237	373	·74	5·880	3·553	2030	IV. *a* 4
grit and dust		1120	4·46	1·760	2·265		
		1493	6·41	1·225	2·157		
Ditto	239	373	·61	3·335	4·310	1936	IV. β 1
			2·04	2·780	1·287		
			1·81	3·230	1·450		
		1120	3·71	1·720	2·722		
			4·41	6·100	2·290		
			4·44	2·430	2·275		
		1493	6·77	·862	2·402		

TABLE IV.b—COMPRESSION TESTS OF CONCRETE PRISMS.

Length 24 inches; Cross Section 6 inches x 6 inches.

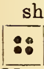
Composition	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 2) inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain × 10⁶	Breaking Load in pounds per square inch	Reference to Curves	Remarks
1	2	3	4	5	6	7	8	9
1 cement, 2 sand, 2 ¾ in. shivers	84	373	2·53	2·344	2·600	1833	IV.b 1	Shattered vertically, about 7 in. left sound at one end. Kept in air till tested.
		747	6·97	1·975	2·285			
		1120	12·55	1·790	2·012			
1 cement, 2 sand, 3 ¾ in. shivers	77	373	2·80	1·762	2·347	1202	IV.b 2	Shattered vertically in centre.
		747	10·04	·888	1·587			
		1120	29·68	·362	·851			
Ditto	78	373	2·50	1·756	2·630	1462	IV.b 3	Broke through the centre, leaving ends sound.
		747	7·79	2·710	2·042			
		1120	14·24	·500	1·775			
Ditto	84	373	2·41	2·530	2·728	1742	IV.b 4	Broke through the centre and one end left sound for 6 in. from end. The rest shattered vertically.
		747	6·87	1·875	2·316			
		1120	13·28	1·625	1·900			
		1493	25·23	·422	1·370			
1 cement, 2 grit with dust	78	373	2·83	2·220	2·323	1741	IV.b 5	Broke through the centre, both ends sound for 6 inches.
		747	7·97	1·600	1·996			
		1120	16·04	1·157	1·575			
Ditto	81	373	3·39	1·772	1·938	1408	IV.b 6	Broke near the top, other end sound for about 12 inches.
		747	9·81	1·280	1·624			
		1120	20·45	·913	1·235			
1 cement, 2 fine Nepean sand, 2 of ¾ in. Nepean shivers; 4 bars  ⅜ in. iron, 15 ties $\frac{3}{16}$ in. iron	82	373	1·70	3·190	3·868	2427	IV.c 1	Shattered in centre, vertical rods bent; concrete thrown off from outside of bars. Ends left sound.
		747	5·07	2·488	3·142			
		1120	9·55	1·740	2·645			
		1493	15·95	1·305	2·165			
Mixture ditto, 4 bars ⅜ in. iron, 10 ties $\frac{3}{16}$ in. iron	63	373	2·06	2·860	3·192	2171	IV.c 2	Ditto
		747	5·81	2·260	2·740			
		1120	10·95	1·605	2·310			
		1493	18·21	1·250	1·897			
Mixture ditto, 4 bars ⅜ in. iron, 5 ties $\frac{3}{16}$ in. iron	63	373	1·43	2·890	4·508	1842	IV.c 3	Ditto
		747	5·31	2·090	2·999			
		1120	9·24	1·352	2·732			
Mixture ditto, 4 bars ⅜ in. iron, 2 ties $\frac{3}{16}$ in. iron	64	373	1·85	3·190	3·553	2551	IV.c 4	Ditto, but concrete thrown off one end also.
		747	4·70	2·900	3·388			
		1120	8·28	2·488	3·050			
1 cement, 2 fine Nepean sand, 3 of ¾ in. shivers; 4 bars ⅜ in. iron 15 ties $\frac{3}{16}$ in. iron	64	373	3·09	2·073	2·126	2047	IV.c 5	Ditto, but both ends sound.
		747	7·86	1·465	2·026			
		1120	16·86	·793	1·496			
Mixture ditto, 4 bars ⅜ in. iron, 5 ties $\frac{3}{16}$ in. iron	64	373	2·88	1·888	2·283	1726	IV.c 6	Shattered near one end, other end sound for 12 inches. Concrete off rods. Vertical rods bent.
		747	8·43	1·490	1·888			
		1120	15·88	1·038	1·590			

TABLE IV.b—Continued.

Composition	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 20 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain × 10^6	Breaking Load in pounds per square inch	Reference to Curves	Remarks
1	2	3	4	5	6	7	8	9
1 cement, 2 fine	64	375	2·06	2·860	3·192	1680	IV.c 7	Shattered near one
Nepean sand, 3		747	5·75	2·260	2·769			end, other end sound
of ¾ in. shivers;		1120	10·96	1·330	2·310			for 12 inches. Con-
4 bars ⅜ in. iron		1493	24·09	·420	1·436			crete off rods. Ver-
5 ties $\frac{3}{16}$ in. iron								tical rods bent.
Mixture ditto, 4	64	373	2·99	2·800	2·197	1891	IV.c 8	Ditto
bars ⅜ in. iron,		757	6·33	2·126	2·515			
2 ties $\frac{3}{16}$ in. iron		1120	11·86	1·384	2·515			
		1493	21·89	1·310	2·125			
1 cement, 2 sand,	192	249	·64	4·146	5·448	2396	IV.d 1	Shattered near end,
2 ¾ in. shivers		498	2·54	2·800	3·820			leaving about 12 in.
		871	6·17	2·500	3·530			sound other end.
1 cement, 2 sand,	192	249	1·24	2·880	2·801	1618	IV.d 2	Ditto
2 ¾ in. shivers		747	6·89	1·500	2·311			
		1120	13·77	1·165	1·821			
		1368	21·41	·592	2·476			
1 cement, 2 sand,	202	373	3·54	2·880	1·050	1493	IV.d 3	Shattered one end,
3 ¾ in. shivers		749	6·88	1·500	2·311			other end sound for
		1120	15·15	1·165	1·667			about 14 inches.
		1246	17·08	·580	2·247			
1 cement, 2 sand,	205	249	1·14 a	2·390	3·048	1618	IV.e 1	Ditto
3 ¾ in. shivers			2·28 b	1·900	1·222			
			1·54 a	3·045	2·255			a—load ascending
			2·21 b	1·830	1·572			b—load descending
			1·73 a	2·680	2·008			
		747	7·03 a	2·508	3·265			
			7·55 b	1·788	2·110			
			7·53 a	2·220	2·115			
		1120	12·08 a	1·110	2·920			
1 cement, 3 grit	208	249	1·32 a	2·320	2·632	1842	IV.e 2	Broken and shat-
with dust			1·67 b	2·550	2·081			tered vertically
			1·59 a	2·355	2·185			
			2·94 b	2·100	1·182			
			2·64 a	2·220	1·315			
			5·50 b	1·555	·682			
			4·82 a	1·788	·928			
		747	8·07 a	2·506	1·973			
			8·07 b	3·884	1·973			
			9·21 a	1·155	1·727			
			14·32 b	1·848	1·113			
			12·98 a	1·872	1·227			
		1120	18·06 a, b	·744	1·430			
			18·67 a	1·465				
1 cement, 2 sand,	159	249	1·00	2·765	3·475	2464	IV.f 1	Shattered vertically
2 ¾ in. shivers,		747	5·16	2·440	3·085			
4 ½ in. bars, 2		1493	15·48	1·322	2·235			
ties $\frac{3}{16}$ in. diam.		1867	26·82	·870	1·636			

TABLE IV.b—Continued.

Composition	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 20 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain	Breaking Load in pounds per square inch	Reference to Curves	Remarks
					× 10⁶			
1	2	3	4	5	6	7	8	9
1 cement, 2 sand,	162	249	1·01	2·765	3·440	2868	IV.f 1	One end shattered,
2 ¾ in. shivers,		747	5·13	2·535	3·103			other end sound for
4 ½ in. bars, 5		1493	13·41	2·074	2·579			about 14 inches, ver-
ties $\frac{3}{16}$ in. diam.		1991	21 29	1·165	2·206			tical bars bent.
1 cement. 2 sand,	166	249	1·03	2·960	3·372	2476	IV.f 2	Ditto
2 ¾ in. shivers,		747	6·14	2·140	2·592			
4 ⅜ in. bars, 10		1493	17·19	1·304	2·100			
ties $\frac{3}{16}$ in. diam.		1867	28·16	·600	1·557			
1 cement, 2 sand,	171	249	·90	3·706	3·860	2763	IV.f 3	Shattered in middle
2 ¾ in. shivers,		747	4·62	2·770	3·447			bars bent.
4 ⅜ in. bars, 15		1493	12·86	1·760	2·687			
ties $\frac{3}{16}$ in. diam.		2240	26·20	·915	2·031			
1 cement, 2 sand,	167	249	1·13	2·385	3·073	1739	IV.f 4	Ends shattered, bars
3 ¾ in. shivers,		747	13·19	·625	1·206			bent.
4 ⅜ in. bars, 2		1120	24·85	·495	1·015			
ties $\frac{3}{16}$ in. diam.								
1 cement, 2 sand,	197	249	1·24	2·765	2·801	1867	IV.g 2	Shattered in centre
3 ¾ in. shivers,		996	9·58	1·660	2·311			and bars bent.
4 ⅜ in. bars, 5		1618	23·95	·626	·947			
ties $\frac{3}{16}$ in. diam.								
1 cement, 2 sand,	173	249	1·04	3·645	3·340	1805	IV.g 3	Broke through the
3 ¾ in. shivers,		747	6·55	1·855	2·431			centre.
4 ⅜ in. steel bars,		996	9·09	2·140	2·435			
10 $\frac{3}{16}$ in. diam. ties		1369	16·50	·990	1·916			
1 cement, 2 sand,	174	249	·99	3·195	3·510	2165	IV.g 4	Shattered and bars
3 ¾ in. shivers,		996	8·22	4·940	2·694			bent.
4 ⅜ in. steel bars.		1244	9·04	3·580	3·135			
15 $\frac{3}{16}$ in. diam. ties		1618	15·04	1·296	2·326			
1 cement, 2 sand,	107	249	2·09	2·764	2·978	2644	IV.h 1	
2 ¾ in. shivers,		622	5·56	2·350	2·800			
7 grills of 8 bars		996	9·86	1·805	2·530			
$\frac{3}{16}$ in. diam.		1369	16·70	1·310	2·050			
1 cement, 2 sand,	105	249	3·06	1·980	2·034	2152	IV.h 2	
2 ¾ in. shivers,		622	7·78	1·553	2·000			
7 grills of 8 bars		996	14·36	1·245	1 734			
$\frac{3}{16}$ in. diam.		1369	23·47	·887	1·458			

TABLE IV. k.—COMPRESSION TESTS, CONCRETE PRISMS.

Length 24 inches, Octagonal Cross Section.

Elastic limit of soft steel wire used in spiral = 39,000 pounds per square inch. Elastic limit of Bessemer steel used in longitudinal rods = 37,770 pounds per square inch. Area 29·75 square inch.

Composition	Age in Days	Compressive Stress, pounds per square inch.	Compression in Units of ·0008 inch on 20 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain × 10⁶	Breaking Load in pounds per square inch	Reference to Curves	Remarks
1 cement, 2 sand, 2 ¾ in. shivers. no bars.	133	301	1·80	4·180	4·180	2786	1 Fig. IV.k	Crushed near one end.
		602	3·35	3·425	4·550			
		1204	8·99	2·400	3·360			
		1806	16·81	1·510	2·680			
		2258	26·88	1·060	2·090			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire	131	301	2·03	3·760	3·700	4098	2 Fig. IV.k	Outside peeled at 90,000 pounds. Broke at 119,000 pounds. One spiral burst.
		602	4·58	2·770	3·320			
		1204	11·23	1·810	2·670			
		1806	22·21	1·140	2·040			
		2258	35·46	·942	1·580			
1 cement, 2 sand, 2 ¾ in. shivers, Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire	130	301	2·40	2·900	3·120	2846	3 Fig. IV.k	Outside peeled at 67,000 pounds, centre of prism crushed at 85,000 pounds.
		602	4·54	2·800	3·310			
		1204	11·75	1·510	2·560			
		1806	22·93	·920	1·197			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire, 6 ½ in. dia. vertical steel rods	129	301	1·70	3·140	4·400	5270	4 Fig. IV.k	Cracked at 101,000 pounds, and outer covering peeled off at 119,000 pounds. Buckled at 134,000. broke at 157,000 pounds.
		602	4·85	1·980	3·100			
		1204	15·00	1·215	2·000			
		1806	31·52	·770	1·430			
		2258	51·26	·522	1·090			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire, 10 ⅜ in. dia. vertical steel rods	129	a 301	2·07	3·300	3·640	4214	5 Fig. IV.k	Cracked at 112,000 pounds; the outside peeled off and broke at 126,000 pounds. Failed in body of prism. a—load ascending b—load descending
		a 602	4·58	2·800	3·270			
		b 602	5·07	3·960	2·970			
		b 301	2·86	2·800	2·620			
		a 301	2·46	3·420	3·050			
		a 602	4·88	3·000	3·080			
		a 1204	10·13	2·510	3·000			
		b 1204	12·51	3·580	2·400			
		b 602	6·86	2·900	2·190			
		b 301	4·01	2·650	1·870			
		a 301	3·68	3·140	2·040			
		a 602	6·09	3·140	2·470			
		a 1204	11·02	2·900	2·720			
		a 1806	16·70	2·250	2·710			
		a 2258	22·79	1·880	2·470			

TABLE IV. m.—COMPRESSION TEST OF CONCRETE PRISMS.

Length 12 inches, Octagonal Section.

Elastic limit of soft steel wire used in spirals = 39,000 pounds per square inch. Elastic limit of Bessemer steel used in longitudinal rods = 37,700 pounds per square inch. Area 29·7589 square inches.

Composition	Age in Days	Compressive Stress, pounds per square inch	Compression in Units of ·0008 inch on 20 inches	Coefficient of Elasticity in millions of pounds per square inch	E = Total Unit Stress / Total Unit Strain	Breaking Load in pounds per square inch	Reference to Curves	Remarks
					$\times 10^6$			
1 cement, 2 sand, 2 ¾ in. shivers, no bars, plain.	141	301	0·80	3·760	3·740	2409	1 Fig. IV.m	Shattered; no signs of fracture before breaking
		602	1·62	3·340	3·720			
		1204	3·80	2·370	3·170			
		1806	7·25	1·250	2·490			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire	136	301	0·81	3·540	3·740	4220	2 Fig. IV.m	Outside peeled off at 101,000 pounds and broke at 126,000 pounds; slightly crushed.
		602	1·74	3·010	3·450			
		1204	3·91	2·410	3·070			
		1806	6·96	1·740	2·580			
		2258	9·98	1·156	2·260			
		2860	19·41	·436	1·470			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire; 6 ½ in. steel vertical rods.	135	301	0·65	4·300	4·630	4517	3 Fig. IV.m	Outside peeled off at 110,000 pounds, and broke at 134,000 pounds. Crushed at centre.
		602	1·42	3·440	4·180			
		1204	3·52	2·410	3·430			
		1806	6·71	1·440	2·690			
		2258	10·73	·990	2·120			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire.	139	a { 301	0·98	2·740	3·070	3158	4 Fig. IV.m	Cracked at 695,000 pounds and outside peeled off, body crushed and bent; broke at 93,000 pounds.
		a { 602	2·49	1·600	2·420			
		b { 602	3·19	4·150	1·890			
		b { 301	2·16	2·510	1·400			
		a { 301	2·09	2·870	1·440			
		a { 602	2·15	2·280	1·910			
		a { 1204	8·12	·765	1·480			
		b { 1204	14·61	3·340	·825			
		b { 602	12·11	1·770	·500			
		b { 301	10·19	1·310	·296			
		a { 301	9·62	2·000	·313			
		a { 602	11·15	2·000	·545			
		a { 1204	14·42	1·400	·836			
		a { 1655	19·69	·450	·844			
1 cement, 2 sand, 2 ¾ in. shivers. Spiral ¾ in. pitch 5 in. dia. No. 5 gauge wire, 10 ⅜ in. steel vertical rods.	137	a { 301	0·64	5·000	4·850	5421	1 Fig. IV.m	Cracked at 134,000 pounds and outside peeled off; vertical rods bent. Prism crushed. Broke at 162,000 pounds. a—load ascending b—load descending
		a { 602	1·41	3·760	4·280			
		b { 602	1·55	6·000	3·880			
		b { 301	0·86	4·150	3·500			
		a { 301	0·83	6·000	3·630			
		a { 602	1·52	4·150	3·950			
		a { 1204	2·96	3·250	4·070			
		b { 1204	3·50	5·470	3·440			
		b { 602	2·20	4·300	2·740			
		b { 301	1·39	3·540	2·160			
		a { 301	1·31	4·900	2·300			
		a { 602	2·06	4·650	2·930			
		a { 1204	3·45	3·900	3·490			
		a { 1806	5·03	3·000	3·590			
		a { 2258	6·76	2·410	3·340			
		a { 3312	12·22	1·470	2·700			
		a { 4274	20·45	·770	2·090			

TABLE V.—AVERAGE RESULTS OBTAINED FROM TESTING THREE CONCRETE BEAMS, Reinforced with three steel rods $\frac{7}{8}$ inch diameter, span 120 inches; cross section 10 x 10 inches. Composition 1 cement, 2 sand, 3 of $\frac{3}{4}$ inch shivers. Length 11 feet, weight 1020 pounds. Age 105 days.

Load in Tons.	Extension on Extreme Fibre.	Extension on 20 inches $1\frac{1}{4}$ inch from top of Beam.	Compression on 20 inches $1\frac{1}{4}$ inch from the bottom of Beam	Deflection in Inches.
·2				
·4	·0005	·00016	·00018	·0038
·8	·0013	·00045	·00079	·0098
1·2	·0022	·00083	·00121	·0169
1·6	·0033	·00114	·00162	·0242
2·0	·005	·00180	·00199	·0401
2·4	·0068	·00252	·00252	·0574
2·8	·0084	·00322	·00309	·0670
3·2	·0102	·00409	·00357	·1011
3·6	·0126	·00508	·00404	·1041
4·0	·0150	·00602	·00457	·1150
4·4	·0174	·00708	·00516	·1432
4·8	·0195	·00779	·00571	·1590
5·2	·0219	·00917	·00621	·1708
5·6	·0240	·01043	·00675	·1952
6·0	·0264	·01141	·00734	·2189
6·4	·0288	·01256	·00793	·2398
6·8	·0312	·01407	·00897	·2662
7·2	·0339	·01550	·00945	·2814
7·6	·0369	·01742	·01016	·3029
8·0	·0400	·01800	·01094	·3135
8·4	·0429	·02191	·01208	·3283
8·8	·0469	·02442	·01318	·3653

NOTE—The average load producing the first crack was 8·8 tons, and the breaking load 9·6 tons.

TABLE V.a.—TRANSVERSE TESTS OF MORTAR BEAMS. Length 4 x 4 inches, containing 1 Hemmoor cement to 3 Emu Plains sand, and 9% water; no bars. Span 40 inches.

Age in Days.	Load in pounds.	Deflection per 0·1 ton mean in ins. reduction.	Total deflection in ·01 mm. reduced to inches	Modulus of Elasticity, lbs. per square inch $\frac{Wl^3}{48\,d\,I} = \frac{W \times 10^3}{16\,d}$	Breaking Load pounds.	Number in Curve.	Modulus of rupture, lbs. per square inch.
				$\times 10^6$			
518	22	0·000000	0·000000		448	Fig.	443
	45	·000390	·000390			V.a 1	
	89	·001023	·001378	3·240			
	134	·000866	·002244				
	179	·000984	·003228				
	224	·001063	·004291	2·460			
	269	·001102	·005393				
	314	·001417	·006811				
	358	·002047	·008858				
	403	·001456	·010315	1·550			
	448						
519	45	0·000000	0·000000		488	Fig.	480
	89	·001220	·001220	2·640		V.a 2	
	134	·000944	·002165				
	179	·000944	·003110				
	224	·001181	·004291	2·370			
	269	·001102	·005393				
	314	·001378	·006889				
	358	·001141	·008031				
	403	·001614	·009645				
	448	·001259	·010905	1·944			

TABLE V.b.—TRANSVERSE TESTS OF MORTAR BEAMS WITH STEEL RODS.

Length 4 inches x 4 inches, containing 1 Hemmoor cement to 3 Emu Plains sand, and 9% water, 3 ½ inch steel bars; span 40 inches.

Age in Days.	Load in pounds	Deflection per ·01 ton in inches.	Total deflection in inches.	Breaking load pounds.	Number in Curve.	Modulus of rupture lbs. per sq. inch.
529	45	0·000000	0·000000	3405	Fig. V.b 1	3218
	89	·000708	·000708			
	179	·001614	·002323			
	269	·001968	·004291			
	358	.001456	·005748			
	448	·001811	·007559			
	638	·002165	·009724			
	627	·001653	·011378			
	717	·001771	·013149			
	806	·002126	·015275			
	896	·002244	·017520			
	986	·001850	·019370			
	1075	·002244	·021614			
	1165	·002283	·023898			
	1254	·002165	·026063			
	1344	·002519	·028583			
	1434	·002953	·031536			
	1523	·002323	·033858			
	1613	·002874	·036733			
	1702	·003504	·048032			
	1792	·002480	·043716			
	1882	·003425	·046141			
	1971	·002323	·048464			
	2061	·002756	·052220			
	2150	·003031	·054252			
	2240	·003307	·057559			
	2330	·003071	·060630			
	2419	·003071	·063701			
	2508	·003661	·067362			
	2598	·004213	·071575			
	2688	·004527	·076103			
	2778	·005472	·079023			
	2868	·005512	·087086			
	2958	·005513	·092637			
	3047	·005169	·097834			
	3137	·006574	·004409			
	3227	·005315	·009724			
	3317	·012598	·018140			

TABLE Vb.—Continued.

Age in Days.	Load in pounds.	Deflection per ·01 ton in inches.	Total deflection in inches.	Breaking load pounds.	Number in Curve.	Modulus of rupture lbs. per sq. inch.
529	45	0·000000	0·000000	3394	Fig. V.b 2	3298
	89	·000748	·000748			
	179	·001889	·002637			
	269	·002165	·004803			
	358	·001732	·006535			
	448	·001889	·008425			
	538	·002047	·010472			
	627	·001968	·012441			
	717	·001811	·014252			
	806	·002322	·016575			
	896	·001929	·018504			
	986	·001850	·020354			
	1075	·001771	·022126			
	1165	·002710	·024843			
	1254	·002322	·027165			
	1344	·002126	·029292			
	1434	·002637	·031929			
	1523	·002598	·034528			
	1613	·002637	·037166			
	1702	·002992	·040157			
	1792	·003031	·043190			
	1882	·002126	·045315			
	1971	·002637	·047953			
	2061	·002913	·050866			
	2150	·002952	·053819			
	2240	·002874	·056693			
	2330	·003543	·060236			
	2419	·002952	·063189			
	2508	·002834	·066024			
	2598	·003819	·070843			
	2688	·003464	·073327			
	2778	·003504	·076811			
	2868	·003819	·080529			
	2958	·003464	·084094			
	3047	·003464	·087559			
	3137	·004055	·091614			
	3227	·003740	·095354			
	3317	·003110	·098464			
	3405	·003299	·104764			

THE FLOOD SILT OF THE HUNTER AND HAWKESBURY RIVERS.

By Professor T. W. EDGEWORTH DAVID, B.A., F.G.S., F.R.S., and Acting Professor F. B. GUTHRIE, F.I.C., F.C.S.

[*Read before the Royal Society of N. S. Wales, October 5, 1904.*]

I.—Introduction.
II.—Bibliography.
III.—Area of Hunter and Hawkesbury Deltas and character of their deposits.
IV.—Volume of flood water.
V.—Amount, chemical composition and value of silt deposited by flood waters.
VI.—Rate of accumulation of silt of Hunter Valley in relation to age of Hunter Delta.

I.—INTRODUCTION.

The Hunter Delta area is in its upper part one of the most fertile districts of New South Wales, especially the portion which extends from a little below Raymond Terrace to a short distance above West Maitland. The fertility of this region, one of the best lucerne producing areas in this State, is due to the rich character of the flood silts, which have proved to that district almost as great a boon as the Nile mud to Lower Egypt. As much as $1\frac{1}{4}$ tons of lucerne are produced per acre, and five crops are obtained a year, their average value being about 35/- per ton.

During the recent flood of July 12th, 1904, it occurred to the authors that it would be interesting for scientific and economic reasons to estimate the amount and chemical composition of the silt in the water brought down by that flood. We wrote to Mr. A. J. Prentice, B.A., of West Maitland, asking him to secure samples of the flood water and flood mud. He very kindly obtained both, and forwarded them at once to Sydney, with his own notes which we publish. We also communicated with Mr. H. W. Potts, Principal of the Hawkesbury College, Richmond, with a view to securing samples of the flood water and silt of the Hawkesbury River, brought down by the same flood. He also kindly obtained both for us.

With regard to the Hawkesbury alluvials fewer data are available than in the case of those of the Hunter. The principal crop grown on them is maize; but lucerne is also grown.

II.—Bibliography.

A number of valuable reports relating to the Hunter Delta have been furnished by the Government Department of Public Works. These deal specially with the subject of flood prevention. The following is a list of these reports:

In 1869 Mr. Moriarty reported to the Works Department. This is a report of special value for the calculation of the amount of flood discharge.

In 1870 the report of the Royal Commission on flood prevention in the Hunter Valley, was published by the Government.

1890, Mr. Gordon furnished a report for mitigating floods in the Hunter Valley, which if carried out was estimated to cost nearly £1,400,000.

Later Mr. C. W. Darley and Mr. H. D. Walsh furnished official reports criticising the preceding.

In 1897 Mr. Price recommended the building of a huge dam at Denman to mitigate the floods, and in 1899 Mr. Napier Bell reported to the Government on this and other schemes for flood prevention in the Hunter.

Mr. R. Etheridge and one of the authors (T.W.E.D.) published a paper on the Raised Beaches of the Hunter Delta in 1890.[1]

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[1] Records Geological Survey of N. S. Wales, Vol. ii., Pt. ii., 1890, pp. 37 - 52, pl. iii.

In 1903 Mr. J. H. Maiden, F.L.S., read a valuable paper on mitigation of floods in the Hunter River, dealing with the matter from the point of view of the forester.[1]

With regard to the alluvials of the Hawkesbury River the information is at present somewhat meagre, at any rate from a geological point of view. One of us (Acting Professor Guthrie)[2] has published a report on its soils in which a rough map is given showing the approximate extent of these alluvials; this map being reproduced from an earlier one in this Journal by one of the authors (Professor David).[3] The Geological Survey of the Department of Mines, Sydney, has lately issued a geological map of the coastal plain near Sydney, in which the above sketch of the alluvials has been reproduced. The alluvials do not form a typical delta, for they terminate 30 miles in a bee line from the coast, the channel of the Hawkesbury below Richmond being bounded by steep slopes and terminating in the fiord of Broken Bay.

III.—Area of the Hunter Delta and Character of its Deposits.

The Hunter River is tidal from its mouth at Newcastle to the Falls above Belmore Bridge, West Maitland, a distance of 44 miles following the river, and about $18\frac{1}{2}$ miles in a bee line. The alluvial plains subject to flood are about 35,000 to 40,000 acres in extent.

This area is, however, only about one-third of the total area of the Hunter Delta, the greater part of the delta lying to the north-east of a line running from Stockton to Sandgate and thence to Raymond Terrace, being covered by blown sand which places the old flood silts out of reach of the agriculturalist. These flood silts in the lower part of

[1] Journ. Roy. Soc. N.S. Wales, Vol. XXXVI., pp. 107 - 131.

[2] The Chemical Nature of the Soils of N. S. Wales, with special reference to Irrigation, by F. B. Guthrie, F.I.C., F.C.S., Journ. Roy. Soc. N. S. Wales, Vol. XXXVII., pp. LI. - LXV.

[3] Journ. Roy. Soc. N. S. Wales, Vol. XXX., pp. 1 - 69, pls. i. - iv.

the delta are moreover, either at sea-level or even a trifle below sea-level. Peat beds dipping below the level of low water occur at Fingal Bay near Port Stephens, and similar peat struck at about 80 feet below sea-level at a bore west of Anna Bay, Port Stephens, points to a recent subsidence of the coast, a movement which is confirmed by the evidence of the quantities of wood and coarse gravel met with in the Stockton Colliery's pit at about 180 feet below sea-level.

The following is a table of the sequence of the Hunter River Delta deposits :—

1. Blown sand and peat together with recent ironstone deposits around swamps in the sand dunes. The ironstone is used as a flux by the Sulphide Corporation Works at Cockle Creek.
2. Recent flood loams.
3. Ancient flood loams which at Elderslie, near Branxton, contain remains of the large extinct diprotodont marsupial *Nototherium.*
4. Raised beaches such as those of Largs, Font Hill, Campbell's Hill, West Maitland Waterworks, Bolwarra, etc.
5. Old valley deposits like those met with in the Stockton Pit.
6. High level gravels, like those near Nicholson's, Oakhampton, West Maitland; and on the north bank of the Hunter near Roughit to the south-east of Singleton.

As regards the alluvial deposits of the Hawkesbury Delta these have been classed in the paper above referred to as Pleistocene and recent.

The Pleistocene comprise (1) the red sandy soils for the most part above the reach of modern floods as shown in a later paper by one of the authors,[1] and (2) the modern flood loams and sands, with coarse river gravels. There is also a development of an older coarse river gravel probably of Tertiary age, like that seen between Windsor and Richmond and in the railway cutting east of St. Mary's, and also near Lapstone Hill between Glenbrook and Emu Plains.

IV.—Volume of Flood Water.

The flood quantities for the flood water of the Hunter Delta have been estimated at 150,000 cubic feet per second above the Paterson, 171,000 cubic feet below the Paterson and above the Williams, and 193,000 cubic feet below the Williams.[2] Mr. R. T. McKay has kindly called our attention to a difficulty in accepting Mr. C. Napier Bell's estimates. If the discharge of the Hunter River when in full flood below the junction of the Williams River be 193,000 cubic feet per second, this amounts to over $11\frac{1}{2}$ million cubic feet per minute, and the water is derived from a drainage area of 9,127 square miles. Now the big flood in the Murray in 1870, coming from a drainage area of about 200,000 square miles discharged at Mildura only about 6 million cubic feet per minute, and it is probable that even this estimate is too high.[3] In 1890 the Murray River when in flood was discharging at Morgan, at the rate of 4 million cubic feet per minute. These figures are fairly correct. This water came from an area of, in round numbers, 400,000 square miles. Is it therefore likely, that even after allowance is made for the greater relative evaporation and percolation of rainfall in the Darling-Murray basin, as compared with the Hunter basin, that the Hunter River with less than $\frac{1}{40}$ of catchment area, should discharge nearly three times as

[1] On an important Geological Fault at the Kurrajong Heights, Journ. Roy. Soc. N.S. Wales, Vol. xxxvi., p. 359, pls. 16, 17.

[2] Report by C. Napier Bell, M. Inst. C.E., *op. cit.*, pp. 20, 21.

[3] The Murray River Irrigation and Navigation, by Robert T. McKay, Sydney University Engineering Society, 1903, pp. 25, 26.

much water as the Darling-Murray in time of flood? At the same time it must be remembered that according to Mr. H. C. Russell's[1] estimates, the Darling River at Bourke discharges only about $1\frac{1}{2}\%$ of the rainfall of its catchment. The Murray River, on the other hand discharges about 25% of its total rainfall.

The total amount of water passing over the delta during a great flood, such as that of 1857, was estimated by Mr. E. O. Moriarty to be 88,000 millions of cubic feet. Mr. Darley on the other hand, quotes Mr. Gordon's estimate of the capacity of a reservoir necessary to contain the surplus water of a heavy flood as 24,514 million cubic feet, or nearly fifteen times the full capacity of Prospect Reservoir.[2]

V.—Amount, Chemical Composition and Value of the Flood Water Silt.

In order to obtain some idea of the amount and fertilizing value of the silt deposited on the land during the progress and subsidence of a flood, samples of flood water and silt were examined, derived from the recent heavy floods in the Hunter and Hawkesbury Rivers. These waters being very different in character will be discussed separately.

(a) *Hunter River Flood Water.*

Samples of the flood water of the Hunter River were obtained through the kindness of Mr. A. J. Prentice of West Maitland. The water was collected on July 12th, 1904, from the centre of the stream off the Belmore Bridge

[1] The Source of the Underground Water in the Western Districts, Journ. Roy. Soc. N. S. Wales, 1889, pp. 57 - 63.

[2] Floods on the Hunter, By Authority, Sydney 1891, p. 2. Mr. Price estimated that the proposed reservoir below Denman to hold the flood waters of the Hunter and its tributary the Goulburn, should have a capacity of 40,000 million cubic feet, and this of course does not allow for the water contributed by the Wollombi brook (Cockfighter), Paterson, and Williams rivers, etc., so that Mr. Moriarty's estimates may not be excessive.

at West Maitland when the river was 23 feet above its summer level. According to observations at Raymond Terrace, kindly indicated by Mr. H. A. Hunt, Acting Meteorologist, the flood was at its maximum on the 10th and 11th July, so that the water had receded somewhat, and no doubt at full flood the amount of suspended matter would have been somewhat greater. Mr. Prentice also sent a sample of silt deposited by the flood to which he attaches the following remarks :—

"The jar contains genuine flood deposit. It comes from near Belmore Bridge, out of a slight depression, in which the water would have been stagnant as the river fell, and down stream from a fence which had arrested practically all débris and vegetation. This deposit would average over 2 inches in thickness, probably 3, and is I consider a fair sample of what the flood deposit would be on land which is covered by real flood waters which either rise and remain motionless, or have a very slight current. The deposit varies every few yards, and fences or slight elevations in the ground, by retarding the current, cause a deposit, in the first place and on the up stream side, of almost raw sand, and then on the down stream side the deposit would be more loamy."

Analysis of Hunter River Water.

		Parts per 1000.		Grains per gallon.
Total residue	=	2·463	or	172·4
Volatile on ignition	=	0·308	,,	21·6
Fixed residue	=	2·155	,,	150·8
Matter in suspension	=	2·182	,,	152·7

(b) *Hawkesbury Flood Waters.*

Through the courtesy of Mr. H. W. Potts, Principal of the Hawkesbury Agricultural College, samples of water and of silt from the flood waters of the Hawkesbury River were also obtained. The following details are supplied by

Mr. Cuthbert Potts, Science Master at the College, who kindly collected the samples, July 14th, 1904:—

"The flood had receded from 42 feet to about 22 feet above summer level when the sample was taken, but the current was running fairly strongly. The water was taken from the middle of the river, near the Kurrajong Bridge. The silt may be slightly contaminated by the washings from some recent diggings, but as far as possible I obtained a true sample. The flood was not high enough to largely break over the river banks, above Richmond, and so the Richmond bottoms were only covered with a back water washing back from about three miles down the river. This back water carries much less silt than the river, and is not considered to do the land so much good. The bottoms round Windsor and further down the river were swept by the current and obtained a fair deposit of silt."

Mr. John Tebbutt, the Observatory, Windsor, has kindly informed us that the flood began to rise on the 9th July, and attained its maximum height of 40·1 feet above the mean tidal level of the South Creek early in the morning of the 12th July.

Analysis of Hawkesbury River Water.

		Parts per 1000.		Grains per gallon.
Total residue	=	·145	or	10·15
Volatile on ignition	=	·03	,,	2·10
Fixed residue	=	·115	,,	8·05
Matter in suspension	=	·116	,,	8·12

Both waters are slightly acid in reaction.

Analysis of Silts.

Analysis of Silt from Hunter River Water.

	Per cent.
Insoluble in hydrochloric acid	=79·25
Soluble in hydrochloric acid—	
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3)	= 10·02
Lime (CaO)	= 1·55
Potash (K_2O)	= 0·09
Phosphoric acid (P_2O_5)	= 0·18

		Per cent.
Volatile matter	=	9·61
Nitrogen	=	·084

Weight per acre, one foot in depth = 3,403,125 lbs.

Analysis of Silt from Hawkesbury River Water.

		Per cent.
Insoluble in hydrochloric acid	=	89·96
Soluble in hydrochloric acid—		
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3)	=	4·77
Lime (CaO)	=	0·49
Potash (K_2O)	=	0·12
Phosphoric acid (P_2O_5)	=	0·08
Volatile matter	=	4·68
Nitrogen	=	0·105

Weight per acre, one foot in depth = 3,307,332 lbs.

Assuming an average based on Mr. Prentice's observations of 2 inches of deposit after the subsidence of a flood, the silt left by the Hunter River in flood would amount to 567,186 lbs. in weight per acre, and would supply the land with a top dressing of fertilising constituents to the following amount per acre :—

Lime	8,791 lbs.
Potash	510 ,,
Phosphoric acid	1,020 ,,
Nitrogen	476 ,,

A manuring which contains sufficient of the necessary plant food to supply the requirements of most crops for nearly 10 years.

On the assumption that the same volume of water was flowing for the same length of time at the same rate in both cases, the amount of deposit left by the flood will be proportional to the amount of suspended matter. Taking 2 inches to be the depth of deposit left by the Hunter River, then the Hawkesbury River would deposit under the similar conditions as to time, volume and rate of flow $\frac{1}{10}$ inch silt.

The weight of this deposit in the case of the Hawkesbury flood would be 27,561 lbs. per acre, or about $\frac{1}{20}$ the weight of that left by the Hunter River flood.

This would provide the land with a top dressing per acre of the following fertilising constituents :—

Lime	135 lbs.
Potash	33 ,,
Phosphoric acid	22 ,,
Nitrogen	29 ,,

All the above estimations as to the amount of fertilising material deposited are based on Mr. Prentice's assumption that the depth of the deposit in the case of the Hunter River flood averaged 2 inches. This appears a very high average, but there are unfortunately no hydrographical data available by means of which this can be checked. It would be a matter of considerable national importance if further data concerning the rate of flow, volume of water, height of flood, and amount of silt deposited etc., could be obtained during the period of such floods as those now discussed. This is a matter which might well engage the attention of the engineers of the Public Works Department.

VI.—Rate of Accumulation of Silt of Hunter Valley in Relation to Age of Hunter Delta.

As stated in the previous section of this paper, Mr. Prentice estimates that approximately 2 inches of silt were deposited over the upper part of the Hunter Delta by the last flood of July 12th, but his observations were confined to a comparatively small portion of the delta close to West Maitland. Observations of this kind to be of real scientific value, need to be taken over a large area ; this Mr. Prentice attempted to do by inviting by advertisement the furnishing of statistics by farmers and others resident in the district, but he was unable to obtain any response.

The construction of levees, which except in cases of very high floods restrict the area covered by the flood water very considerably, further complicates the question of estimating the amount of silt deposited by each flood.

It is interesting to note that as there are 2·463 parts per 1000 of solid residue in the flood water of the Hunter, and its specific gravity is assumed to be about 2·, this would obviously prove that if all this residue were deposited from a sheet of water 10 feet in depth, it would yield ·0123 foot in thickness of silt, or in round numbers ·15 inches. At this rate as much of the Hunter Delta silt is at least 30 feet thick, this would have taken 2,400 years to form on the assumption that there is a flood every year. If the average be taken at one flood every five years the time for the delta formation would be extended to 12,000 years. This is probably less than the actual time needed, and is less than the 30,000 years assumed as necessary for the formation of the delta of the Nile. It serves, however, to show something of the order of the time needed for the building of a delta like that of the Hunter.[1]

APPENDIX.—The following letter from Mr. R. Bailey to Mr. J. Hall, dated on October 28th, 1904, at the "*Mercury Office*," West Maitland, and read to the Society when our paper was being discussed, by Mr. J. Hall is of such interest, on the economic side of the question, that by Mr. Hall's kind permission we quote it in full:—

" In reply to yours *re* floods in the Hunter, I beg to state that having questioned a number of farmers in the district on the matter, they are unanimously against floods despite the value of

[1] If Mr. Gordon's estimate of 24,500 millions of cubic feet of flood water be assumed to be the correct amount for the flood water over and above what would be discharged by the river while flowing between its banks, the weight of the silt brought down by it would be over 1½ millions of tons, and over 5 millions of tons on Mr. Moriarty's flood estimates, viz., 88,000 millions of cubic feet of water.

the deposits which such leave behind, as a rule. There are times, such as 1893 and this present year, when a number of the farms were practically ruined by heavy deposits of sand brought down by the flood currents, but these of course are isolated cases. In the majority of instances the deposits are rich alluvial soil, and would be of special value were it not that the destruction caused in other ways is very much greater than the value of the deposits, even though they exceeded the sum you mention. The farmers of Bolwarra have been doing their best for the past 20 years to keep floods out by the erection of embankments, and others wish they could do the same. Floods are very uncertain in their coming, and besides destroying growing crops render the land unfit for the plough for some weeks, very often too late in the season for the sowing of another crop. The land around the Hunter, is all as you know, built up 30, 40 and 50 feet, and is invariably so rich, that despite constant cultivation for the past 60 years, is practically as good to day as ever it was, with careful cultivation, and consequently the question of manuring by flood deposits or otherwise gives the farmers no concern. From practical experience, very often of a bitter and ruinous character, they are down on floods as being the greatest evil they have to contend with. Doubtless some day the soil will become exhausted, as is only reasonable to expect, but with a judicious rotation in the crops, they hope that the day is far distant when they will either be looking forward to a flood to help them out of the trouble, or be compelled to manure their lands to ensure better crops. This shortly is a consensus of the opinions I have been able to gather from a number of them in different localities, and I trust it will meet the objects of your enquiries."

ETHNOLOGICAL NOTES ON THE ABORIGINAL TRIBES OF NEW SOUTH WALES AND VICTORIA.

PART I.

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[*Read before the Royal Society of N.S. Wales, October 5, 1904.*]

INTRODUCTION.

IN the following pages it is intended to supply a succinct account of the social organisation, languages and general customs of our aborigines. Throughout a comparatively long life I have had special opportunities of studying the habits of these people. I was born in the Australian bush and black children were among my earliest playmates. In my youth I was engaged in station pursuits in the back blocks of New South Wales and in the new country of Queensland, when the blacks were in their pristine condition. In later years I was employed as a surveyor on the Barwon, Namoi, Castlereagh, and other distant inland rivers, where I was continually in contact with the sable sons and daughters of the soil.

Fortunately, also, I always had a keen proclivity for collecting all the information available in regard to their numerous highly interesting customs. It so happened, too, that I possessed some little capability for investigating the grammatical structure of their language, being able to cope with the difficulty of correctly hearing and correctly writing down the native words. Owing to my familiarity with the ways of blackfellows, I always received the complete confidence of the chief men, and thus gained admission to their secret meetings. Moreover, my training as a draftsman enabled me to copy every description of aboriginal drawings with great facility, for some of which I was awarded the medal of this Society in 1894, ten years ago. And the knowledge of astronomy which my profession demanded, made it easy for me to identify with precision all the different stars and stellar groups which figure so prominently in the aboriginal folklore.

I have made the foregoing brief mention of my opportunities of acquiring some knowledge of aboriginal customs, because the reader will readily understand that investigations of this character require many years of patient work among the different tribes. It is essential that these inquiries should be conducted by a person well acquainted with the daily life of the people, and that his observation should extend over a considerable period. I have adopted none of the opinions nor followed any of the methods of other Australian authors, but have struck out on my own lines, recording all the new and interesting facts within my reach. Possibly further researches may modify some of my conclusions, but this is the inevitable lot of all scientific pioneers.

I write not in the expectation of exhausting the subject of the languages, ceremonies and customs of the Australian aborigines, but in the fervent hope of exciting the interest and encouraging the investigation of younger students; and trust that some foundations have been laid by me for others to build upon, or to correct if necessary.

Attention is called to the fact that all the particulars contained in every branch of the subject dealt with in this treatise, have been collected by myself in the native camps, without the assistance or suggestions of any man, and therefore, I only am responsible for any defects which may be discovered in studying the following pages. The present work is only one of a series of similar treatises on various ceremonies and customs of the Australian aborigines, which I have published in the journals of some of the leading learned societies of Europe and America, as well as in this country. See "Bibliography" at the end of this article.

The system of orthoëpy adopted is that recommended by the Royal Geographical Society, London, but a few additional rules of spelling have been introduced by me, to meet the requirements of the Australian pronunciation.

Eighteen letters of the English alphabet are sounded, comprising thirteen consonants, namely: *b*, *d*, *g*, *h*, *k*, *l*, *m*, *n*, *p*, *r*, *t*, *w*, *y*, and five vowels: *a*, *e*, *i*, *o*, *u*.

As far as possible, vowels are unmarked, but in some instances, to prevent ambiguity, the *long* sound of ā, ē, ī, ō and ū are given as here represented. Where the *short* sound of these vowels was otherwise doubtful, they are marked thus: ă, ĕ, ŏ and ŭ.

It is frequently difficult to distinguish between the short sound of *a* and that of *u*. A thick sound of *i* is occasionally met with, which closely resembles the short sound of *u* or *a*.

B has an intermediate pronunciation between its proper sonant sound and the surd sound of *p*. The two letters are practically interchangeable.

G is hard in all cases, and often has the sound of *k*, with which it is generally interchangeable.

W always commences a syllable or word, and has its ordinary English sound. The sound of *wh* in our word "what" has no equivalent in the native tongue.

Ng at the beginning of a word or syllable has a peculiar nasal sound as in the English word "singer." If we alter the syllabification of this word and write it "si-nger," then the *ng* of "-nger" will represent the aboriginal sound. Or if we take the expression "hang up" and change it into "ha-ngup," and then pronounce it so that the two syllables melt into each other, the *ng* of "-ngup" will also be the sound required. At the end of a syallable, *ng* has the sound of *ng* in king.

The sound of the Spanish ñ frequently occurs. At the beginning of a word or syllable it is given as *ny*, but when terminating a word the Spanish letter ñ is used.

Dh is pronounced nearly as *th* in "that," with a slight sound of *d* preceding it. *Nh* has likewise nearly the sound of *th* in "that," with a perceptible initial sound of the *n*.

Th is frequently used at the commencement of a word instead of *dh*, and in such cases an initial *t* sound is substituted for that of the *d*. *Dh* and *th* are generally interchangeable. At the beginning of a word our English sound of *d* and *t* seldom occurs; it is generally pronounced *dh* or *th*, in the way just explained.

A final *h* is guttural, resembling *ch* in the German word "joch."

Y at the commencement of a word or syllable preserves its habitual sound.

R in general has a whirring sound, at other times it is rolled, and occasionally the English value is assigned to it.

T is interchangeable with *d*, *p* with *b*, and *g* with *k*, in most of the words in which these letters are used.

Ty or *dy* at the commencement of a syllable or word has nearly the sound of the English *j* or Spanish *ch*, thus *-tya* in the word min-tya, closely resembles *cha* or *ja*.

Some native words terminate with *ty*, as 'kūr-gaty,' one of the frogs. The last syllable of this word can be pronounced exactly by assuming *e* to be added to *y*, making it -gat-ye. Then commence articulating the word, including the *y*, but stopping short without sounding the added *e*. An accurate pronunciation can also be readily obtained by substituting *ch* for the *y*, making it gatch, but omitting the final hissing sound when pronouncing it.

Where double *l* occurs, it often closely resembles *dl*; thus 'kullu,' a lizard, could be spelt 'kŭdlu.' The same thing happens with double *n*; thus, the word 'kunnai,' a yam-stick, could almost be pronounced 'kŭdnai.' *M* and *b* are often interchangeable in the same way.

In several native words, an indistinct sound of *r* seems to come before some consonants. Thus, it is difficult to distinguish between thurl-tha and thul-tha; between kur-nu and ku-nu; between bur-al and burd-al. In modifying the terminations of words for inflection or declension, *r* is often changed into *l*.

When there are double consonants, the second one must begin the following syllable.

Sociology of the Ngeumba Tribe.

In treating of the Ngeumba language in subsequent pages the boundaries of this nation will be defined. I shall here supply an abridged account of their social organisation, which has never before been published.

The community is divided into two primary phratries, called Ngurrawun and Mūmbun, with their feminine equivalents Ngurrawunga and Mūmbunga. The Ngurrawun phratry is again divided into two sections called Ippai and Kumbo, and the Mūmbun phratry into two, called Kubbi and Murri. In each of these sections the names of the women are slightly different from those of the men, as will appear from the following tabular synopsis, which also shows what sections can intermarry, and to what section the resulting offspring belongs:

Table No. I.

Phratry	Father	Mother	Son	Daughter
Ngurrawun	Ippai	Kubbitha	Murri	Matha
	Kumbo	Matha	Kubbi	Kubbitha

Phratry	Father	Mother	Son	Daughter
Mūmbun	Kubbi	Ippatha	Kumbo	Butha
	Murri	Butha	Ippai	Ippatha

It will be observed that the children inherit the name of the other moiety of their mother's phratry. Thus, if a Ngurrawun man, of the section Ippai, marry a Mūmbun woman of the section Kubbitha, the offspring will be Mūmbun the same as their mother, but they will not bear the name of her section, but will take the name of the other section in the Mūmbun phratry—the sons being called Murri, and the daughters Matha. Again, the children inherit their mother's totem; for example, if the mother be a pelican, her sons and daughters will be pelicans also.

Like the people themselves, everything in the universe, animate and inanimate, belongs to one or other of the two phratries, Ngurrawun and Mūmbun. And every individual in the community, male and female alike, claims some animal or plant or other object, as his *dhingga* or totem. The totems of the Ngurrawun phratry are common to the two sections, Ippai and Kumbo, of which it is composed; and the Mūmbun totems are common to the sections Kubbi and Murri.

Among the *dhingga* or totems of the Ngurrawun phratry may be mentioned the following:—emu with dark head, kangaroo, bandicoot, bilbai, pelican, opossum, swan, plain turkey, mosquito, musk duck, porcupine, bat, dog, kurrea, bulldog-ant, yellow-belly fish.

The undermentioned totemic names, or *dhingga*, may be enumerated as some of those belonging to the Mūmbun phratry:—emu with grey head, house-fly, tree iguana, ground iguana, eaglehawk, scrub-turkey, shingleback, large fish-hawk, wanggal or small night-jar, black duck, padamellin, crow, carpet snake, codfish, bream.

Beside the phratries, sections and totemic groups above illustrated, the whole community is further divided into what may, for convenience of reference, be called 'castes.' These castes regulate the camping or resting places of the people under the shades of large trees in the vicinity of water or elsewhere. The shadow thrown by the butt and lower portion of a tree is called 'nhurrai'; that cast by the middle portion of the tree is 'wau-guē'; whilst the shade of the top of the tree, or outer margin of the shadow, is 'winggu.'

Again, the men, women and children, whose prescribed sitting places are in the butt and the middle shades of the tree are called 'guai′mundhan,' or sluggish blood, whilst those who sit in the top or outside shade are designated 'guai′gulir,' or active blood. This further bisection of the community into Guaimundhun and Guaigulir, which may be referred to as 'blood' divisions, has happened so long ago that the natives have no explanation regarding it. The Guaigulir people—those who occupy the 'winggu' or outer margin of the shade—are supposed to keep a strict watch for any game which may appear in sight, the approach of friends or enemies, or anything which may require vigilance in a native camp.

Each phratry, and consequently every section and every totemic group, contains men, women and children belonging to the Guaimundhun and Guaigulir bloods, with their respective shades. We have just seen that the Guaimundhun people are subdivided into nhurrai and wauguē, the butt and the middle shades, whilst the Guaigulir folk are intact in the winggu or distal shade. The additional regulations which are brought into the laws of intermarriage by the 'blood' and the 'shade' divisions are as follow:—

A Guaimundhun man of the butt shade marries a Guaigulir woman. He can also marry certain of the Guaimundhun women in the middle shade. And a Guaimundhun man of the middle shade marries a Guaigulir woman, and certain of the Guaimundhuns of the butt shade. A Guaigulir man (who is always a winggu), can marry a Guaimundhun woman of the middle shade, and certain of the women of the butt shade. No man or woman can marry into his or her own personal shade; for example, a nhurrai cannot marry a nhurrai, nor a winggu a winggu.

We shall now deal with the descent of the progeny. It will of course be borne in mind that the phratries, sections and totems are the principal elements in the laws of marriage and descent, and that the castes of 'blood' and 'shade' are ramifications or extensions of them. The following table will exhibit the intermarriage and descent of the castes:—

Table No. II

Blood.	Father	Mother	Ofispring
Guaimundhun	Nhurrai	Winggu	Winggu
	Nhurrai	Waugué	Waugué
	Waugué	Winggu	Winggu
	Wangué	Nhurrai	Nhurrai
Guaigulir	Winggu	Wangué	Wangué
	Winggu	Nhurrai	Nhurrai

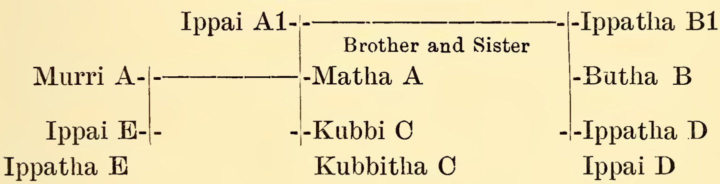
It will be observed that a Guaimundhun mother produces Guaimundhun children, who moreover take their mother's shade, whether nhurrai or waugué. A Guaigulir mother produces Guaigulir children, belonging to the winggu shade.

Going back to Table No. I. at an earlier page, we see that Ippai marries Kubbitha, who is his tabular or 'regular' spouse; but he has the right, in certain cases, of taking a Matha maiden instead, which may be distinguished as an irregular or 'alternative' marriage. He can also, subject to prescribed restrictions, have an Ippatha allotted to him as his wife, and such a marriage may be designated 'rare.'

Before a union can take place under the 'regular' law, or under the 'alternative' regulations, or under those which I have called 'rare,' the genealogy of the contracting parties is subjected to the test which I shall now endeavour to illustrate.

In examining Table No. I. it is found that the children of a brother and those of a sister belong to different phratries sections and totems. Let us assume that Ippai A1 bandicoot, marries Kubbitha iguana; then his sons and daughters will be Mūmbun and Mūmbunga—Murris and Mathas—iguanas. His sister, Ippatha B1, will marry, say, Kubbi, padamellin, and her children will be Ngurrawun and Ngurrawunga—Kumbos and Buthas—bandicoots. As the children take their mother's totem, the padamellin of her husband is not inherited by Ippatha's children.

Diagram of Genealogies.



Let us call the Murris and Mathas of the last example A, and the Kumbos and Buthas B. According to Table No. 1, Murri marries Butha, but a Murri A cannot marry a Butha B. She is *mia* to him, and he is *mia* to her. By continuing the genealogy for another generation, Murri's sister, Matha A, iguana, marries some other Kumbo and has a son, Kubbi C. Butha B, bandicoot, marries another Murri, and has a daughter, Ippatha D. Then Kubbi C can marry Ippatha D, and by an interchange of sisters, Ippai D can marry Kubbitha C. He is *mumma* to her and she to him. They are what we call second cousins, being a brother's daughter's child and a sister's daughter's child. If we had taken a brother's son's child and a sister's son's child, the result would have been the same. Such a marriage is 'regular' or 'direct,' as in Table No. I., and could not be disturbed by the totemic regulations, because the parties could not possibly belong to the same totem.

Instead of tracing the descent through Ippai's daughter, Matha A, as above, let us suppose that Ippai's son, Murri A, has married some strange Butha and produced a son, Ippai E, then such a son could marry Ippatha D of the last paragraph. This would be a brother's son's child marrying a sister's daughter's child; or a brother's daughter's child marrying a sister's son's child. This constitutes the 'rare' marriage spoken of in a previous page. In this case it would be possible, in certain circumstances, for the totems of the parties to be the same, and therefore the union would not be sanctioned.

Ippai's grandson, Ippai E, has still another source of getting a wife. Ippai's maternal uncle, Kumbo, has a daughter Kubbitha, who marries, and produces Matha F, (not shown on diagram). Then Ippai E can marry Matha F. The brother of Matha F could in like manner marry the sister of Ippai E. That is, a man's grandchild marries his uncle's grandchild. This is what I have called the 'alternative' marriage; and like the first, it is free from totemic interference.

A wife for Kubbi C could also be found by following the descent of his mother's mother's relatives, or his mother's father's relatives, or his father's mother's relatives, in an analogous manner. Again, Kubbi C could marry a Matha of the proper lineage. In other words, a man of any given division can marry into one or other of the three remaining sections, and also into his own.

In the above examples I have traced the genealogy through the grandfather, Ippai A1, down to Kubbi C, and have shown the marriages of his offspring with that of his sister Ippatha B1. But if we go over to the other side of the diagram, and run Ippai D back to his grandmother, Ippatha B1, it becomes evident that Ippai D marries his mother's mother's brother's daughter's daughter, Kubbitha C, for the 'direct' alliance; and he mates with his mother's mother's brother's son's daughter, Ippatha E, for the 'rare' marriage. The proper husband for any given woman is ascertained in the same manner, and need not be further exemplified.

In studying the foregoing rules and the diagram, it will be manifest that any individual's pedigree, when followed back to the grand parents, is subject to several variations. We can either trace a man back, (1) to his father's father; (2) to his father's mother; (3) to his mother's father; or, (4) to his mother's mother. From that point the descent is followed out as in the examples given above. It is for the elders of the tribe to settle what particular genealogy will be adopted when choosing a husband or wife for any given person. Previous family marriages and a number of other matters are considered in arranging this point. Although polygamy is practised, a man is not allowed a wife from each of the four lines of descent. If more than one wife is allotted, they must belong to the same lineage as the first, if available.

The rules of intermarriage and descent illustrated in the preceding six paragraphs, were briefly outlined by me in 1900, when treating the Kamilaroi laws, in which I showed that a man marries the daughter of his father's father's sister's son.[1]

It has not been thought necessary to encumber the foregoing examples with the 'blood' and the 'shade' distinc-

[1] "Marriage and Descent among the Australian Aborigines," Journ. Roy. Soc. N.S. Wales, Vol. xxxiv., page 126.

tions, which are peristent in them all, and must be taken into account in arranging a marriage. There are also regulations depending upon the totems of the affianced parties, and upon whether they are the elder or younger members of the family. The uncles of the parties are, in all cases, among the principal personages in conducting the betrothals.

Sometimes a man or woman belonging to a distant tribe, where the phratries and sections have different names, will come and settle among the Ngeumba people. In such a case a conjugal mate would be found by means of the totemic, blood, and shade records of the stranger.

Sociology of the Kamilaroi Tribe.

The Kamilaroi territory may be approximately described as extending from Jerry's Plains on the Hunter River as far as Walgett and Mungindi on the Barwon, taking in the greater part of the basins of the Namoi and Gwydir rivers. They are divided into four sections which have the same names as those of the Ngeumba, but the names of the phratries are Kuppathin and Dhilbai, with their feminine equivalents Kuppathingŭn and Dhilbaigŭn, as shown in the following table. Kuppathin is equal to the Ngeumba Ngurrawun and Dhilbai equals Mūmbun.

Phratry	Father	Mother	Son	Daughter
Kuppathin	Ippai	Kubbitha	Murri	Matha
	Kumbo	Matha	Kubbi	Kubbitha
Dhilbai	Kubbi	Ippatha	Kumbo	Butha
	Murri	Butha	Ippai	Ippatha

All that has been said in preceding pages of this article respecting the Ngeumba subdivisions into 'shade' and 'blood' castes, totems, 'alternative' and 'rare' marriages, apply to the Kamilaroi, and will not be repeated.

Rev. Wm. Ridley, B.A., was the first to report the names of the four sections of the Kamilaroi, with their rules of intermarriage and the descent of the progeny. Mr. Geo. Bridgman, Superintendent of Aboriginal Stations at Mackay in Queensland reported to Mr. R. B. Smyth, as follows:— "All blacks are divided into two classes, irrespective of tribe or locality. These are Youngaroo and Wootaroo. The Youngaroo are subdivided into Gurgila and Bunbia, and Wootaroo into Coobaroo and Woongoo. . . . Children belong to the mother's primary division, but to the other subdivision. . . The blacks divide everything into these classes—alligators, kangaroos, sun, moon, the constellations, trees, and plants. . . . An intelligent native who has been living with the Kamilaroi people, says the Kamilaroi system is the same as that here in Mackay."[1]

Since the time of Mr. Ridley and Mr. Bridgman down to the present day, nothing important has been added to our knowledge of the Kamilaroi organisation. Neither of the gentlemen mentioned, nor any writers who have copied them, have attempted to supply the minute details of its structure, which are now published by me for the *first time.* In short the 'blood' and 'shade' subdivisions have never been even mentioned by any writer until now. The feminine forms of the phratry names are also new.

The initiation ceremonies of the Kamilaroi had been, if possible, even still more neglected until my description of the Bora appeared.[2] Little or nothing was known of the speech of this tribe until the publication of my grammar and vocabulary last year.[3] Until described in the present treatise, nothing at all has ever been written in regard to the ceremonies connected with scarring the bodies of the

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[1] "Aborigines of Victoria," by R. B. Smyth, (Melbourne 1878), Vol. I., p. 91.

[2] "The Bora or Initiation Ceremonies of the Kamilaroi Tribes," Proc. Roy. Soc. Victoria, Vol. IX., (N.S.) pp. 137 – 173.

[3] "Languages of the Kamilaroi, etc.," Journ. Anthrop. Inst., Vol. XXXIII. pp. 259 – 283. See also my "Kawambarai Language," a dialect of the Kamilaroi, Journ. Roy. Soc. N.S. Wales, Vol. XXXVI., pp. 145 – 147.

men and women. A secret language in use among the initiated men of the Kamilaroi tribe was reported by me, with vocabulary in 1902.[1]

Sociology of the Thurrawal and kindred Tribes.

In an article contributed to this Society in 1900,[2] and in other publications, I have described the social organisation, with the laws of intermarriage and descent, among all the native tribes inhabiting the south-east coast of New South Wales from the Hawkesbury River to Cape Howe. The same organisation extends onward among the tribes throughout the eastern half of Victoria.

In later pages of the present work I am supplying additional information on the social structure of other communities, under the separate heads of 'Sociology of the tribes of Western Victoria,' and 'Sociology of the tribes of Eastern Victoria,' to which the reader is referred.

Among many of the tribes in the Northern Territory of South Australia, in the north-west corner of Queensland, and in the northern portion of Western Australia, there are eight intermarrying divisions. Although the tribes in the respective regions mentioned do not fall within the scope of the present treatise, yet I desire to state, in passing, that there is no great difference between their organization and that of the Ngeumba, Kamilaroi, or Thurrawal, as well as that of the tribes of Western and Eastern Victoria. In all of them the selection of a wife or husband is determined through the grand parents of the parties to the matrimonial alliance. In some tribes the totem is perpetuated through the men, whilst in others it descends through the women.

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[1] Journ. Roy. Soc. N.S.Wales, Vol. xxxvi., pp. 159 - 160.

[2] Journ. Roy. Soc. N.S. Wales, Vol. xxxiv., pp. 263, 264.

Early in the year 1898,[1] I reported the eight sections of the Wom-by'-a tribe, in the Northern Territory, with their laws of marriage and succession. Again, in 1900, in dealing with the same eight sections, I stated that "a man marries the daughter of his father's father's sister's son, or the daughter of his mother's mother's brother's daughter."[2] The direct, alternative and rare laws of marriage prevalent in the Wombya and kindred tribes, were shown to follow the same rules as in the Kamilaroi and Parnkalla communities. On that occasion (1900), I also stated: "owing to the different methods of subdividing the tribes, the details of the rules regulating intermarriage and descent, are somewhat varied in each system, but the fundamental principles are the same in them all."[3]

CHILDBIRTH.

While obtaining the particulars given under this heading, I was assisted by the wife of a station manager in the north-western districts of New South Wales. This lady had been a trained nurse and had witnessed several cases of accouchement among the black women on the station where she resided.

When a woman approaches the period of labour, she is taken charge of by one or two old female relatives, but not by her own mother, and is conducted to the locality which has been assigned as the place where that particular woman must give birth to her offspring. Certain spots are fixed by the elders for women to repair to in such cases, and when the expected event draws near, the woman's tribe proceeds to the neighbourhood of that place and

[1] "Divisions of Australian Tribes," Proc. Amer. Philos. Soc. Philadelphia, Vol. xxxvii., pp. 151 – 154.

[2] "Marriage and Descent among the Australian Aborigines," Journ. Roy. Soc. N. S. Wales, Vol. xxxiv., p. 126. See also my "Ethnological Notes on the Aboriginal Tribes of the Northern Territory," Queensland Geographical Journal, (1901) Vol. xvi., pp, 69 – 90.

[3] *Op. cit.*, p. 121.

camps there. When the time arrives, the woman who has charge of the patient presses her hands along the back from above downwards, and continues this treatment until the child is born. The umbilical cord is cut quite six inches away from the infant's belly, the severance being effected with a sharp flint or other suitable stone. It is then bound tightly round and round with string made from human hair or the fur of animals. The umbilicus, being about six inches in length as above stated, is doubled back into a circular loop, the cut end being then tied to the point of origin at the navel. This loop of the umbilicus is laid flat on the child's belly, extending upwards towards the chest. A string, made of animal fur, is then passed through the loop, and is carried up around the nape of the child's neck and back again, when it is knotted, thus forming a sort of sling or suspender for the umbilicus, to keep it in position. The excised portion of the umbilical cord which protrudes from the mother is now placed in the mouth of the infant, into which the nurse squeezes as much blood along the tube of the cord, as the child can swallow without being sick. An infant is never fed from the breast for about three days after its birth—the dose of blood which it drinks in the way described sufficing for that period. The natives say that if a baby swallow plenty of blood from the umbilical cord it will not require so much food in later times. To get away the afterbirth, the patient sits on her heels, with her knees bent and her hands behind her back, the fingers touching the ground. The old women present then stroke the belly and back, commencing above the abdomen and stroking downwards. The patient assists these manœuvres by moving her body and straining. As soon as the afterbirth is discharged, it is burnt in a fire or buried in the ground. The attendant places the newly born infant in warm sand or ashes to get it dry and clean, this treatment serving the purpose of a bath. The child is subsequently carefully greased all over with animal fat, but has no clothing of any kind. The mother is generally able to get about in a day or two, when the infant is placed in a kind of basket or girdle made of paper-bark, and is carried on its mother's hip. Certain foods are forbidden to women during portions of their pregnancy and lactation.

Infanticide is common, and if twins be born, one of them is almost invariably killed. The children of young unmarried girls are usually killed a few months after they are born, by the old women filling their mouths and nostrils with sand. They are opened along the belly and the intestines removed, and the leaves of a kind of Acacia are put inside the body, after which they are cooked like any other animal, and are eaten by the old men. A man cannot go near the spot where a child has been born. This prohibition is called *guruan*.

The Ngeumba Language.

The Ngēumba speaking people formerly occupied the country from Brewarrina on the Darling River southerly up the Bogan almost to Nyngan. They stretched thence westerly beyond Cobar and Byrock, including the upper portions of Mulga Creek and surrounding country.

The Wailwan tribe occupies the country to the north-east of the Ngēumba, whilst the Wongaibon people adjoin them on the south. The languages of both the tribes referred to have already been published by me.[1]

Nouns.

Nouns are subject to inflection for number, gender and case.

Number.—There are three numbers, the singular, dual and plural. Womboin, a kangaroo; womboinbula, a couple of kangaroos; womboingirba, several kangaroos.

[1] "Le Langage Wailwan," Bull. Soc. d'Anthrop. de Paris, tome IV., 5 Serie, pp. 69-81. "The Wongaibon Language," Journ. Roy. Soc. N. S. Wales, Vol. XXXVI., pp. 147-154.

Gender.—For the human family this is expressed by different words, as, maie, a man; winnar, a woman. For animals the gender is indicated by using a word signifying 'male' and 'female,' as, mundaiwa, a male; guninger, a female. These words follow the name of the animal spoken of, and are declined like other adjectives.

Case.—The principal cases are the nominative, causative, genitive, instrumental, accusative, dative, and ablative.

There are two forms of the nominative. When the action is described by an intransitive verb, as, winnar yuwunna, the woman lies (on the ground), the noun is without flexion. But when a transitive verb is used, the noun takes a causative suffix, as, murrawandu wirmedhi, a kangaroo scratched me.

Genitive—Murrawanggu dhun, a kangaroo's tail. Maingu bulga, a man's boomerang.

Every object or article over which ownership can be exercised is subject to inflection for person and number, as: bulgadhi, my boomerang; bulganu, thy boomerang; bulgalugu, his boomerang, and so on through the dual and plural, which also contain 'inclusive' and 'exclusive' forms in the first person.

If a couple or several articles be claimed, an infix is inserted between the root of the noun and the possessive affix, as: bulgambuladhi, my two boomerangs; bulgagirbadhi, my several boomerangs.

Instrumental—When an instrument is the remote object of a transitive verb, it takes the same affix as the second nominative which I have called the causative.

Ablative—Ngurandidhi, from my camp.

The dative is the same as the first nominative.

Adjectives.

Adjectives follow the nouns which they qualify, and are subject to similar declensions for number and case, examples of which are not considered necessary.

Comparison is made by positive assertions, as: bamir nginna—bumba ngunnala, this is long—that is short.

When an adjective is used as a predicate, it can, by adding the necessary suffixes, be converted into a verb, and it then follows all the forms of conjugation of that part of speech. Yuttadhu, I am good; yuttagēdhu, or more euphoniously, yuttadhugē, I was good. Yuttalagadhu, I shall be good, and so on.

Pronouns.

Pronouns have number, person and case, and contain two forms in the first person of the dual and plural, one of which includes the person addressed, and the other excludes him. I was the first author to report, in any of the Australian States, these important grammatical forms. The following is a list of the nominative, possessive and objective pronouns in the singular:

1st Person	I, ngadhu	My, ngaddhi	Me, dhi
2nd ,,	Thou, ngindu	Mine, nginyu	Thee, nu
3rd ,,	He, ngillu	His, ngigulu	Him, lugu

There are also variations of the objective case of pronouns, meaning 'towards me,' 'away from me,' 'with me,' and so on.

Interrogatives—Ngandi, who? Nganngundawa, whom for? Nganguanni, whom belonging to? Widdyuwandu ngulagai, what is the matter with thee? Minya, what? Minyanggo, what for? Minyunguri, what from? Minyunggalmai, how many?

Demonstratives—Nginna, this. Nginnilla, there. Ngunna, that. Ngunnala, that, (farther). Ngunnaingulu, that, (farther still). Ngunnigal, that (yonder). Ngunnigal mannha, that far away. Nginnagē, that, (is the thing I meant). Nginnillana, this is the very one. Nginyalanga, that (is the one which was acted upon). Ngillu, this (did it). Ngullu, that (did it). Ngunnalabu, that (may be it). Most of these demonstratives can be declined for dual and plural.

Verbs.

Verbs have number, person, tense and mood. There are inclusive and exclusive forms in the first person of the dual and plural. A contraction of the pronoun is added to the root of the verb to show number and person. The following is a short conjugation of the principal parts of the aboriginal verb, Bumulli, to strike or beat :

Indicative Mood—Present Tense.

Singular	1st Person	I beat,	Bumurradhu
	2nd ,,	Thou beatest,	Bumurrandu
	3rd ,,	He beats,	Bumurralu
Dual	1st Per.	We incl., beat,	Bumurrali
		We excl., beat,	Bumurralina
	2nd ,,	You beat,	Bumurrandubla
	3rd ,,	They beat,	Bumurralainbula
Plural	1st Per.	We incl., beat,	Bumurrane
		We excl., beat,	Bumurraninna
	2nd ,,	You beat,	Bumurrandugal
	3sd ,,	They beat,	Bumurrawullugal

In the past and future tenses of verbs there are variable terminations to indicate that the act described was done in the immediate, recent, or remote past; or that the act will be performed in the proximate, or more or less distant future; that there was, or shall be, a repetition or continuance of the action, and other modifications of the verbal suffixes. These terminations remain the same for all the persons of the singular, dual and plural, so that it will be sufficient to give an example in the first person of the singular number, in the past and future tenses:

Past Tense.

Singular 1st Per.	I beat, indefinite,	Bumaidyu
	I beat this morning,	Bumulngurriyedhu
	I beat last night,	Bumulngubbinyedhu
	I beat all day,	Bumulbenadhu
	I beat again,	Bumulallidyadhu

Future Tense.

Singular 1st Per.	I shall beat, indefinite,	Bumulagadhu
	I shall beat in the morning,	Bumulngurriagadhu
	I shall beat all day,	Bumulbenagadhu
	I shall beat in the evening,	Bumulngaiagadhu
	I shall beat in the night,	Bumulngubbiagadhu

Imperative.

Beat, Buma. Beat not, Kurria buma.

Conditional.

Perhaps I shall beat, Yama bumulagadhu.

Reflexive Mood.

I am beating myself, Bumadyillingedhu
I beat myself all day, Bumadyillibenadhu
I shall beat myself, Bumadyilliagadhu

Reciprocal Mood.

This modification of the verb is applied to those cases where two or many persons reciprocally beat each other, and is consequently limited to the dual and plural:

Dual We, excl., are beating each other, Bumullinnalina
Plural We, excl., are beating each other, Bumullinnaninna

Adverbs.

Following are a few of the more commonly used adverbs which are generally placed after the verb: Yes, ngaua. No, wongai. Now, dhallun. Yesterday, kŭmbirrabutthe. To-morrow, kumbirrabutthalagu. To-day, dhallun. Presently (future), dhallumbutthalagu. Just now (past), dhullumbutthe. Some time ago, gumbirranabutthe. Long ago, murradhal.

Some adverbs admit of inflexion for number, person and tense, as: Where am I, wundhalawadhu. Where art thou, wūndhalawandu. Where is he, wundhalaguana. Where are we, dual inclusive, wundhalawali. Where are you, dual, wundhalawandubla. Where are you, plural, wundhalawandugal.

When, wittyubara. Where, wundhala. How, widdyuwa. Perhaps, ngakillaga. I do not think so, wongaia. Certainly or certain, kurrimunkan. How (was it done), widdyumindumi.

Prepositions.

In front, murrubil. Behind, kukkirbil. Inside, kurugunna. Round at the back (of something), ngunnungurra. Between, bauwungga. At the side (of anything), ngunnalangurra. Around (a tree, rock, etc.), ngunniguliai. Round there, ngunnibingura. Up there, ngunnianya. Down there, ngunnidyar. Outside, wāgiga. Around (a person, as a belt), guranggadha. This side, nginnangur. The other side, ngunnaingur. Through, guruga. Over or across, burabiddya. On the top, wampana. Underneath, ngunnidyingura. Up the river or stream, wambagirri. Down the river, dhunggagulli.

Some prepositions can be inflected for number and person, as: kukkiridhi, behind me; kukkirrinu, behind thee; kukkirrilu, behind him; and so on through the remaining numbers and persons.

Numerals.

One, mukku. Two, bulagar.

NGEUMBA VOCABULARY.

The vocabulary herewith contains about 460 words of the Ngēumba language, collected by myself in the camps of the aborigines. The words of a similar kind are grouped under separate headings, as, Family Terms, the Human Body, and so forth. It is hoped that this classification will be more convenient for reference than if arranged in alphabetic sequence. In all grammars and vocabularies minor inaccuracies are of course inevitable—they will creep in despite the greatest care.

Family Terms.

A man,	maii
Husband,	mamambon
Old man,	bukaianggai
Very old man,	kukun
Clever man,	wirringin
Boy,	butthudhul
Boy just walking,	warru
Uninitiated youth,	iramuru
Youth after tooth out,	minbaddyurai
Initiate,	wallui
Elder brother,	murrumbai
Second brother,	bauuma
Younger brother,	kakirgilli
Elder sister,	thathi
Younger sister,	gidyurai
A woman,	winnar
Old woman,	kukaianggai
Woman during menses,	mŭrpi
Wife,	buttong
Small girl,	bulkaligu
Young woman,	marrianda
First menses,	goañbōn
Maid at puberty,	wirringga
Father,	papa
Father's mother,	dhurbaga
Mother,	gūnni
Mother's mother,	muki
A small child,	warrudhul
All the people, men, women, and children	maingirba
All the initiates,	wallugirba
All uninitiated,	irramurrungirba
All the little girls,	bŭlkalligŭlka

The Human Body.

Head,	bulla
Top of head,	kumbuda
Forehead,	ngulu
Hair of head,	bullandhur
Beard,	yerrai
Eye,	mil
Nose,	murudha
Back of neck,	wuru
Throat,	nuki
Windpipe,	nugal-nugal
Ear,	wuttha
Knee-cap,	pundai-kiwai
Knee,	pūndai
Shin,	biyu
Foot,	dhinua
Ankle,	burrunggal
Heel,	wurta
Sinews,	kaia
Heart,	gi
Liver,	guralu
Blood,	go-ai
Fat,	gutthal

Cheeks,	thuggal	Bone,	ngimbi
Mouth,	ngurndal	Foreskin,	ngulumbilla
Lips,	willi	Penis,	mundai
Teeth,	wirra	Glans penis,	muru-un or nyirin
Tongue,	thullai	Testicles,	būrru
Breast, female,	ngammu	Pubic hair,	o-i
Navel,	gindyer	Sexual desire,	giridyai
Afterbirth,	ngalgir	Copulation,	dhani [murra
Belly,	purpibirti	Masturbation,	kuppa-kuppa-
Back,	mukkulla	Sodomy,	ngindyi-dhani
Fore arm,	pi	Noise made in copulating,	mintya
Elbow,	ngūnnugu	Semen,	butthe or bai
Armpit,	gilkin	Emission,	kalkinyi
Shoulder,	kunna	Vagina,	munai
Shoulder-blade,	pikkilgirra	Labia major,	willir
Hand,	murra	Clitoris,	wukkur
Finger-nail,	yulu	Nymphæ,	ninti
Loins,	gumbul	Anus,	ngi
Hip,	milla	Excrement,	guna
Thigh,	dhurrakur	Urine,	kil
Buttocks,	mūrta	Venereal,	mundai-būkkin

Inanimate Nature.

Sun,	thunni	Night,	ngau-ap-a
Moon,	giwir	Morning,	ngauo-guramba
Stars,	girala	Evening,	ngauo-ngauapa
Orion's belt,	thūrkallunggalka	A splinter,	dhurinyi
Pleiades,	mullumullurga	Hill,	dhirrama
Sky,	gunnunggulla	Sand-hill,	gumbogūn
Light clouds,	thurai	Grass,	gurun
Storm clouds,	gūnda	Leaves of trees,	gira
Rain,	yuru	Bird's nest,	mutthe
Rainbow,	yulubirki	Egg,	kuppugo
Dew,	dhimbur	Honey,	warrungunna
Fog,	pupilla	A tell-tale,	wurrimurra
Frost,	dhukkur	Grub in box tree,	butthu-gurnidya

Hail,	wirranggurra
Water,	kulli
Earth, ground,	dhukkun
Ground sun-heated,	marawurra
Mud,	windya
Stone,	kurrul
Sand,	gurrawir
Light,	ngullun
Darkness,	ngauo
Heat,	wiwi
Cold,	gunundai
Camp,	ngura
Bark hut,	kukur-ngunnu
West wind,	gulyi-yeto
East wind,	guru-annha
Whirlwind,	būrumuga'
Dust storm,	miar
Mirage,	kullu-kulli
Hole,	munilla
Pipe-clay,	munnha
Red ochre,	kūppŭr
Corroboree,	dhŭnkurrumunna
Fire,	wi
Smoke,	putthu
Flesh food,	bunna
Vegetable food,	kakullu
Thirst,	bungkunnu
Day,	dhirranba
Grub in gum tree,	bityulla
Grub in ground,	birka
Bloom on trees,	gurawin
Pathway,	dhinnakkal
Shadow,	gual
Tail of animal,	thun
Summer,	tharrialpa
Winter,	tukkar
Echo,	yulpur
Emu feathers,	gurungunna
Feathers generally,	bubil
Fur of opossum etc.,	mu-a
Spines of porcupine,	thikkar
Scales of fish,	wallugar
Skin of animal,	yulai or bauar
Skin shed by snake, iguana, lizard etc.	ginggai
Shell of turtle or mussel,	bukkai
Edge of water,	bukki
Charcoal,	guri
Ashes,	nummur
Live coal,	gurnuñ
Firestick,	wirunggunni
Trumpeting of emus,	muppamingga
Top-knot feathers, of any bird	thikkūn

Animals—Mammals.

Dog,	mirri
Opossum,	guragi
Kangaroo-rat,	bulpu
Native cat,	būbbilla
Bandicoot,	guru
Small kangaroo-rat,	gūnnhur
Water-rat,	pikkun
Bat,	butthaiballa
Porcupine,	thikkarpilla
Kangaroo, grey,	wamboiñ
Kangaroo, red,	murrawē

Birds.

Birds collectively,	thibbi	Top-knot parrot,	ko-ri-ē
Laughing jackass,	kukuburra	Nankeen,	thŭrkun
Curlew,	guribun	Musk duck,	wukkarbutta
Crow,	wakan	White crane,	būllun
Mallee-hen,	yūnggai	White-necked crane,	murku
Bustard,	gŭmbal	Grey crane,	barra
Native companion,	buralga	Small night jar,	dhi-ell
Pelican,	birraia	Swift,	pil-luru
Swan,	dhundhu	Bronze-wing pigeon,	yammar
Wood-duck,	gunāru	Rosella parrot,	dhenkutthenku
Quail,	buludhur	Brown hawk,	burrawar
Eaglehawk,	mŭl′-le-an	Larger kingfisher,	birrimbirru
Emu,	nguri	Smaller kingfisher,	dhutul
Young emu,	ung-ga	Peewee,	gulititi
Black and white magpie,	kāruawar′	Plover,	bildadhirradhirra
		Weejuggler,	būnyan
Black magpie,	wi-u	Fish-hawk,	pipiddya
Black duck,	būrangun	Galah parrot,	gillā
Mopoke,	thūrkū	Bowerbird,	ngurambula
Dove,	kōpatha		

Reptiles.

Death adder,	burnu	Brown snake,	bullabului
Shingle-back lizard,	kullu	Black snake,	ngundaba
Ground iguana.	thuli	Tiger snake,	wurrala
Tree iguana,	gugar	Jew lizard,	kanni
Sleepy lizard,	goarri	Whip snake,	dhuru
Carpet snake,	yeppa	Turtle,	wurrumba

Invertebrates.

Locust,	wirai	Centipede,	gilga
Blow-fly,	nukui	Jumper ant,	bungai
Louse,	kuppul	Maggot,	thurrabut
Nit of louse,	dhinnil	Grasshopper,	murru
House fly,	burimul	Spider,	murramurraga
Sugar ant,	bippainbilla	Mosquito,	gam′ugin

Common ant,	wunggai	Scorpion,	ganigandhera
Butterfly,	bullabullā	Greenhead ant,	buddyar
Bulldog ant,	burū-ingga	Mussel,	bukkadyerra

Trees and Plants.

Any tree,	gugur	Gum of sandalwood,	thukkabella
Bark of any tree,	munggar	Whitewood,	balkan
Squeaking tree,	muppuran	Beefwood,	mumbo
Wild willow,	wilgar	Leopard wood,	ngarkarri
Myall,	buri	Kurrajong,	yumma
Wattle,	billibar	Hop bush,	gidya
Pine tree,	kurrabar	Gidyea,	karriwan
Oak,	billār	Wild orange,	mukil
Red gum tree,	gŭngun	Quandong tree,	kwanda
Grey box,	girrāl	Currant bush,	warriar
Sandalwood,	kuttawu	Tar bush,	thurramurra

Weapons, Utensils, etc.

Stone tomahawk,	wukkar	White brow-band,	kambai
Handle of ditto,	birra	Red brow-band,	ngulunggira
Stone chisel,	kainda	Waist-belt,	gular
Wooden vessel,	gūlkur	Nose-peg,	murudhagi-ūr
Jagged spear,	mura	Girl's apron,	kumil
Yamstick,	kunnai	Whet-stone,	kiwai
Reed spear,	thirril	Stone knife,	irrangin
Spear-lever,	wammur	Lower millstone,	yauai
Spear shield,	mŭrka	Upper millstone,	murra
Waddy shield,	muttha-muttha	Skin cloak,	burta
Fighting club,	bundi	Bone needle,	ki-ur
Hunting club,	kuttyura	Sinews for sewing with,	kaia
Boomerang, returning,	bulka	Net for catching emus,	mukir
Fighting boomerang,	wukkara	Propstick for net,	bidyilli
Old man's bag,	bun'-ko	String of nets,	mau-irr
Woman's bag,	kulai	Lower string of net,	kuruguru
Large bag,	bukitta	Vessel for drinking with,	kuttyŭl

Adjectives.

Alive,	moan	Strong,	wallan
Dead,	ballune	Afraid,	giandunna

Large,	buppir	Right,	yetta
Small,	butthu	Wrong,	wumma
Long or high,	bamir	Straight,	bintul
Short or low,	bumba	Crooked,	nirra-nirrai
Good,	yettama	Tired,	yellamunnha
Bad,	wurrai	Deep,	ngurambul
Wide,	pikkaba	Shallow,	gunnai
Narrow,	ngambur	Blunt,	muku
Jealous,	guringtatai	Sharp,	wirrandul
Dry,	bun-kai	Fat,	muruanda
Wet,	muttha	Lean,	ngimbi-ngimbi
Lame,	kutthiburra	Hot,	wi-wi
Thirsty,	bunkunna	Cold,	gunundai
Red,	girrabarai	Angry,	kulkai
White,	bunggaba	Sleepy,	muka
Black,	bullui	Glad,	kaia
Mad or crazy,	bullawarrai	Greedy,	kai-ili-dyai
Full,	wirrambu	Sick,	giranggira
Empty,	bintyi	Stinking,	buka
Half-full, some,	gulangai	Pregnant,	ngurkambōn
Quick,	burra-burrai	Sweet,	nguttha-ngutthai
Slow,	yarur	Hard,	wallan
Blind,	muki	Soft,	thalpai
Deaf,	wuttha-muku		

Verbs.

Die,	ballune	Stare at,	mukamirra
Eat,	dhai	Cut off,	kukka
Drink,	ngurruni	Hang up,	wambainma
Snatch or grab,	thunmanyi	Put into,	guruga
Sleep,	muka	Pull out of,	thuranma
Stand,	warrana	Pull down,	wirrima
Sit,	winya	Shut,	nunpani
Touch,	ngukkunma	Open,	kunkaima
Hold,	mina	Cough,	karra
Twist,	warwainma	Sneeze,	thikkartuna

Spill,	kalkinya
Pinch,	nimma
Pull,	wuru-unma
Carry,	wamba
Grow,	yurunnha
Startle,	dhullagurra
Lie (animate thing, as a man),	yuwunna
Lie (inanimate thing, as a boomerang),	gurinya
Crawl, as a child,	karanna
Put down,	gurimanni
Pick up,	mamanni
Lift (if heavy),	girramanni
Shake, as a tree,	dhillama
Talk,	ngeara
Shout,	gulaga or gulagunni
To call anyone,	ngealugu
Walk,	yananna
Run,	bippuna
Bring,	gaka
Take,	ngullupi
Make,	mulla
Break,	gumma
Strike or beat,	bumulli
Wound,	mundhunmai
Arise,	barraka
Fall down,	thuwatta
See,	ngaga
Look,	ngani
Hear,	winnungga
Give,	nguka
Sing,	wukkaima
Weep,	yūngunna
Cook,	wirrunggurri
Cough up anything, as from the throat or lungs,	yandyarra-murra
Shiver as with cold,	bulpūrrinya
Pierce, with a weapon,	dhura
Hurt,	girrimpathi'
Bend,	nirraibunma
Make a hole,	bungaga
Sound or test,	thurabia
Drawn,	nŭnkanni
Split,	wirpadhia
Chop,	bindhea
Send,	nginnakaka
Shine,	dhallarbirra
Suck as a child,	ngammuna
Suck a wound,	wuruandirra
Suck through a reed or the like	thurtirra
Swim,	yawinya
Bathe,	gurungunna
Search for,	gurrandirra
Spit,	dhumbia
Spit or hiss towards an enemy or game as a spell	wi-ung-kurra
Smell,	buttha
Throw forcibly,	gurarba
Pitch or heave,	wannaga
Roast,	wirrungga
Whistle,	wilpadha
Pretend,	warrimirra
Kiss,	putharbattha
Vomit,	kapi
Dance,	wakuttha
Corroboree,	dhŭnkurrumurra
Dive,	ngupungginya

Steal,	murnumulli	Sting,	dhuni
Request,	ngukatti	Hunt on ground,	munnabiddya
Blow with breath,	bumbea	Hunt in trees,	wulkagirri
Climb,	wulkagirri	Go,	ngullubi
Conceal,	nunbimulli	Come,	dhaiana
Jump,	barāgirri	Burn,	bŭnga
Laugh,	gindadha	Bite,	kuttha
Scratch,	birma	Fly, as a bird,	burrana
Tear with claw,	kappia	To trim timber by chipping	bukkibiddha
Forget,	nunbanna		

Language of the Thangatti Tribe.

The remnants of the aboriginal tribes who speak the Than'-gat-ti language are located chiefly in the valley of the Macleay River, on the north-east coast of New South Wales. This language is a highly interesting one, both on account of its euphonic and flowing intonation, and also because it possesses strong affinities to the speech of the great tribes of the Wirraidyuri and Kamilaroi, who occupy extensive regions in Central New South Wales. The social organisation of these people, and their ceremonies of initiation, have been described by me elsewhere.[1]

Adjoining the Thangatti on the north is the Kūmbainggeri tribe, a grammar and vocabulary of whose language was contributed by me to the Anthropological Society at Vienna.[2]

Nouns.

Nouns have number, gender and case.

Number.—Nouns have the singular, dual and plural numbers, as in the following example:—Womboiñ, a kangaroo; wamboiñbutōbu, a couple of kangaroos; womboiñdyillong, several kangaroos.

[1] Queensland Geographical Journal, Vol. xvi., pp. 35 – 41. Proc. Amer. Philos. Soc., Vol. xxxvii., pp. 54 – 73, with map of N. S. Wales.

[2] "Das Kūmbainggeri, eine Eingeborenensprache von N. S. Wales," Mitteil. d. Anthrop. Gesellsch. in Wien, Bd. xxxiii., (1903), p. 321 – 328.

Gender.—In the human family sex is denoted by different words, as, guri, a man ; gulban, a woman ; guraman, a boy; thukalbang or muna, a girl ; dhulle, a child of either sex. Among animals, gender is distinguished by words meaning "male" and "female," placed after the name of the creature, as, wille yimbukai, a male opossum; wille nyukabang, a female opossum.

The principal cases are the nominative, causative, instrumental, genitive, accusative, dative and ablative.

Nominative.—This case merely names the subject, and is without flexion, as, mirri, a dog; burragan, a boomerang; yarre, a native bear. It is also used with an intransitive verb, as, guri nyinne, a man sits.

Causative.—When a transitive verb is used the noun takes a suffix, as, guri-nga burragan guru, a man a boomerang threw. Mirri-nga wille-nga baiin, a dog an opossum bit. Gulban-nga dhulle-nga bunyun, a woman a child beat (or hit).

Instrumental.—This case is the same as the causative, as, gulban-nga mirri bunyun gunni-nga, a woman beat a dog with a yamstick.

Genitive.—Guri-gudhun burragan, a man's boomerang. Gulban-gudhun gunni, a woman's yamstick.

Accusative.—Frequently there is an inflexion like the causative, as, Guri-nga yarre-nga bunyun, a man a bear hit. It is generally the same as the nominative when followed by the instrumental case, as illustrated above.

The dative and ablative cases also have distinguishing postfixes, as, nguragu yung, to the camp go.

Adjectives.

Adjectives are placed after the nouns they qualify, and are similarly declined for number and case. They are compared by making two positive statements, as, this is good —that is bad.

Pronouns.

There are two forms of first person of the dual and plural one in which the person or persons addressed are included with the speaker, and another in which they are exclusive of the speaker.

The following is a list of the pronouns in the nominative case :—

Singular	1st Person	I,	Ngaia
	2nd ,,	Thou,	Nginda
	3rd ,,	He,	Nong
Dual 1st Person		We, incl.,	Ngutti
		We, excl.,	Nguttiwalgu
Plural 1st Person		We, incl.,	Ngenang
		We, excl.,	Ngenawalgu

The genitive and accusative forms of the pronouns, in the singular number only, are exhibited in the following table :—

1st Person	Mine,	Dhalga	Me,	Ngŭnya
2nd ,,	Thine,	Nginnumbo	Thee,	Nginna
3rd ,,	His,	Nonningbo	Him,	Nonninyang

The dual and plural are omitted, for the purpose of saving space.

Interrogative pronouns.—Who, ngannung. Whose, ngannumbo. What, miang. What for, miangrai. How many, minnhan.

Demonstrative pronouns.—This or here, dying. That or there, ngāndha. Those two, ngandambural. Those, plural, ngandadyillong. The demonstratives are numerous and of various forms, frequently taking the place of pronouns of the third person, a circumstance which explains the great diversity of the third personal pronouns in all the numbers.

Verbs.

There is a difference in the termination of the verb for each tense. Any required person and number in each tense can be shown by using the necessary pronoun from the foregoing table.

An example of the conjugation of the singular number of a verb will be sufficient:—

Indicative Mood—Present Tense.

Singular	1st Person	I sit,	Ngaia nyinne
	2nd ,,	Thou sittest,	Nginda nyinne
	3rd ,,	He sits,	Nong nyinne

and so on through all the persons of the dual and plural.

Past Tense.

Singular 1st Person I sat, Ngaia nyinnimbin.

Future tense.

Singular 1st Person I will sit, Ngaia nyinniling

The imperative, conditional, reflexive, and reciprocal forms of the verb will be omitted for want of space. The adverbs, prepositions and interjections are also passed over for the same reason.

The numerals are, Wadhu, one; Buta-buta, two.

Including the Ngeumba and Thangatti grammars contained in this treatise, I have now illustrated, wholly or in part, the grammatical structure of fifty Australian dialects and languages. This vast amount of work has been rendered possible by the kindness of several learned Societies in Australia, Europe, and America, who promptly published the manuscript dealing with all these languages. It may be added that I still have in my note-books the grammars and vocabularies of several other native tongues, awaiting an opportunity for publication.

Thangatti Vocabulary.

About 200 of the words in most common use in the Thangatti language, are comprised in this vocabulary. I have thought that placing groups of words of the same character together under distinctive headings will prove more acceptable for reference than the common method of arranging the vocabulary alphabetically. Every word, both in the grammar and the vocabulary, has been carefully written down by me from the mouths of the aboriginal speakers, whilst visiting them in their own camps.

The Family.

Man,	guri	Woman,	gulban
Youth,	murranggil	Girl,	muna or thukalbang
Novitiate	murrawin	Mother,	nanggo
Small boy,	guraman	Child of either sex,	dhulle
Father,	bēanggo	Elder sister,	meanngun
Elder brother,	binghai	Younger sister,	weran
Younger brother,	kumbiri		

The Human Body.

Head,	bō	Hand,	yamma
Forehead,	ngutu	Shoulder,	mirka
Hair of head,	murra	Thigh,	dhurra
Beard,	yerran	Knee,	gutung
Eye-lash,	dhilmirra	Calf of leg,	gŭnde
Eye,	mi	Foot,	dhinna
Eye-brow,	yindirri	Blood,	gunggurra
Nose,	ngummurra	Fat,	bibban
Throat,	gugurra	Bone,	dhirral
Ear,	binnagun	Penis,	bunmai
Mouth,	gunnung	Testicles,	burru
Lips,	witting	Semen,	buttumbun
Teeth,	dhirra	Vulva,	binnhun
Breast (female)	ngubbung	Copulation,	yingmuddinge
Navel,	wiri-wiri	Urine,	gittuddhai
Belly,	bindyil	Anus,	miri
Tongue,	dhuttuñ	Excrement,	gunang
Back,	munu	Venereal,	wullan
Arm,	dhalburra		

Inanimate Nature.

Sun,	dhunnui	Camp,	ngura
Heat of sun,	guyung	Bough hut,	wurrui-gurrilu
Moon,	gittañ	Bark hut,	ngurē
Stars,	wupu	Smoke,	dhung
Thunder,	murungai	Fire,	wakai
Lightning,	mikki	Water,	ngaru
Rain,	gurrēa	Food (flesh)	buggara
Rainbow,	dhulaweng	Food (vegetable)	wigai
Fog,	munggul	Day,	burrañ
Frost,	murragan	Night,	ngunmurra
Snow,	yigan	Morning,	ngundagango
Ground,	burri	Evening,	bimmai
Stone,	dhurru	Hill,	būkul
Sand,	bunē	Flat rock,	wullara
Grass,	gurral	Leaves of trees,	wurui
Light of day,	burrañ	Bird's nest,	gŭndē
Darkness,	ngunmurra	Egg,	gŭlgang
Heat,	guyung	Honey,	gubbung
Cold,	gurring	Path,	yurŏn
Moonlight,	dhallai	Shadow of tree,	muttong
Shadow,	muttong	Tail of animal,	dun

Mammals.

Kangaroo,	wamboiñ	Flying fox,	bullawirri
Wallaroo,	yindibai	Porcupine,	nguggañ
Wombat,	nguliñ	Bandicoot,	gumbung
Native bear.	yarri	Native cat,	duluñ
Opossum,	wille	Rock wallaby,	burrē
Ringtail opossum,	bukurri	Flying squirrel,	bunggo
Padamelon,	munni	Dog,	mirri

Birds.

Emu,	nguruin	Peewee,	gulirti
Laughing-jackass,	gurruga	Plover,	butthurrañ
Lyre-bird,	murran	Swan,	ngubbudhar

Wild turkey,	ngumbullung	White cockatoo,	garebun
Scrub turkey,	ngurwiñ	Eaglehawk.	millambai

Fishes.

Mullet,	gauang	Silver eel,	gurrigung
Catfish,	willang	Crab,	burambañ
Large eel,	burro	Perch,	gubirra

Reptiles.

Carpet snake,	dhunggiñ	Brown snake,	bukkulla

Invertebrates.

Locust,	goarra	Nits of lice,	dimmin
Blow-fly,	burungun	Mosquito, large,	yira
Maggot,	diwin	Mosquito, small,	wura
Louse,	ṁunyo	Bee,	yilberi

Weapons.

Tomahawk,	bubbung	Spear-shield	gunmer
Koolamin,	gitti	Waddy-shield,	bungungga
Yamstick,	gunni	Club,	murre
Spear,	gummai	Boomerang,	bŭrgan
Spear-lever,	wommera	Fighting-hook,	gupin

Adjectives.

Large,	wutubang	Hungry,	giddhal
Small,	butyikunnung	Afraid,	murrar
Tall or long,	gurarbang	Tired,	watta
Low or short,	gulminbang	Angry,	gutui
Good,	murrung	Sleepy,	burungging
Bad,	nunnai	Greedy,	yittiñ
Quick,	gunnung	Stinking,	buka
Strong,	ngulluñ	Pregnant,	bindyaldyurai
Jealous,	ṅingiri		

Verbs.

Die,	buttinne	Look,	naia
Eat,	dhummone	Hear,	ngurrene
Stand,	wurrāne	Give,	nguya

Sit,	nginninne	Sing,	baiarelo
Talk,	goi-ite	Weep,	wuteling
Walk,	munnene	Steal,	wudunggumeling
Pitch,	gute	Request,	ngimbutte
Throw,	bimbea	Climb,	wandati
Whistle,	wenbutti	Conceal,	dhurundeling
Pretend,	gurambin	Jump,	bullaia
Break,	gūlbumma	Laugh,	gindene
Run,	gromatti	Suck,	ngumbene
Bring,	ngeta	Swim,	wirrungati
Take,	manda	Spit,	gute
Destroy,	gungulla	Smell,	bu-ye
Strike,	bungga	Vomit,	mutine
Arise,	beni	Dance,	bete
Fall down,	dokkane	Dive,	dhurakutte
Scratch,	ginninmatti	Sting,	dhŭngin
Cough,	gunyumputti	Put,	yūnda
Sneeze,	ginyilputti		

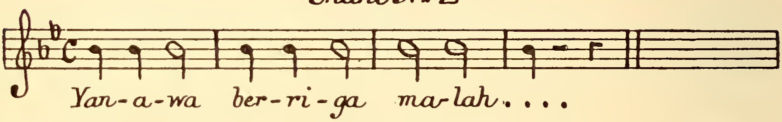
Pirrimbir, or Avenging Expedition.

Among the aborigines of the south-eastern districts of New South Wales, *Pirrimbir* is the name of a party organised for the purpose of revenge. As this custom has never been described, a short account of the manner of its execution is now given, prepared from details gathered by myself in the camps of the remnants of the native tribes.

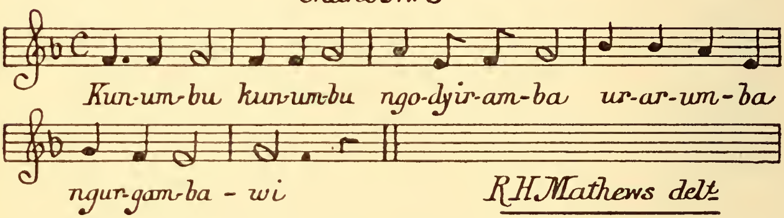
When a man is killed by open violence by any of the people of a hostile tribe, the relatives and fellow-tribesmen of the deceased hold a council at the *bambilli*, at which all the old headmen and warriors assemble, painted with pipe-clay on the forehead, breast and shoulders. Two of the eldest men then sing one of their tribal dirges, the words and music of which are as shown in "Chant No. 1" hereunder:—

Chant No. 1

Chant No. 2



Chant No. 3



When this song has been droned for some time, the warriors get small portions of hair which have been cut from the head of the deceased. Each man takes one of the fragments of hair and plaits opossum fur around it, making a small parcel about the thickness of a pencil, and a few inches in length, called 'mūrūr,' and puts it away in a little bag, called 'gurāga,' which he uses for storing similar charms.

At the same time the women are also mustered in the camp, which is within sight of the *bambilli*, and sit down in a convenient place, singing a 'nyūnggoan' or weeping song, of which "Chant No. 2" above is an example.

After the above ceremonial has been gone through, the people patiently wait for a suitable opportunity to organize a party to punish the individual who has caused the death of their friend. Many months may pass over, or a year, or even a longer period, but the matter is not forgotten. When the time at length arrives, a party of warriors, accompanied by some old men, go away into the enemies' country. The chief features of the procedure in despatching such a hazardous expedition may be summarised as follows:—

The band of men who are to perform this important duty are selected from among the most active and fearless of the relatives and friends of the man whose death they are deputed to avenge. Some of them belong to the same totem as the deceased, and the totems of others are those with whom he could have intermarried. They are mustered on one side of the camp, accompanied by the men who are to lead them, and are decorated with red ochre and grease. The best spears and other weapons are chosen and well greased with human fat. They assume a crouching attitude, by bending their bodies at the haunches and knees, and form into single file. Each man produces one of the 'mūrūrs' already described, and holding it up in his hand, mutters *yah! yah!* They now march away in their bent position, in single file, till they get out of sight of the camp where the women are. They then straighten their bodies and walk on, every man joining in the song shown on the music-block as "Chant No. 3," which is repeated for a short time. While singing, they gesticulate with their weapons as if assaulting an enemy.

Shortly after the departure of the warriors, the women pack up their belongings, singing a prescribed song as they do so, and remove the camp to another locality, whither they are conducted by the men who remain at home. At this place which may be distinguished as the "women's camp," all the occupants keep quiet, in order that the sorcerers or spies of the enemy may not suspect that a revenge party has been sent out.

In the meantime the chosen band already described has marched on till near sundown. They generally select a depression between ridges, or a dry watercourse, as their camping place for the night. Their fires are lit in small excavations made by digging the ground with the end of a nulla-nulla or other weapon to a depth of some inches, and the earth thus removed is used to raise a bank around the margin, as additional protection for the fire. Short pieces of firewood are used, to fit in the holes, and when finally leaving the place the fires are covered over. These precautions are taken in order that any straggling blacks belonging to the enemy may not observe the fires at a distance.

Next morning a tree is selected in or adjacent to the camp and is marked in the following manner: As many men as there is room for squat on the ground close around the butt of the tree, facing it, and mark the portion of the bole within their reach, with their tomahawks. An equal number of men mount, in a sitting posture, upon the shoulders of the first, and mark the tree in the same way. A third tier of men now sit upon the shoulders of the second lot, and make their marks. By this time the bole of the tree is marked up to about the height of a man. All the markers now withdraw and a fresh detachment of men stand around the tree and mark as high as they can reach. The same number of men get astride the shoulders of the first cordon and likewise mark the tree. Another tier of men sit on the shoulders of the second tier and do the same. The two tiers of seated men now jump down to the ground, but the men who are standing around the base of the tree remain in position. A fresh lot of men now mount with their feet on the shoulders of the last mentioned, and standing up, mark the bole as high as they can reach. The tree is now marked about ten or twelve feet from the ground, or even higher than that.

The whole ceremony is enacted for the purpose of making the people of the hostile tribe powerless to screen the predestined victim. This is why as many men as possible join in marking the tree, muttering incantations during the continuance of the proceedings. Some of the old sorcerers rub the marks with a quartz crystal or bullroarer to render the operation all the more efficacious and irresistible. Other men jump around, putting their beard into their mouth and biting it savagely.

At the conclusion of the tree-marking ceremony, preparations are made for the resumption of the journey. Four men are sent on ahead of the main contingent to reconnoitre, and if all is well, to select the site of the night's camp. Having decided upon the best spot, two of them start back to meet and inform their comrades, who in the meantime are coming on. The other two travel forward several miles from the selected camp, to examine the country and see that no strangers are located anywhere in the vicinity. Having satisfied themselves upon this point, they return to the camping place and rejoin the party. On the following morning, another tree is marked, and the scouts are again sent ahead. The proceedings are substantially the same for every day, unless delayed by rainy weather.

In this way the armed warriors journey on by easy stages into the enemies' territory, and endeavour to discover what part of their hunting grounds they are then occupying. When this information has been obtained by cautious tracking, listening and watching, a temporary bāmbilli is made in an unfrequented place, where there is sufficient timber to hide them from view, and here the avengers remain very quietly. This bāmbilli is as close to their enemies' camp as they consider prudent—the distance being less in hilly or scrubby country than in places which are open and level, or are badly watered. Two or more strong, active men, who are also supposed to be clever sorcerers, are then sent forward as spies to report upon the precise place where the tribe they are in quest of is located. They hold up the 'mūrūr' in their hand as they travel stealthily along, because it is supposed to possess the magic power of guiding them to the quarter of the camp occupied by the slayer.

While the spies are away on their dangerous task, the other men who remain at the secret bāmbilli clear a small, circular patch of ground, by scraping away the leaves, small pieces of sticks, grass, loose stones, or the like, which may be lying on the surface. For this purpose they generally select a place where there is a tree growing in the centre, and clear the ground for several yards around it. A tree with soft bark is preferred, such as a gum, grey box or peppermint. With their stone tomahawks, or with the sharp ends of their clubs, the men in the way already described chop into the bark of the tree some rude marks, such as lines and zig-zag devices, resembling the marks on trees at 'Būnan' grounds or burying places, but not so elaborate. [See illustration and descriptive letter-press.] Somewhere within the clearing a hole or hollow place is made in the ground, into which the men discharge the products of the emunctories, throw remains of food, or other refuse. These precautions are taken lest a spirit or conjurer belonging to the enemy should become possessed of any of their refuse, excreta, or the like, and thereby frustrate their designs. The men who are in charge of this bāmbilli go out hunting to renovate their supply of food, but they make as little noise as possible—their operations being chiefly confined to fruits, reptiles, and game caught with nets.

When the spies have ascertained the position of the predestinated person in the hostile camp, and his surroundings, they start back to their fellows without delay. On their way thither they gather green grass and leafy twigs which they fasten under their brow-bands and in their hair, to show that they have been successful. When approaching the secret camping place they mutter mū-ū-ū! and their comrades answer them in the same way. On arriving in sight they commence singing the following song:—

Wurrigangaia ngurábun bunnungga
Wurrigangaia gungóara muggu.

On reaching the camp, the men there spread out and form a semicircle into which the messengers walk. Each man composing the semicircle has a spear in his hand, which he holds in a nearly vertical position. An old man now asks the spies if the enemies' camp has been found, and on receiving an affirmative reply, all the men bring down the points of their spears upon the ground, with the exclamation wirrh! wirrh! This is illustrative of the manner in which they mean to punish the offender. The old man further enquires as regards the approximate number of people in that camp, and when the answer is given the spears are again brought down to the accompaniment of wirrh! wirrh! as before. Queries are next made as to the quarter of the camp their special enemy occupies—is it easily got at—who camps near him, whereabouts is the chief man camped, and so on, each reply being received with the same exclamation and gestures.

If the actual slayer is not in the camp visited by the spies, they endeavour to locate the sleeping place of one of his brothers, or his father, or other near relative who may be available, and such person is selected as the victim.

The spies then remove the twigs and grass out of their hair and put them into the hole in the ground already referred to. They also discharge into this hole as much excrementitious matter as they wish to be relieved of, covering it up with the earth which had been scooped out.

All the men around then turn their backs to the hole and commence scratching backwards with their hands and feet like fowls. They scrape all the loose rubbish off the surface of the ground and continue backing towards the centre till a small heap is raised over the excavation. Next, all the men lie down with their heads toward this heap—as many as possible having their heads resting upon it—and pretend to sleep. This feigned repose is believed to have the same exhilarating effect upon them as that produced by a corroboree in ordinary circumstances. After a while, an old man breaks the silence and enquires sorrowfully, "Where are all my grandchildren?" This is an exaggerated way of referring to the death they are about to avenge. It is also symbolical of the sorrow of the doomed man's friends, when his death shall have been reported to them. All the sleepers answer, "*i-i-i-wah!*" in a very mournful tone. All hands now get up, and jump around the tree and the heap of rubbish, holding their noses between the thumb and fingers, muttering 'mūnyūnga irrimbulbul.' Each man then goes away a few paces and provides himself with a couple of sticks about three feet long, one in each hand, to make believe he is very sick and unable to walk without such support. These men turn their faces toward the enemies' camp and at every step they bring their walking sticks to the ground, exclaiming '*nyeh! yukka! yukka!* These proceedings are supposed to work a spell upon the adversary and render him powerless to defend himself.

The members of the party then lie down and rest till near daylight next morning, when they all start quietly away to fulfil their mission, being conducted by the men who acted as spies. These two men have their heads ornamented with grass and boughs as before, with a *murur* placed on top, projecting over the forehead. A vine is bent through the brow band and hair to keep the appendages firmly in their place. This decoration is believed to appal the enemy and make it impossible for him to escape. All the men have their faces painted with pipeclay, so that they can readily recognize each other during the encounter. They also have leafy twigs fastened in front of their bodies and faces, to prevent the enemy from observing them in the darkness. On reaching the confines of the camp they halt till daylight.

They have timed the approach of the dawn so well that they have not long to wait. The first bird which hails the morning is the signal for the assailants to surround the hostile camp, some men branching off in single file round one side and some going round in the opposite direction, until they meet on the other side of the camp. While marching round, they tramp heavily on the ground with their feet. Let us assume that a magpie begins to sing. All the men at once commence to imitate the call as they start away. This will startle other large birds, whose calls are also imitated. Little birds will chirp, dogs will bark, and they are likewise mocked. This and the heavy trampling of the men, gives the enemies the impression that a numerous host is surrounding them, as they cannot in their excitement distinguish between the calls of the animals and those of the men. The assailants also shout out the names of some of the principal stars which may appear in the orient at the time. The planet Venus, if then a morning star, is mentioned.

The ringleader or headman of the Pirrimbir party now calls out to the headman of the people in the camp, and asks for the surrender of the man they wish to punish. He uses the secret name only, so that the women and children will not know who is doomed. The headman addressed then also invokes some of the eastern stars, to wait a little, while he shouts out the secret or Kuringal name of the man who has been asked for,[1] and tells him to be ready to defend himself.

The doomed man then catches his best shield and stands out to parry the spears which are thrown at him by the kinsmen of the deceased. All the spears intended for this purpose have been charmed and anointed with human fat, to render their course unerring and increase their power. The spears must all be thrown from one direction, namely, the front of the victim. Perhaps the man wards off a considerable number of the missiles with little or no injury, until one spear, which is therefore believed to have been more specially greased than the rest, catches him in a vital part, and he falls to the ground. Two or three of the assailants then rush upon him and despatch him, and the members of the surrounding cordon thereupon shout, wirrh! wirrh!

The avengers quickly gather round the dead man and with their stone knives flake off portions of skin and flesh from the middle of the back down to the buttocks, from the chest, and from the backs of the legs. This skinning is not done all in one piece, but may be in flakes about the size of a man's hand. His kidney fat is also taken out. As soon as the pieces of flesh are secured and placed in their guraga bags, the invaders leave the camp hurriedly and make their way back to their secret bambilli of the previous night, where they roast and eat some of the flesh of the murdered man. They now sing and jump around the marked tree in a defiant manner, throwing their clubs at it to exorcise its power, while they mutter "*um! um!*" This is believed to have the effect of preventing their enemies from following them.

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[1] In 1896 I reported that every man has a secret name which is known only to himself and the initiated men of the tribe. Journ. Anthrop. Inst., Vol. xxv., p. 310.

A start is then made upon the return journey, and they all travel as speedily as possible, hunting as they go. They return along the same route as they travelled out by, and use the same camping places. They again dance and sing around the marked trees for the purpose of exorcising all the magic and potency which had been injected into them when they were first marked. This restores them to their position as mere ordinary trees of the forest, and makes them of no service to the enemy. It also destroys the spell of any adverse sorcerer.

On reaching within about a mile of the place where the women and others were directed to make a new camp, mentioned in an earlier page, the returning warriors continue muttering *mu-u-uh!* until they reach the vicinity of the camping ground. Every man has bunches of leafy twigs or green grass fastened in his brow-band, the same as the spies already described, and the actual slayers are in the lead. When the old men hear this sound they go and meet the avengers and conduct them to the bāmbilli. On the following morning the result of the expedition is related very fully, and the portions of the victim's body which they have brought with them are produced.

Some green bushes are laid on a smouldering fire to make a smoke, and the dead man's skin, with the flesh attached, is placed on top, and smoke-dried. Red ochre powder is sprinkled over, or rubbed upon the skin to assist in drying and preserving it. Each head-man takes a piece of the preserved flesh and puts it into his gurāga bag, which he carries slung over his shoulder. These bags are never brought into the camp where the women and children reside, but are hung up on some convenient tree or sapling at the bāmbilli on the confines of the camp, where none but the initiated are allowed to consort.

At certain times the old head-men and warriors warm the pieces of fleshy skin to make the fatty matter soft, and rub it on their own bodies. Small portions of it are occasionally eaten, to make the participants fearless and vengeful. The men also rub the greasy skin on the noses, eyes, and feet of their dogs, to make them good hunters and unusually expert in discovering game. Spears, boomerangs and clubs are similarly rubbed to increase the force and accuracy of their flight when thrown at game, or when used for punitive purposes.

It should be mentioned that when an early morning attack, such as that particularised in the foregoing pages, is made upon an individual, none of his fellow tribesmen interfere, because they are probably all acquainted with the facts of his having shed the blood of some man in another neighbouring camp, and retributive justice must take its course. When they hear the shouting of the *pirrimbir* party, they sit up at their camp fires, or perhaps spring to their feet, and take particular notice of the man who strikes the fatal blow, because they know that, sooner or later his blood, or that of a tribal brother, will also be required by the relatives of his present victim.

Explanation of Illustrations.

The tree shewn in the illustrations was marked by a Pirrimbir expedition in the Thoorga territory many years ago. It was first pointed out to me by two old aborigines in 1899, who at the same time gave me all the details and the songs of the Pirrimbir, recorded in the foregoing pages.

It is a tall, green tree of the grey box species, measuring some ten feet in girth at about a foot from the ground. It stands on hard, stony ground, and probably the annual growth has been slow, which accounts for the good preservation of the marks.

The tree is situated in the parish of Noorooma, county of Dampier, and is about 300 or 400 yards westerly from the south-west corner of Portion No. 381 of 40 acres in the said parish.

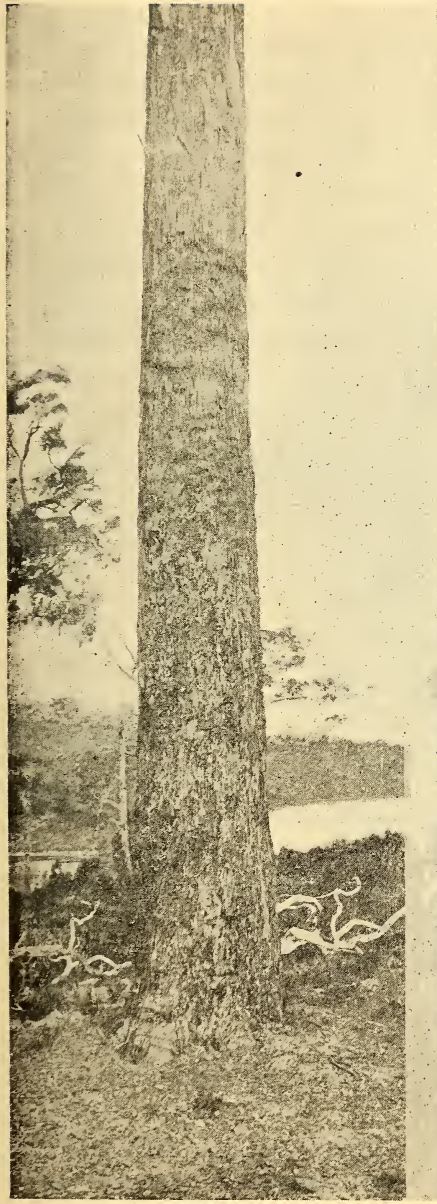

Fig. 1.

Fig. 2.

Photographs of a tree marked by Pirrimbir Warriors.

Fig. 1 shews the northern side of the tree, whilst Fig. 2 shews the south-western side, because on these aspects of the tree the marking appears more clearly than on the remaining sides. The same kind of marking is continued all round the bole, and extends up the tree to a height of about 14 feet.

In Fig. 2 the camera was placed nearer the tree than in Fig. 1, to give a larger picture on account of being the shady side of the tree. This is the first illustration of a Pirrimbir tree which has ever been published. Such a tree has never been even mentioned by any previous author.

The Search for Food.

The ordinary, everyday methods of searching for the different kinds of game, fish, plant food, etc., practised by Australian tribes have so often been described by several writers, that they will be passed over in this paper. But the following contrivances respecting the procuring of food have been gathered by me among the aborigines in various places in New South Wales and Victoria. In describing the contrivances employed in hunting, the State in which they were observed will be mentioned in each instance. It will be noticed that the exogamous divisions of the people, and their peculiar superstitions, are scattered through these customs. A few examples collected from the natives of the south-east coast and other parts of New South Wales will be given first, followed by some interesting items from the aborigines of Victoria.

When the natives observe a whale, 'mūrirra,' near the the coast, pursued by "killers," mánanna, one of the old men goes and lights fires at some little distance apart along the shore, to attract the attention of the "killers." He then walks along from one fire to another, pretending to be lame and helpless, leaning upon a stick in each hand. This is supposed to excite the compassion of the "killers" and induce them to chase the whale towards that part of the shore in order to give the poor old man some food. He occasionally calls out in a loud voice, ga-ai! ga-ai! ga-ai! Dyundya waggarangga yerrimaran-hurdyen, meaning "Heigh-ho! That fish upon the shore throw ye to me!

If the whale becomes helpless from the attack of the "killers" and is washed up on the shore by the waves, some other men, who have been hidden behind scrub or rocks, make their appearance and run down and attack the animal with their weapons. A messenger is also despatched to all their friends and fellow-tribesmen in the neighbourhood, inviting them to come and participate in the feast.

The natives cut through the blubber and eat the animal's flesh. After the intestines have been removed, any persons suffering from rheumatism or similar pains, go and sit within the whale's body and anoint themselves with the fat, believing that they get relief by doing so. It may be added that the "killers" eat only the tongue and lips of the whale.

Catching pens or fish-traps, *ngullaungang*, are made across narrow, shallow inlets on the sea coast or along the course of rivers. These are made by tying together bundles of tea-tree, and laying them close together like a wall across a creek or narrow shallow arm of the sea. These walls or barricades are slightly above the surface of the water. A gap or gateway is left in mid stream so that the fish can pass through, and when a sufficient number are enclosed, the gateway is blocked up by other bundles of tea-tree, which have been prepared beforehand for this purpose. If the pool is large, one or more smaller portions of it are partitioned off in a similar manner, into which the fish are driven by splashing the water, and are thereby more easily caught by their pursuers.

Just within the gateway leading into the outer barricade, one of the old men ties a little bag containing a portion of the skin of a dead man. This is supposed to cause the fish to flock into the enclosure in larger numbers than could be obtained otherwise without this magical help.

If fishing is done by hook and line, these instruments are often rubbed with a dead man's skin or fat to make them more effective. Mullet fat thrown in little pieces on the waves in a lake or estuary, is supposed to make the water smoother, while the people are engaged in fishing.

When the men are fishing in canoes, or standing upon rocks in the water, they break into small pieces crayfish, sea-eggs, congewoi, or shell fish, and cast the fragments on the water for the purpose of collecting schnapper. As soon as they appear and commence eating the bait, they are empaled with a spear made for the purpose. Groper fish are caught in the same way.

Early in the morning, while the dew is on the trees, the men and women take each a koolamin, 'bung'gulli,' and go among the small honey-suckle trees, 'bābir,' when they are out in blossom. A native puts his koolamin under one of the bunches of bloom and shakes the twig, which deposits the honey from flowers into the koolamin. The dew dilutes the honey exuding from the blossoms, and causes it to come away when they are shaken. Each bunch of bloom is shaken in succession, and when a sufficient quantity of honey has been collected, water is added to form a pleasant beverage, which can be drunk at any time during the day.

When a man went out hunting he took with him a charmed wommera or spear-lever, the hook of which consisted of a bone from a dead man's arm, ground to a point.

The fat of the corpse was mixed with the gum used in lashing the hook to the shaft of the weapon. When the hunter espied an emu, kangaroo, turkey or similar game, he held up the wommera in sight of the animal, which would thereby be spell-bound and unable to run away until the man got near enough to throw his spear with fatal effect.

When a clever man is out hunting and comes across the tracks of, say, a kangaroo, he follows them along and talks to the footprints all the time for the purpose of injecting magic into the animal which made them. He mentions in succession all the parts of the foot, and then names the different parts of the leg right up to the animal's back. As soon as he reaches the backbone, the creature becomes quite stupid and is an easy prey when overtaken by the blackfellow. Before cooking such an animal, the man and his companions dance round the body for the purpose of exorcising the magic which it has absorbed from his incantations.

Dhuran is the Wirraidyuri name for what we call "wind-clouds." When such clouds are seen in the sky in the early morning, the men whistle for the purpose of causing the wind to arise and then start out into the bush. Kangaroos, emus and simliar game generally keep their heads facing the wind, making it more easy for a hunter to approach them in the rear. Besides, the wind prevents them from hearing small noises, as the crackling of sticks under a man's feet, or catching the scent of the hunters. A man carries a mat of boughs fastened together, reaching from his nose down nearly to the ankles, and comes up a little closer every time the animal lowers its head to feed. When he gets within killing distance of a bird he launches his spear. Whenever possible, the natives always hunt any animal against the wind. Again, a blackfellow generally goes up a creek or river when spearing fish, because the water which is made muddy by wading into it is washed down the stream into the rear, and does not disturb the fish higher up. Besides, it is easier to see the animals in the clear, undisturbed water.

During my rambles among the aborigines of western and northern Victoria, I gathered some hunting customs, a few of which are as under:—The wild turkey of the plains is timid and watchful. The following is one of the devices employed by the natives in catching them: The hunter provides himself with a little bird and ties its legs together. He lays it on the ground in an open space which he knows is frequented by turkeys. A plant or shelter of bushes is made a little way off, behind which the man hides. A string reaches from him to the bird, which continues to flutter its wings. A turkey feeding on the open ground adjacent sees the bird, and being tempted by curiosity, comes up to it. The hunter with one hand gradually hauls in the string with the bird attached, and the turkey follows till it comes within reach of a noose fastened to the extremity of a small tough wooden rod which the hunter holds in his other hand. The turkey is so intent upon watching the fluttering little bird that it does not perceive the proximity of the end of the rod. The blackfellow dexterously passes the noose over the turkey's head till it reaches the upper or small part of the neck. The hunter then twists the rod round and round in his hands with great rapidity. This twists and tightens the noose and chokes the bird without making much noise or disturbance, and it is dragged quietly into the bough screen. Perhaps another turkey, following its companion at a little distance may be snared in the same way.

If the turkey, which belongs generally to the Guro-gity phratry, be too shy or wary to approach the "call-bird," then that individual is supposed to be a Kappaty turkey. If a dog pursue a "forester," which is usually Kappaty, and fail to bring him to bay, that animal is said to be Gurogity.

A hunter takes some fat, or skin, or piece of bone, of a dead man, and puts it into a little bag. He then goes to some place in the bush frequented by kangaroos, emus, turkeys or other game, such as a favourite feeding ground or watering place or sand hill. Here he selects a tree belonging to the proper phratry, and hangs his little bag on one of the spreading branches. When an animal gets within "shooting distance," as it were, of this magical artillery, it becomes stupid and wanders about heedlessly until the hunter gets an opportunity of spearing it.

Another custom was, as soon as some emus or kangaroos appeared in sight, the men commenced chewing human hair and spitting towards the animals, accompanied by magical incantations. This was expected to work a charm upon the game and cause them to remain quiet and sluggish, so that a man could steal upon them, holding a bough in front of him, until he got within killing distance. *Wurrity* is the native name for fat, hair, or other portion of a human body, used to work spells, or conjure with.

In following along the tracks of an emu, kangaroo, wild dog, or such like game, if the hunter at intervals drop hot coals in the footmarks of the animal, this will have the effect of making it hot and tired, or induce it to come round again towards its pursuer.

In other instances the sweat and hair taken from under the arms, as well as the hair of the head, were used to rub on hunting weapons to increase their precision in killing game. These charms were also employed to enable a man to climb trees dexterously, or to carry out any project successfully. A girdle made from the hair of a warrior, alive or deceased, confers great powers upon the wearer.

Food Regulations, Totems, etc.

Dyim'ber is a term applied to the laws regulating the dividing of all food caught by the people. Food which is strictly forbidden to a man or woman is called *mugu*. These are the terms used in the Thurrawal and Thoorga tribes of New South Wales. A few examples only will be given.

The rules of *dyimber* will be first described:—A boy must not eat anything which he catches himself, neither can his sister eat it, but his father can, and in certain cases, his mother too. Two brothers must exchange anything they catch, with some boy who is not their brother. Young children of both sexes can eat anything which is given to them by their parents or relatives, because the rules of *mugu* do not apply to them. The forelegs of animals are given to little boys to make their arms strong.

A young woman may not eat anything which she catches herself, or which is caught by a boy, but she can eat what an initiated man catches. A young man cannot eat anything which a woman kills with a stick or club, but he may eat what she catches on a line, provided it be not *mugu* to him.

When a man kills a mammal, say an opossum, he splits it lengthwise with a stone knife into two equal parts, the cut extending down the middle of the back. He then keeps for himself the half containing the right fore and hind legs, and gives the left half to a friend. Birds and reptiles are divided in the same way as an opossum.

If a man catches a fish he lays it down on its left side, and about midway between the nose and the tail he makes a transverse incision from the back to the belly, penetrating halfway through the body. Then he splits off the upper portion, between the transverse cut and the tail, which he keeps for himself, and gives the remainder to a friend. In other words, the person who catches the fish gives away about three-quarters of it to his fellows, and they divide with him in a similar manner.

Mugu or Forbidden Food.—When a youth is first admitted to the status of a tribesman, either by means of the *Bunan*[1] or by the *Kuttya* ceremonies, he is forbidden to eat the male of the native bear, kangaroo, opossum, or short-nosed bandicoot. Neither can he eat the emu, porcupine, pelican, or ducks. Schnapper, groper and eels are also forbidden, but he may eat any other kind of fish but those mentioned. The flesh of any animal which burrows in the ground, or which has long teeth, is likewise interdicted. He can, however, eat the long-nosed bandicoot, swans, honey, yams and other edible roots. There are other animals and plants beside those mentioned in the above lists.

Again, during the time a youth is out in the bush with the old men, going through the initiation ceremonies, he must only eat certain kinds of food, and his mother and father are restricted to the same diet as he. And when a novice is released from any taboo regarding food, in the manner described farther on, his mother is freed at the same time. Generally, however, the laws of taboo do not apply to a woman—she is not thought of sufficient importance, but eats everything which is given her.

Any food which falls to the ground under any circumstances, must not be picked up again by an adult person, but young children may lift it and eat it. Eating the gum of the grass-tree and certain others is interdicted, because these gums are used in fastening handles upon stone

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[1] "Bunan Ceremony," American Anthropologist, Vol. IX., pp. 327 – 344, with plate; Journ. Roy. Soc. N. S. Wales, Vol. XXXIV., pp. 276 – 281

hatchets and chisels, or for any other purpose where gum would be serviceable.

When a woman is enceinte she cannot eat fish which come in "schools." If she did so, it would cause them to turn away to another place. This ban applies to little girls and uninitiated boys, and lasts for some weeks after "schools" commence to arrive. The bones of fish during this period must not be given to dogs, but must be burned, otherwise "schools" of fish would go elsewhere. A pregnant woman is allowed to eat rock-cod, flathead and leather-jacket, but not schnapper, groper, or bream.

If a woman who is enceinte were to eat forbidden fish at such a time, the spirit of the unborn babe would go out of its mother's body and frighten the fish away. If a male infant, it would have a fishing spear—if a female a yamstick—and stand on the water at the entrance to a fishing pen, or in front of a net, and turn the fish back. The fish are more afraid of a male infant, on account of its carrying a spear, than of a female. Although these spirit children are invisible to human eyes, the old men know they are present by the movements of the fish, and at once suspect some woman of having broken the food rules.

When a man visits the people of another tribe, one of them takes him a mouthful of cooked flesh on the end of a small stick, like a skewer, and reaches it out to the stranger who bites it off the stick with his mouth. As soon as this ceremonial is over the stranger can enter into conversation with his hosts, but not before. After a while, the hosts take a vessel, in which there is water and mix a little earth into it, and give the visitor a drink. From that forth he can eat the food and drink the water in their territory. If he were to do these things without the ceremony described, he would become ill and sores would break out over his body. The first night of a stranger's arrival, his entertainers make a bed for him by placing small sticks on the ground and covering them thickly with leaves. On all subsequent occasions he must make his own sleeping place.

A mother-in-law receives food from her son-in-law while sitting down. She does not reach out for it, but he sends some one to place it in her lap. He must not approach his mother-in-law himself, and if any conversation takes place, their backs must be turned towards each other. In such case she would clap her hands, indicating that she wished to speak to him. See also "Language of Mothers-in-law," *infra.*

When a man is out hunting, he will not kill his totemic animal, no matter what opportunity he may have of doing so; and if his totem be an edible plant, it is likewise left uninjured by him. It is believed that thus allowing the animal to escape, or leaving the plant unplucked, will augment the supply and increase the fruitfulness of such game or vegetable.

It is apparent, therefore, that a specific animal or plant is left unharmed by each individual in the tribe, whether male or female. Supposing, for example, that ten men go out into the bush in quest of food. Every man of the party will take care that he does not injure his own totem during the day's rambles. If we assume that each hunter has a different totem, then each man will allow a certain object to go free; or in other words, ten different animals or plants will not be molested. But in such an expedition there would generally be groups of men belonging to the same totem. For example, there might be three kangaroo men, two iguana men, one porcupine man, and four yam men. Then, three of the party would not harm a kangaroo under any circumstances, two would allow iguanas to escape, one would not interfere with a porcupine, and four would not gather yams. Let us suppose that a mob of kangaroos is encountered, then our hunting party, instead of numbering ten men, really consists of only seven. If iguanas are met with, the hunters comprise but eight men. And if they come to a fertile patch of ground, only six yam-diggers are available.

It is manifest that this arrangement conduces to preserve the supply of food by diminishing the number of those in quest of it. It should perhaps be stated that in some instances a man can eat his totem if killed and given by another person, but as the chief difficulty consists in the capture and gathering of the food, the tendency is still towards its preservation.

I have also observed that animals and plants which are prolific or numerous are the totems of a greater number of men than those which are more or less scarce. For example wallaby, duck and yam men are more numerous than porcupine and pelican men. Again, game and other things which are scarce are tabooed to the young people, who must hunt among the animals which are plentiful, in order to give the old folk a chance.

Mumbirbirri or Scarring the Body.

Raising cicatrices by means of cutting into the flesh on the shoulders, arms, and chest is a custom of wide prevalence among the Australian aborigines. The position and extent of the scarring is regulated by the custom of the tribe to which the novice belongs. When visiting the natives on the Upper Lachlan, I obtained the following particulars of the practice in that part of the country. My informants were old men who had been operated on in their youth, who showed me their scars, and had a very vivid recollection of the formalities connected with the ordeal. These people speak the Wirraidyuri language, a grammar and vocabulary of which I contributed to the Anthropological Institute of Great Britain.[1] Their ceremonies of initiation were described by me in a communication to the Royal Geographical Society at Brisbane in 1896.[2] I also dealt with a portion of their social organisation in two articles to the Anthropological Society at Washington in 1897.[3]

As no account of the import of scarring the body and the ceremonial connected with it has ever been published, I shall give a brief description of some of its main features. At the Būrbung, or ceremonies of initiation already referred to, certain restrictions regarding the eating of animals and other articles of diet are imposed upon the novice, such prohibited food being called *wanal*. As the youth grows older, he is liberated from these taboos one by one, his release from each object following a prescribed routine, and being accompanied by a ceremony. It is unnecessary to add that no man can be scarred who has not passed through the Būrbung ceremonies.

In the tribe with which I am dealing, the first *wanal* from which a youth is liberated is the fat male opossum. Hitherto he has only been allowed to eat lean and tough animals of that species. He is taken into the bush by his mother's brothers, the brothers of his potential wives, and his father's people, and a number of leading tribesmen are also present. A fire is kindled and the subject is carefully painted and rubbed over with opossum fat. The animal itself is cooked and some of the flesh is given to the youth by his uncle, which he eats while the old chiefs sing the song prescribed for the fat opossum; and the other men

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[1] Journ. Anthrop. Inst., July - December, 1904.

[2] "The Initiation Ceremonies of the Aborigines of the Upper Lachlan," Queensland Geographical Journal, Vol. xi., pp, 167 - 169.

[3] American Anthropologist, Vol. ix., pp. 411 - 416, and Vol. x., pp. 345 - 347. See also my "Totemic Divisions of Australian Tribes," Journ. Roy. Soc. N. S. Wales, Vol. xxxi., pp. 154 - 176.

dance around, shouting out the names of waterholes, shady trees, etc., in the novice's country.

On the first cold night after these proceedings, the novice is kept in the camp without food and is not allowed to sleep. He is not permitted to speak above a whisper and remains in the same place. Early next morning, while it is still very cold, he is taken charge of by the men and is seated on bushes laid upon the ground. His future brother-in-law, or his maternal uncle, or a tribal representative of one of these men, comes behind him, and with a piece of sharp flint makes several vertical cuts about two and a half inches long on the back of his left shoulder—on the central portion between the point of the shoulder and the spine. The blood flowing from the incisions is rubbed into them by the operator, after which ground charcoal, mixed with grease, is applied. Being sleepy, cold and weary, his body appears to be numb and almost insensible to pain.

Before commencing the cutting, the boy's maternal uncle or his father licks or sucks the top of his skull. It is said that some years back, the lad's skull was bitten by the old man.[1] One of the sorcerers present rubs a bullroarer across the youth's shoulder or perhaps a large quartz crystal is used instead; these manœuvres being supposed to increase the graduate's fortitude and alleviate the pain or bleeding.

If there be more boys than one to be dealt with, the same ritual is gone through, but a fresh scarifier is appointed for each one. These men profess to undertake their duty with hesitancy, and therefore some mock persuasion has to be enacted before they start work. They are usually chosen from among men who have come from some of the neighbouring tribes. Probably the unwillingness of these operators is due to their fear of any fatal results following the

[1] "Burbung of the Darkiñung Tribes," Proc. Roy. Soc. Victoria, Vol. x., N.S. (1897) p. 8.

scarring, because their own lives would be demanded by the relatives of the deceased. See "Pirrimbir," *supra.*

While the scarring is in progress the men standing around make a great noise by beating their shields with other weapons. The novitiate is then taken away by some initiated men who act as his guardians and provide him with food. These men are generally the brothers of his future wife and his own elder brothers. Firesticks are occasionally held close to the wounds to make them open and protrude as much as possible during the process of healing, in order to leave raised scars. Every afternoon, just before sundown, he is freshly painted, and a mixture of grease and ashes or ground charcoal applied to the cuts on his shoulder.

In the course of a few months, when the wounds are healed, the graduate is painted again and his body anointed with the fat of the doe opossum, which up till this time has been *wanal* to him. Some cooked flesh of the animal is then given him and while he eats it the old men chant a different song to that used on the first occasion, the dance being also varied. As soon as convenient after this ceremony, the subject is kept awake throughout a cold night, as before, and in the morning he is again placed sitting on boughs spread upon the ground, while a man cuts vertical lines on the right shoulder, similar to those appearing on the left, and the wounds are treated in the same manner.

There is now a band of vertical marks reaching across the back from shoulder, which shows that the bearer has creditably kept the law relating to opossums and that the headmen have thought fit to release him from that particular *wanal.* If a youth were sly and deceitful, and surreptitiously eat something which was *wanal* to him, and the elders became aware of it, they would punish him by refusing to release him from his forbidden food, for a much longer time than would otherwise be considered necessary.

Shortly after the last marking has healed, the headmen despatch a messenger to the mother and friends of the novice, and another messenger to his future wife's people, stating that the graduate will be taken to a certain place at such a state of the moon. If it is any time between the new and full moon, the messenger stands before his audience and holds up his boomerang horizontally or nearly so, with the convex edge towards the west. The time between the full and new moon is indicated by holding the convex edge of the weapon towards the east. As both these positions of the moon occupy a fortnight, lesser periods would be explained verbally by the messenger.

The youth's mother, as well as his betrothed, have been expecting this message, and repair as early as circumstances will permit to the appointed meeting place and erect their camp. A U-shaped enclosure is built of boughs, the open end being farthest from the women's quarters. On the last morning preceding the arrival of the bush contingent with the novice, another messenger is sent forward to report that the party will arrive in the afternoon. The graduate's *buddunggan* or future wife, and his mother, accompanied by some old women, repair to the bough enclosure and kindle a fire, and make everything ready.

About an hour before sundown, the bush mob make their appearance in single file. The novice and his custodians are near the front, and he is conducted into the bough yard where his mother and buddunggan are standing together. The latter approaches him and taps him on the breast with a *dhullabulga* or portion of a man's apron, after which green boughs are thrown upon the fire and he passes through the smoke. The women then retire, and the youth is taken to the quarters of the single men where one or two old fellows will chant for the occasion. The women also sing at their own camp.

During the early part of the following day, the men take the novice again to the bough yard, where the women meet them. There are present the graduate's mother and father, some of his sisters, brothers, maternal uncles and aunts. His *bundunggan* or promised wife, accompanied by similar relatives, is also there. Some leaves have been strewn thickly over the surface of the ground in front of the buddunggan, on which are laid the following articles of a man's dress, which she has brought there for presentation to the graduate:

1. A *wullunggaiir*, or wide brow-band, painted red. 2. A *gambun*, or narrow brow-band, painted white. 3. A *willa-willa*, consisting of a few of the top-knot feathers of the white cockatoo. The feathers are fastened with string or gum on a small piece of stick, and are intended for inserting under the brow-band as an ornament. 4. A *dhullabulga*, made of the skin of the kangaroo-rat, cut into narrow strands about a foot long. These strands are bound together at one end, and are worn attached to the front part of the waist-girdle, so as to hang down over the pubes. 5. A *kurbubundhan*, or girdle for the waist, made of woven opossum fur. 6. A pair of *buggurbundhan*, or strings to be tied around each of the upper arms, woven from opossum fur. 7. A *gudyugang* or necklace, made of pieces of reed cut into short lengths of say, half an inch, and an opossum fur string passed through the hollow of each one. 8. A *baigur*, another neck ornament, made of pieces of skin cut from around the genital appendages of a male kangaroo, and fastened on a string of opossum fur.

The buddunggan walks up to the graduate and passes the *gudyugang* necklace over his head. Next she decorates him with the *baigur* in the same way. These are the only articles with which she invests him—the remainder of the turnout being put on the youth by his guardian. In return for these gifts the sister of the graduate presents the buddunggan with a complete set of a woman's regalia. The youth now goes back with the single men to their camp, and the women stroll away to theirs. In the evening a corroboree is held in celebration of the youth's release from the opossum *wanal*.

Some months after the above ceremony, or it may be the best part of a year, or longer than that, if the graduate is young, he is again taken charge of by the elders of the tribe, and another animal is added to those which he can hunt and eat. As the procedure connected with each ceremony is somewhat similar, I shall very briefly describe the position of the scars, or *mumbir*, on the different parts of the body.

The next *wanal* on the list is the *girwa* or iguana. For the full-grown male animal, the graduate is cut, vertically, on the left shoulder, a little below his first marks for the opossum. After a while his right shoulder is similarly branded for the female or young iguana, and when he has recovered from its effects, he is marched to the women's camp, as on the first occasion, and is shown to his relatives. He has now a second tier of *mumbir*, or marks extending across the back, and is received with the usual congratulations. The songs and dances connected with the iguana, both in the bush and at the women's camp, are different to the opossum ceremony. No bough-yard is erected on this occasion, nor are any presents given by the buddunggan.

After a considerable time the young man is allowed to eat the full-grown male emu, *ngurun*, being painted and greased as on other occasions, but the old men continue singing special chants throughout the night. There is a superstition that the emu never sleeps at night, because if it did all the aborigines would die. Therefore, in discharging a man from this *wanal*, everybody in the camp keeps awake all night. In the morning the graduate is marked by vertical cuts on the left shoulder just under the previous scarring. There is a further interval of time, and the man is released from the tabu regarding the female and half-grown emus, when a similar ceremony is held, after which he is marked by vertical incisions on the right shoulder immediately below the iguana *mumbir*.

The graduate now has three rows of scars, extending from shoulder to shoulder, which completes all the *mumbir* which will be cut upon his back. At some convenient time after this he is marched to a place near the women's camp, where he is met and welcomed by his male and female relations as before.

Next in order comes the graduate's liberty to eat the *maugang*, a large grub found by chopping into the boles of trees, for which he is marked on the left arm with vertical cuts. For the *burragang*, a large grub in the roots of trees, he is similarly incised on the right upper arm.

After another interval he is relieved from his *wanal* respecting the *dhugganan*, a small grub obtained in the boles of trees and is marked on the left arm below the first *mumbir*. The *gurthan*, a small grub found in the roots of trees comes next, for which he is cut on the right upper arm, below the *burragang* scars. In each of the four last cases, one of the grubs is rubbed around the graduate's mouth by an old man before it is eaten, and each has its own peculiar chant.

The chest is the seat of the next *mumbir*. With ceremonies similar to those already described, the *yubba* or full-grown male carpet snake is added to the man's dietary scale, and he is marked by vertical cuts on the left breast, commencing at the collar bone, high enough to leave room for another row of marks between it and the nipple later on. When these wounds have healed the novitiate is branded on the right breast in a corresponding position, which enables him to eat the female and half-grown carpet snakes.

After a while the man is released from the prohibition regarding the flesh of the male *wandaiela* or porcupine, which is made known to whom it may concern by vertical incisions on the left breast, between the carpet snake *mumbir* and the nipple. For the female or half-grown *wandaiela*, he is similarly marked on the right breast.

Another interval elapses and the graduate is permitted to eat the male of the *gudamang* or turtle, which is denoted by a transverse or horizontal scar across the breast between the nipples ; and for the female turtle another horizontal scar is made below the former, in the intermammary region.

When the graduate is admitted into the rank of eating the carpet snake and the porcupine, the old men chant all night, and the people keep awake, the same as at the emu ceremony already detailed. At all these gatherings there is a good deal of sexual license allowed, such as men lending their wives to visitors, similar to what I have elsewhere referred to at the Burbung ceremonies. During these assemblages, too, the people often barter weapons and other articles—and sometimes the teeth which were extracted at the initiatory rites are returned—particulars of which have been reported by me in other publications. Want of space compels me to omit many matters connected with the Mumbirbirri ceremonies, which may be included in a future communication.

Some Burial and Mourning Customs.

The rites connected with death and burial vary somewhat among different tribes, and it would be highly interesting if all the ceremonial connected with this subject could be collected over the whole of Australia. The following is an example of the procedure in ordinary cases among the Thoorga tribe on the south-east coast of New South Wales, whose language I have already reported.[1] The initiatory rites of these people were described by me in 1896,[2] and their sociology in 1900.[3]

If a man dies a natural death, as of old age, accident or the like, his body is placed full length between pieces of bark, and the whole is then bound round with string outside the bark. During the afternoon a few wizards, *muyulus*, gather up all the men and women and take them to a very tall tree, or at any rate the tallest tree within sight of the camp. Some of the old men are left sitting close to the corpse.

The women sit on the ground near the base of the tree, with their rugs folded in front of them, and keep quiet, as if listening for something. Two of the *muyulus* now climb the tree, one following the other, either by cutting steps or by means of vines. The front man ascends the tree as far as it is possible to go, and the other keeps about 6 or 8 feet lower. The topmost man, looking in the direction of the native country of the deceased, calls out in a loud, clear voice, *kagalgal nunnup!* The lower man repeats the call in quick succession. Simultaneously with the men's call, each woman brings her open hand down upon her folded rug, with a thudding sound. The same rug may be used by several women.

The lower man, who may be distinguished as B, then descends about 5 or 6 feet, and the top man, whom we will call A, comes down to the place just vacated by B, and both men repeat the call as before, and the old women again clap their hands on their rugs. B and A each

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[1] "The Thoorga Language," Queensland Geographical Journal, Vol. xvi., pp. 49 - 73.

[2] American Anthropologist, Vol. ix., pp. 327 - 344, pl. vi.

[3] Journ. Roy. Soc. N.S. Wales, Vol. xxxiv., pp. 262 - 264.

descend another stage of 5 or 6 feet, and shout again, and the women repeat the clapping. This is continued stage by stage until B reaches the ground and A is a few feet up the trunk of the tree, when the final call is given by both men, accompanied by the beating of the rugs by the women.

It is supposed that at a man's death, his inside or spirit, called *bulubulaty*, goes away back to its native place and visits all the haunts and camps occupied by the man during life. Perhaps the man has left some of his weapons at his old camping places, or has hidden away his bullroarer or other secret belongings somewhere in the bush. His *bulubulaty* is supposed to go and see if these belongings are alright. The ceremony of calling from the tree-top is for the purpose of bringing the *bulubulaty* back to the body before burial.

While the two men are calling out from the tree, the other old fellows who were left sitting near the corpse are attentively listening, and they generally report that they have heard a rustling sound within the bark covering of the corpse, as if the *bulubulaty* had returned to the body. Moreover, the men who climb the tree frequently aver that they have heard the *bulubulaty* in the distance answering their calls. If the deceased had been strangled in his sleep by the sorcery of an unseen enemy, the answering voice would be very hoarse and feeble; but if no injury had been done to him, the voice of the returning spirit would be clear and distinct. If the man has met his death by foul play on the part of any of the people present, it is supposed that the old men at the butt of the tree will see the *bulubulaty* touching the guilty party as it flies past him.

The spirit and body of the deceased being now reunited, a grave is dug in some soft ground, such as loamy soil or sand, and the body, with its covering of bark, is placed lying full length on its back, with the head pointing towards the native country of the deceased's mother. Or if he died within the territory of his mother's tribe, then his head would be laid to the west, so that when his *bulubulaty* sits up in his place of sepulture his face will be towards the rising sun, to enable him to get warm. The native country of one's mother is called "i-dhŭng'-ū-rū."

The men who ascend the tree, and the other mourners, are painted with *millin*, pipeclay, and *gubur*, red ochre, on the limbs, bodies and faces. Some of the maternal uncles of the deceased are present at his burial ceremonies, and take a prominent part.

When a woman's husband dies or is killed, her hair is overspread with the white down of birds and pipeclay. Kangaroos' teeth and porcupines' claws are bound in her tresses, and on top of the head is fastened a barrañ which hangs down between her shoulders. Her face is painted with small daubs of white and red, and she wears a brow-band painted with pipe-clay. Strings made of the skin of the ring-tail opossum, to which are attached small pieces of bone, are tied around her arms. She wears a waist-belt made of opossum fur. The chest and limbs are painted with streaks of white mixed with red. A man's mother, sisters, mother-in-law, and daughters also mourn for him.

The widow has a bag in which she puts any food which may be given to her by her husband's relatives or her own. She does not go out hunting, but remains in the camp with any other widows who may be there, who look after her wants. Food from her bag can be eaten only by herself and her family. The brothers and sisters of the deceased can also partake of the contents of the bag. All remnants of the widow's food must be burnt or covered in the ground, and no dogs, excepting those of the deceased, must be allowed to eat any of the bones or refuse.

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No person except the brothers of deceased are allowed to use his weapons and other belongings, which are called *dhundhal.* If the brothers of the dead man take his spears or other weapons and kill any game therewith, no one excepting the widow and relatives of the deceased, can participate in the feast. If more game or other food has been obtained than the relatives can eat, they cannot give away the surplus to other people of the tribe who are not relatives, but must burn or bury it.

The widow does not converse with any one, but every morning and evening she raises a lamentation, and chants certain customary dirges. This is continued for many months, at the termination of which one of the younger brothers of the deceased may claim her.

When a man of the Ngeumba tribe is buried, a grave is dug in which the body is placed in a sitting posture, leaning backwards with its head towards sunrise. A doctor, or clever man, goes into the grave and places the body in position. The face of the corpse is bent forward till the chin touches the chest. This bowing down of the head is done to prevent the friends of the deceased from dreaming about him. *Yerrudhami* means a dream. When everything is ready, the men on the top throw down earth and short pieces of sticks, with which the doctor packs the corpse in position. Afterwards, the men return to their camp and are smoked at a fire with green boughs layed upon it.

Sorcery or Magic.

Upon the decease of a tribesman, the old men, *muyulus*, generally, if not always, ascribe his death to the machinations of some enemy, either in their own tribe or among their neighbours. The following is one of the methods adopted by the Tharumba tribe to discover the person who has secretly caused a man's death :—His body is taken by the women, who rub it all over with a mixture of burnt bark and grease. The bark used is that of the apple-tree,[1] which is burnt to a fine powder. The body is kept for several days, perhaps for some weeks, as this application possesses the property of preserving the body to some extent. The bark-powder and grease is applied every day or two, and after a number of applications a kind of incrustation is formed on the surface of the body.

Some of the old men who are related to the deceased now come and scrape off some of this ashy layer from his body. This mixture, which now comprises exudations from the corpse, as well as the original ingredients, is called *ngurrung'arat*, and is supposed to possess occult powers of retaliation by guiding the possessor of it into the camp of the guilty party. The *ngurrungarat* scraped from the exterior of the dead man's body is placed in a little bag called gūr'aga, and is carried away by the old men to the bahmbilli, a sheltered place where the tribal councils are held, out of sight of the camp. There a fire is lighted and when it has burnt down to a mass of hot coals, one of the old fellows steps forth and throws a few pinches of *ngurrungarat* powder on the embers. The substance immediately begins to burn and send up smoke. If the smoke ascends straight up, and goes a good height in the air before it disperses, that signifies that the murderer lives a considerable distance off. But if the smoke goes up a little way and bends to one side, this indicates that the murderer is located near them, and the direction in which the smoke bends in either of these cases, shows the direction of his camp.

A council is then held to consider who is the most likely man in the locality pointed out by the smoke to have

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[1] Not the fruit tree, but the so-called apple tree of Australia, the *Angophora* of botanists.

caused the death of their comrade. Perhaps two or three, or even more men are equally suspected in a certain camp which the smoke indicated, and further measures are necessary to sheet it home to the guilty individual. A couple of clever men are selected to enquire into this matter, and the first opportunity which occurs of visiting the tribe containing the "suspects," these chosen men go on pretence of bartering, or other feasible business. When they get among the men of the other tribe, they let their fire burn down, and some time when no one is looking, one of them throws a little of his ngurrungarat powder on the fire, and watches which way the smoke goes. Whichever one of the suspects happens to be in the direction taken by the smoke is then singled out as the sorcerer who killed their kinsman. These two men next go and sit down near the suspect and watch him closely, to see if he is very much perturbed and guilty-looking after the smoke has found him out. The man by this time probably concludes that he is suspected, and whether he is guilty or not he becomes rather disconcerted, because he realizes his dangerous position. This conduct confirms the spies in their conclusions, and they go back to their own people and report the result of their mission.

A consultation is then held at the bahmbilli, and the duty of retaliating is assigned to one or more of their special sorcerers—fellows who are equal in skill to those in the adversary's camp. Several other men go with them, including generally a couple of young men as recruits to learn the mode of procedure, so that in later years they may be able to take charge of similar expeditions. Some of the older men will each have a little bag, *guraga*, containing *ngurrungarat* powder fastened on the top of the head amongst the hair. This bag, of its own accord, falls over on the side of the head towards the camp of the man they are seeking. When they get into the hunting grounds of the adverse conjurer, they hide in scrubs or thickly wooded or rocky places where he is likely to pass by. When they see him, they "sing a spell" upon him in a low tone. This is done to cause him to want to go about by himself, unaccompanied by any of his relatives or friends. If they see him climbing a tree they "sing" at him to cause him to get giddy and fall to the ground.

If this "singing" has not the desired effect and the enemy persists in keeping in company of another man, one of the invading muyulus takes off his belt, *ngulya*, and tears it down the middle, "singing" while he does so. This is supposed to cause the two men to part company, in the same way that the belt is parted. It is believed that if a man be alone he is more easily overcome by the "black art." If they are fortunate enough to surprise their enemy when he is separated from all his people, they approach him, muttering incantations and pointing at him, and tell him he has only so many moons to live. This generally so terrifies him that he really believes he must die.

In addition to being guided by the *ngurrungarat* powder above mentioned, a muyulu or sorcerer will mount upon a log, rock or leaning tree, and point one of his fighting boomerangs first in one direction and then in another, until he feels the weapon pulling toward a particular quarter. Then he knows that the camp of the enemy whom he is seeking is located in that direction.

If a sorcerer obtain some of the excreta, hair, nails or other part of an enemy's body, he takes it to a "squeaking tree," *mauaraty*, and places it between the touching surfaces of the two branches causing the "squeak." When the wind blows, this fragment is squeezed and ground to atoms, and the owner is believed to suffer in the same way. During the whole performance the old man "sings" toward the person he wishes to injure. If the party whose destruction is sought be a greater conjurer than the man who "sings" him, no harm can result from it.

Aboriginal Astronomy—the Zodiac.

All aboriginal tribes have names for many of the principal fixed stars, and also for remarkable stellar groups. There is generally a story about the star, which was in olden days a man, the wondrous doings of which are duly recorded. Not infrequently there are families of stars—the parents and offspring, husbands and wives, and other relationships—all being pointed out, and assigned their places in the narrative. Legends are more numerous concerning stars situated in the neighbourhood of the moon's path through the heavens, and in this way a zodiac may be said to exist. The stars near the ecliptic and the zenith change their positions in the sky more rapidly than those toward the poles, and therefore more readily arrest attention. Besides constellations at these high altitudes can be seen easily when the people are camped in thickly wooded country, whereas stars near the horizon would not then be visible.

Throughout the summer months, and during fine weather at other periods, the blacks usually camp out in the open air, where they have every opportunity of watching the starry vault above them. The fact of the moon, who was a human being in ancient times, wending its way through these stars month after month, helps to increase the peoples' interest. There are always some clever old men in the camp, who are the recognized repositories of the lore of the tribe, who take advantage of this out door life to teach the young people stories about some of the different stars which may be visible at such times.

As soon as an old man commences one of these stories, the young folk from the neighbouring camp fires congregate around him and listen with avidity to his marvellous narrations. A love of the supernatural seems to be born in the human breast, and the Australian natives are no exception. The young people of the audience listen so attentively that they are themselves able, in years long after, to repeat the stories to another generation. In this way the star myths and other native legends have been handed down from time immemorial.

Conspicuous stars and star clusters all the way along the zodiacal belt, have well-known names and traditions. Moreover, each star figuring in the myths belongs to a phratry, section, clan or other subdivision, precisely the same as the people of the tribe among whom the tale is current. The names of the subdivisions, as well as the names of the stars, change amongst the people inhabiting different parts of the country. Sometimes the legends and nomenclature of the stars will be substantially the same among several adjoining tribes over an extensive region. In other instances, not only are the names of the stars different, but the traditions and the stars connected with them are altogether divergent.

The aborigines have no methods of accurately measuring the annual circuit of the sun, but they know when the cold weather commences; then the period when the flowers come, and plants shoot forth buds; and lastly, they realize the time of the hot weather. They have discovered that these periods follow each other in a certain fixed order year after year; and the stars which occupy the northern sky in the cold winter evenings travel on, and are succeeded by others in the following season; and that these are again displaced by different constellations during the warm evenings of summer.

The aborigines of the Clarence River have a story that the Pleiades, when they set with the sun, go away to bring the winter; and that when these stars reappear early in the evening in the eastern sky, they are ushering in the warm weather. They are supposed to be a family of young women, whose name was War-rīng′-garaí, and who belonged to the section Wirrakan.[1] Among the same tribes, α Tauri was a young man named Karambal, of the Womboang division, who absconded with another man's wife. He was pursued by the injured husband, and took refuge in a tall tree. His pursuer piled wood around the bole of the tree, which he then set on fire, and Karambal was carried up by the fierce flames into the sky, where he still retains the colour of the fire.[2]

In the frosty nights of the winter months, about three or four hours before sunrise is a time when there is generally a stir in a native camp. The people have had their first sleep, and the cold begins to make itself felt. The men and women, especially those who are old, sit up and replenish their fires. While doing this, their attention is naturally directed to the sky, where they observe that the stars then shining in the eastern quadrant are different from those which were visible the previous evening. They observe that these stars are trudging along after the others, and will disappear at daylight.

Among the Ngeumba blacks, in the cold weather of midwinter, when the Pleiades rise about three or four o'clock in the morning, the old men take some glowing coals on bark shovels, and cast them towards this constellation as soon as it is visible. This is done to prevent the spirit-women, whom these stars represent, from making the morning too cold. The women in the camp are not permitted to look at all at the Pleiades in winter nights, because such conduct would increase the severity of the

[1] See my paper on "Totemic Divisions of Australian Tribes," Journ. Roy. Soc. N.S. Wales, Vol. xxxi., p. 169.

[2] Compare with my "Folklore of the Australian Aborigines," (Sydney, 1899) pp. 26 – 29.

frost. If a woman transgress this law, her eyes will become bleary, and she will suffer from uterine troubles.

The blackfellows have not mapped out the sky into constellations in the same way as Europeans have done, but there is a certain amount of method in their arrangement of the stars. For example, a man and his wives, his family, his weapons, his dogs, are not generally far apart. Brothers, uncles and other relationships are often separated by considerable distances.

Among the tribes inhabiting the south-eastern portion of New South Wales, α Canis Majoris is Gūndyeran; α Orionis is Gunung'ama; α Argus is Mirridyugga, the short-nosed bandicoot. The Pleiades is Wanggatti; Milky Way, Kurrēwa; the stars in Orion's Belt and Club are Yuiñdya.

They have names for the Magellanic clouds. Nubecula Major is Kurrug'gur, the shortnosed bandicoot. Nubecula Minor is Wangalli, a kangaroo rat. At the time when these star-clusters—the bandicoot and the kangaroo-rat—are at their lower culmination, and therefore so near the horizon that they are not noticed by untutored natives living in thickly wooded country, they are supposed to have gone away through the skies on a Pirrimbir expedition. After they have taken revenge upon the culprit, the nubeculæ come into view again.

In the county of Kara-Kara, Victoria, there was an immense pine tree growing out of the earth, the topmost branches of which reached up to the sky. In the far away past, people used to climb up the tree and walk about and reside on the starry vault; and blackfellows who belonged to the sky occasionally descended by the tree to the earth to see their friends, and remained for a while. Visits were frequently made for purposes of barter between the blacks who were located on the earth and those whose hunting grounds were away in the sky. In short, the tree was a regular highway between the earth and the upper regions, for a very long period. Old blackfellows have told me stories of similar trees which reached up into the sky in other parts of Victoria.

At that time the common magpie and black jay went out hunting one day, and speared a dog which they thought was a wild one. They lighted a fire and cooked the animal in a hole with its head pointing towards its *miyur*, but they had not time to remain there and eat it. So the magpie picked up the carcass of the dog, still hot from the fire, and carried it across the back of his neck home to the camp. The hot body resting on the magpie's neck so long, burnt the skin and caused the white mark still seen across the neck of that bird.

It turned out that it was the largest and best hunting dog belonging to the lark which had been speared. By and bye the lark called in his dogs and they came to him one by one. As each dog appeared, the lark said impatiently, "That's only a puppy! Where is my big dog?" But the favourite dog did not return, and the lark was determined to have revenge upon the whole tribe, but he said nothing. He took his waddy and went and sat down by a fire near the base of the great tree, and pretended he was carving ornamental lines on the weapon. When no one was looking he put live coals into a hollow in one of the roots, and shoved them well underneath with the end of his waddy.

After a while the fire began to make headway and crackled under the ground. Some blackfellows asked the lark what noise that was. He replied that it must be two of the top branches rubbing against each other, and they appeared satisfied with this answer. But the fire increased in vigour and fierceness under the soil, burning all the roots until the principal one was reached, which shared the same fate. Then the tree came down with a tremendous crash, killing all the people who were under it. The fire continued to burn the trunk and every branch, until the whole was consumed. The top of the tree formed Morton Plain, with the charred remains of the people, turned to stone, still to be seen there. A hollow was burnt in the ground where the tree stood, making a large lagoon.

On the Darling River, New South Wales, from Bourke down to Louth, I gathered the following star names from old natives. There are longer stories connected with each but I had not time to record them fully. The larger of the two stars in the extremity of the tail of the Scorpion is a crow and belongs to the phratry Kilpungurra. α Aquilæ was a great hunter, named Wukkarno, who was a Mŭkungurra. He kept several dogs, and his boomerang is now the Northern Crown. The planet Venus was a man named Mirnkabuli, who lived in a gurli, or hut, made of grass, and subsisted upon mussels and crayfish.

The Pleiades were a lot of young women who went out on a plain searching for yams and a whirlwind came along and carried them up into the sky, depositing them where they are now seen. α Scorpii is an eaglehawk and belongs to the Mŭkungurra phratry. The planet Jupiter was a great Kilpungurra man of the olden days, called Wurnda-wurnda-yarroa, who lived on roasted yams, and got his reddish colour by being so much about the fire cooking his food.

A great warrior of ancient times, named That-tyu-kūl, was camped at Swan Hill on the Murray River. One day his two sons were out playing about the camp, getting wattle-gum on the bank of the river. They saw a monstrous cod fish, Ban'-dyal, in a big waterhole, and ran home and told their father. He got his canoe and hastened to the spot, armed with all his spears. Upon sighting the fish he heaved a spear which stuck into its back between the shoulders, but it swam on to the end of the waterhole and commenced forming a channel by tearing up the ground, and in this manner allowing the water to flow after it and bear it away from its enemy.

Bandyal did this so rapidly that Thattyukul was not able to keep pace with him. He kept on travelling towards the south-west, leaving a sinuous line of water behind him. At dusk he camped and excavated a long, deep lagoon, where he rested for the night. Thattyukul paddled his canoe along the watercourse, and upon overtaking the cod fish he hurled another spear at him, which stuck deeply into the median line of his back, as before, but somewhat lower down. This caused the great fish to start forward again, digging out a channel wide enough to allow his immense body to swim along. When night came he camped as previously, and made a large lagoon to rest in.

Here Thattyukul again overtook him and threw another spear, which penetrated the spine in the rear of the two former weapons. Thattyukul continued the pursuit for several days with similar experiences until they reached the neighbourhood of where the Murray Bridge has since been erected. By this time Thattyukul had used up all his spears, and had, besides, broken a piece off the end of his paddle. At this spot, Bandyal the cod fish made a larger hole, and Thattyukul lost sight of him, being unable to propel his canoe fast enough with the broken paddle. He therefore abandoned the chase and landed on the bank, where he set his canoe up on its end and it became a bial-bial, or red-gum tree. He stuck his broken paddle into the ground and it was transformed into a pine-tree.

The watercourse dug out by the cod fish in this encounter became the present Murray River, and the spines now found projecting from the back of the cod fish represent the spears thrown by Thattyukul in his vain attempt to capture it.

Ever since that time canoes have generally been made of the bark of gum trees, and pine wood is mostly used for making paddles.

Thattyukul then started back overland through the mallee scrubs and continued his course onward by way of the Grampian Hills until he reached his own country. He looked about and found his wife and children, accompanied by his mother-in-law, Yerretgurk, on top of a mountain whose sides were so steep that he could not climb up to them, neither could they descend to him. He then called out to his wife and children to jump down, one by one, and he would catch them in his arms. First, his wife jumped, then his eldest son, and lastly the youngest boy, and all were landed safely. He next persuaded Yerretgurk, his mother-in-law, to jump too, but he pretended he could not catch her, and she fell heavily on the ground, and hurt her face very much, which made her feel revengeful.

In time Yerretgurk recovered from her injuries, but she kept the matter in her mind. One day she was prodding her yamstick into the ground in a swampy place, and the water spurted up. She shoved in her yamstick farther and could feel something biting it. Upon probing deeper she came to the conclusion that it was some large and vicious creature. Then she dug a large hole in the ground, which at once filled with water, in the bottom of which she could feel the mouth of some animal with her yamstick. She now spread rotten sticks across the top of the hole and covered them over with leaves, grass, and rubbish, to resemble a huge bandicoot's nest. Then she brooded over her past wrongs.

Yerretgurk next called Thattyukul's two boys, and asked them to go and tell their father she wanted him to come and kill a large bandicoot whose nest she had just discovered. She requested Thattyukul not to strike at the animal with his weapons, because that would break the body to pieces, but to jump upon it with his feet. Being willing to make amends to his old mother-in-law for his bad behaviour in letting her fall from the rock, he came stealthily up to the heap of rubbish and gave one bound upon the centre of it. As expected, he went flop into the water, and the monster at the bottom caught hold of his feet and drowned him.

Thattyukul's uncle, Kulnapittyik, went in quest of him, and having tracked him to the pond, put in his long arms and pulled the body out on the bank. He was a great conjurer and succeeded in bringing his nephew to life again. After a while they both went away to the sky, where Thattyukul became α Aquilæ; his uncle was apotheosised as α Capricorni, and his mother-in-law, Yerretgurk, was transformed into α Eridani.

Sociology of the Tribes of Western Victoria.

Within substantially the same region outlined in my account of the Dōlgarrity ceremony, *infra*, the people are bisected, primarily, into two phratries, called Gurogity and Gamaty; the feminine forms of these being Gurogigurk and Gamatygurk respectively.[1] Each phratry is again divided into what may be distinguished, provisionally, by the name of "clans" or "castes," because they are not so well defined as the "sections" of the Ngeumba tribes treated in earlier pages. The names of the clans are taken in some instances from animals, and in others from inanimate nature. Attached to each of these clans are lists of totems, consisting of animals, plants, the heavenly bodies, the elements, and so on. In other words, all creation, animate and inanimate, is divided between Gurogity and Gumaty.

[1] Compare with my description of the "Group Divisions of the Barkunjee Tribes," who adjoin the people herein dealt with on the north.—Journ. Roy. Soc. N.S. Wales, Vol. xxxii., pp. 241 – 255, with map of their territory. The Sociology of the Wiradjuri Tribes is given by me in Journ. Roy. Soc. N. S. Wales, Vol. xxxi., pp. 171 – 176.

Then the totems of each phratry are apportioned among the clans of which it is composed, some clans possessing a certain aggregate of totems and some another, as illustrated in the lists farther on.

Again, every clan has its own spirit-land, called *mi'-yur*,[2] a native word signifying "home" or final resting place, to which the shades of all its members depart after death. The names of the miyurs are in all cases identical with the names of the clans. These miyurs are located in certain fixed directions from the territory of the tribe, some being situated toward one point of the compass and some another. Every man knows the direction of all the miyurs of his tribe in addition to his own.

The following are the names of the "clans" into which the phratry Gurogity is subdivided, together with the directions of the miyurs as pointed out to me by some old aborigines, and which I then observed with a compass:—Dyālup, the miyur of which bears W. 5° S. Būrt mūrnya, which has the same amplitude as Dyālup. Nyaui, E. 10° N. Kuttyaga, the same direction as Nyaui. Būrt Wirrimul has a miyur bearing W. 25° S. Wartwurt bears N. 25° W. Wŭrt-pattyangal, E. 15° S.

The totems of these clans will now be given, following the same order as the names in the last paragraph. First, then, are the totems allotted to Dyālup:—grey emu, porcupine, curlew, white cockatoo (ngaiuk), wijuggla, wood duck, mallee-lizard (yurkun), stinking turtle (widdyeruk), flying squirrel, ring-tail opossum, bronze-wing pigeon.

Būrt Mūrnya, a yam, has the plain-turkey, native cat, mopoke, dyim-dyim owl, mallee-hen, rosella parrot, peewee, all yams.

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[2] I first drew attention to these *miyurs* in my "Native Tribes of Victoria, etc.," (read March 4, 1904), Proc. Amer. Philos. Soc., Philadelphia, Vol. XLIII., p. 69.

Nyaui, the sun, has the bandicoot, moon, kangaroo-rat, black and white magpie, opossum, ngŭrt-hawk, gum-tree grub, wattle-tree grub, planet Venus. Kuttyaga, the white crestless cockatoo, has substantially the same totems as Nyaui.

Būrt Wirrimal, the white owl, has a number of totems, but I was unable to classify them.

Wartwurt is the heat of the sun at noon, and has buiwurrak or grey-headed eagle-hawk, carpet-snake, smoker parrot, shell parrot, murrakan-hawk, dikkomur snake, ringneck parrot, mirndai snake, shingle-back lizard.

Wŭrt-pattyangal, or shadow of Pattyangal is related to Wartwurt and Durrimurak.

The following are some further totems of Gurogity, but I could not ascertain the castes among which they are apportioned:—quail, mosquito, wallaby, tree iguana, mussel.

The names of the clans into which the Gamaty phratry is subdivided, with my compass bearings of the miyurs, are as follow:—Durrimurak, and its miyur N. 15° E. Wuran, with the same azimuth as Durrimurak. Muiwillak bears N. 5° E. Dyallan, S. 5° E. Pattyangal has a miyur situated S. 40° W. Wanguguliak, S. 20° E. Burriwan's miyur bears N. 40° E. The totems attached to each of these clans are as under:—Durrimurak has the warrungurra or large turtle, musk duck, black duck, honey, native bee, gatgat bird, ground iguana, death-adder, quandong tree, biergalk tree.

The feminine equivalents of any of these clans are obtained by adding *gurk* to the masculine name.

Wuran, the black cockatoo, has dyirkok hawk, pine tree, grey-box tree. Muiwillak, a black snake, has the darker emu, red-gum tree, water-mallee tree, all reeds. Dyallan, a whipsnake, has the swan, dog, water, larger crow, white-gum tree, grass parrot, platypus, water-rat or berper, werpal or dark-headed eaglehawk, native companion, wattle-bird or yanggak. Pattyangal, the pelican, has all kangaroos, fire, buiba or non-stinking turtle, brambambullak, plover, laughing jackass, *α* Crucis. Wanguguliak or crow's men; Wa is crow and guli, a man; the smaller crow belongs to this clan. Burriwan, a hole in the ground or in a rock. I could not find any totems of this subdivision, but it is friendly with Muiwillak and Wuran.

Other Gamaty totems, which I was unable to assign to their proper castes are:—stringybark tree, wild hop, bulldog ant, white ant, leech, blackfish, perch, jew lizard, mountain duck, honey bird.

It is unnecessary to state that the foregoing lists of totems, collected by me from the blacks for purposes of illustration, are only some out of a large number. And it is probable that there are other clans attached to each phratry beside those which I have enumerated. It should also be explained that the district in which the totems were obtained is a very large one, and I occasionally found that an animal or plant which belonged to one clan in a certain locality, was claimed by another clan at a different place. In a few instances it was likewise observed that a totem which was Gurogity in a certain portion of the tribal territory was Gamaty in another.

The laws of intermarriage of Gurogity and Gamaty, and the descent of the offspring are as exemplified in the subjoined table:—

Husband.	Wife.	Son.	Daughter.
Gurogity	Gamatygurk	Gamaty	Gamatygurk
Gamaty	Gurogigurk	Gurogity	Gurogigurk

According to the above table, Gurogity and Gamaty intermarry one with the other, but this is subject to the following regulations. Take for example a Gurogity man and his sister; then, the man's son's child marries his sister's son's child. In this case, which is the general custom, a Gurogity marries a Gamatygurk, in accordance with the table. In some instances, however, the man's son's child marries his sister's daughter's child, which gives the exceptional custom of a Gurogity marrying a Gurogigurk, subject to the totemic regulations. If a Gamaty man and his sister be taken as an example, the same laws will apply, *mutatis mutandis.*

When referring to the origin of the intermarrying divisions of Australian tribes in an article read at the International Congress on Anthropology and Archæology held at Paris in 1900, I stated that I was quite clear that the system of divisions into sections was not devised for the purpose of preventing consanguineous marriages, but had developed in conformity with the general surroundings.[1]

In 1897 I stated that "the sectional divisions may have been inaugurated for the purpose of a distinctive nomenclature among members of the same family, . . . to distinguish the mothers from the daughters, the uncles from the nephews, and the fathers from the sons, in their respective generations."[2]

In 1900 I ventured to raise a hypothesis that possibly in the distant past the present names of the sections represented small independent tribes, which became incorporated with each other, for the purpose of mutual defence, or for other reasons.[3] This theory was promulgated to evoke discussion among the ethnologists of Europe and America, as to its feasibility or otherwise. On the other hand, the

[1] "Les Indigènes d' Australie," Congrès Internat. d' Anthrop. et d' Archéol. préhistoriques, Compte Rendu, 12 Session, pp. 488 – 495.

[2] "Totemic Divisions of Australian Tribes," Journ. Roy. Soc., N.S.W., Vol. xxxi., (1897) pp. 160-161.

[3] Proc. Amer. Philos. Soc., Vol. xxxix., p. 564, *seq.* L'Anthropologie, Vol. xiii., pp. 233 – 240.

sectional names may have originated from repeated partitions of larger groups, but this is a controversial point which need not be investigated here.

It is shown by the table that the children of both sexes take the phratry name of their mother. This law also extends to the clans; for example, a Dyālupgurk produces Dyālup children. And if she belong to the porcupine totem, her offspring will be porcupines too. Again, the miyur of the progeny has the same name and compass bearing as that of their mother. To sum up the statements in this paragraph—the children take their phratry, clan, totem and miyur from their mother; or what amounts to the same thing, from their mother's brother.

Every individual in the community claims some animal, plant or inanimate object as his own special totem, which he inherits from his mother. But all the totems of his fellow-clansmen are friends of his. For example, if you ask a Wartwurt man what totem he is, he will tell you his own totem, and will then probably go on to enumerate those of his clan.

The general law is as just laid down, but there are some irregularities upon which I shall make a few observations. For example, among the Gurogity people, the clans Dyālup and Burt-Murnya are so much alike that they almost merge into each other, and have the same miyur or ancestral home. These remarks apply to Nyaui and Kuttyaga; and among the Gamaty folk the same thing is observed in regard to Durrimurak and Wuran.

Moreover, a man who belongs to Dyālup also claims Burt-Murnya, whilst a Burt-Murnya man calls himself Dyālup as well. Between Nyaui and Kuttyaga a similar affinity exists, and also between Durrimurak and Wuran. If ever Wŭrt-Pattyangal and Pattyangal were in harmony, they now belong to opposite phratries and can marry one with the other. Wŭrt-Pattyangal has some reciprocity with Wartwurt and Durrimurak; Nyaui with Burt-Murnya; Burt-Wirrimal with Kuttyaga. Muiwillak has affinities with Wartwurt, Dyālup with Wuran. Dyallan and Pattyangal are related to each other.

The divisions have not reached the stage of development which would enable one clan to marry only into another specified clan, but there is a tendency in that direction. For example, marriages of common occurrence are Wuran with Kuttyaga; Pattyangal with Wartwurt; Dyālup with Dyallan. Muiwillak is also a favourite clan when betrothals are being arranged by the old men.

In order to further emphasize or distinguish the different divisions, the phratries and clans have their own style of painting their bodies and dressing their hair. A very old Gurogity blackfellow on the Wimmera River assured me, some years ago, that he could discern a Gamaty man by his walk. He also gave me to understand that the speech of each clan was slightly divergent. The Wartwurt clan spoke Wereka-tyalli; Muiwillak and Wŭrt-Pattyangal spoke Bēwa-tyalli; Durrimurak and Wanguguliak spoke Yerra-tyalli. He also mentioned Yagwa-tyalli; Yardwa-tyalli, Buiba-tyalli and some others, but could not connect them with any specific clan.

Each of the dialects just mentioned are named from their negative adverbs. Werreka, bēwa, yerra, yagwa, yardwa, buiba, all mean "No." They are all sister tongues of the Tyat-tyalli, a grammar and vocabulary of which I published in 1902,[1] and together constitute one great language over the whole territory referred to in my Dōlgarrity Ceremony of Initiation in later pages.

[1] "The Aboriginal Languages of Victoria," Journ. Roy. Soc., N.S.W., xxxvi., pp. 71 - 106.

The divisions outlined in the foregoing pages not only pervade all the principal events of a man's life, but they accompany him into the grave and the land beyond. When a member of a clan dies and is buried, the body is laid horizontally, face upward, with the head placed toward the part of the horizon which leads to the *miyur* or spirit-land of the clan to which the deceased belonged. These miyurs are divided into the same phratries and clans as the people of the tribe, as explained in previous pages. The spirit of a Gurogity man or woman goes to a Gurogity miyur, and a Gamaty spirit travels away to a Gamaty resting place; this matter being regulated, in both cases, by the geographic position of the spirit-home of his clan.

Each miyur has its fabled watering place. For example, the shades of Dyālup, Burt-murnya and Burt-wirrimal drink at Mūmbūl. Bial-bial water supplies Muiwillak, Wuran, Durrimurak and Burriwan. Wartwurt drinks at Bummir. Dyallan and Wanguguliak quench their thirst at Dyŭrnera. In some of these places there is clear, spring water; in others ordinary water-courses; some have greyish water; whilst others have sea-spray. I forgot to enquire about the mythic watering places of some of the miyurs.

The spirits of the dead congregate in the miyurs of their respective clans during their disembodied state, and from there they emerge and are born again in human shape when a favourable opportunity presents itself. See my remarks on the transmigration or reincarnation of souls in later pages of this work, under the head of "Miscellaneous Superstitions."

When the men go out hunting and catch kangaroos, snakes, opossums, emus and any other game, every animal is cooked with the head pointing to the miyur of its clan. And if dead animals are temporarily laid upon the ground while the hunters are resting themselves on the way home to the camp, their heads are turned towards their respective miyurs.

A hunter carries weapons made from the wood of each phratry. If he throws at a Gamaty animal, he uses a Gurogity missile, but Gurogity game are killed with Gamaty weapons. If a Gurogity animal be the subject of pursuit, and a Gamaty spear has been hurled at it with good aim, without effect, then the hunter concludes either that the game in question was partly or wholly a Gamaty, or that there has been some mistake about the wood of which the spear was manufactured. Forest kangaroos are usually Gamaty but should one of them be chased by dogs and escape from them, then that particular animal would be considered Gurogity.

In the south-western portion of Victoria, along the coast from the Glenelg River to Geelong, and reaching inland approximately to the main dividing range,[1] we discover that the phratry names, with their feminine equivalents, are slightly different from those already described, as shown in the following synopsis. The offspring take the phratry, clan and totem of their mother.

Gurogity	Kappatyar	Kappaty	Kappatyar
Kappaty	Gurogityar	Gurogity	Gurogityar

Everything in the universe is divided between these two phratries. Among the totems of the Gurogity are included the following; Flying squirrel, small squirrel, opossum, pelican, plain turkey, eaglehawk, kurogity (white crestless cockatoo), plover, white cockatoo (ngaiuk), crane, black duck, small night-jar, ironbark, oak, bloodwood, broom, red-gum tree, peppermint tree, white-gum tree, red bull-dog ant, tiger-snake.

[1] For the language of these people, see my "Native Tribes of Victoria," Proc. Amer. Philos. Soc., Vol. XLIII., pp. 54 – 70; also my "Language of the Bungandity Tribe, South Australia," Journ. Roy. Soc. N.S.W., Vol. XXXVII., pp. 59 - 74.

The undermentioned are some of the totems of Kappaty; Dog, native cat, forest kangaroo, bat, crow, native companion, swan, pelican, black cockatoo, wattle-tree, blackwood, cherry tree, honeysuckle tree, stringybark tree, black bull-dog ant, whipsnake (kirtok), eel, fire, rain, stone tomahawk.

Spears, boomerangs, clubs, spear-levers, shields, etc., may belong to either phratry, according to the kind of tree from which they have been cut. This matter is also sometimes determined through the owner of the weapon in question.

The totemic families belonging to Gurogity and Kappaty are divided into clans or castes, somewhat similar to those in use among the tribes already described, but they are not so numerous or elaborate. It is not, therefore, thought necessary to furnish details of their structure.

In the country from Beaufort towards Hexham and Wickliffe, a part of the region we are dealing with, I discovered that the names of the phratries had changed—Kuttyaga being substituted for Gurogity and Kirtōk for Kappaty—as in the annexed table. The terminal syllables of the male names are modified to suit the feminine suffix and afford a euphonic pronunciation:

Kuttyaga	Kirtogurk	Kirtōk	Kirtōgurk
Kirtōk	Kuttyaragurk	Kuttyaga	Kuttyaragurk

According to this table and the last preceding one, the two phratries intermarry, the one with the other, but the parties to the alliance must have the same relationship to each other as those stated in the Ngeumba and Wimmera tribes already dealt with. Moreover, a Kappaty sometimes marries a Kappatyar, and a Gurogity marries a Gurogityar, of the proper lineage. These laws are likewise the same as those of the Parnkalla organisation, where the two intermarrying divisions are Maturri and Kirraroo, extending from Port Lincoln to Lake Eyre basin, in South Australia. In describing the marriage laws of the Parnkalla nation in 1900, I showed that "a man marries the daughter of his father's father's sister's son."[1] In the same year (1900), I described the limits of the country occupied by the Parnkalla nation, and supplied a map, which no previous author had attempted, in which the boundaries were accurately delineated.[2] Likewise in the same year, I described the initiation ceremonies of the Parnkalla nation, including the whole of Lake Eyre basin.[3] It must be stated that Rev. C. W. Schürmann was the first to report the names of the two phratries of the Parnkalla tribe.[4] He also described the ceremonies of circumcision and subincision.

Kuttyaga, as the reader will remember, is one of the clan names among the tribes north of the dividing range on the Wimmera River and tributaries, and means the white crestless cockatoo. Gurogity is the name of the same bird among the coast tribes. Kirtōk is the equivalent of Dyallan, also a Wimmera clan, both words meaning the whip-snake, in their respective languages. It appears therefore that Kuttyaga and Kirtōk have developed into the status of phratries.

When Mr. James Dawson was writing his book on the "Australian Aborigines of the Western Districts of Victoria" in 1881, at pp. 26 – 28, he mentions certain divisions of the aborigines who can intermarry. He says, "Kuurokeetch (my Gurogity), and Karkpœrapp (my Kŭrtpirrap), are

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[1] "Marriage and Descent among the Australian Aborigines," Journ. Roy. Soc., N.S.W., Vol. xxxiv., p. 126.

[2] "Divisions of the South Australian Aborigines," Proc. Amer. Philos. Soc., Philadelphia, Vol. xxxix., pp. 78 – 93, with map.

[3] See my "Phallic Rites and Initiation Ceremonies of the South Australian Aborigines," *op. cit.*, Vol. xxxix., pp. 622 – 638.

[4] "Aboriginal Tribes of Port Lincoln, South Australia," (Adelaide, 1846), p. 9; and "Native Tribes of South Australia," (Adelaide 1879), p. 222.

looked upon as sister classes. It is the same with Kappatch (Kappaty) and Kirtuuk (Kirtōk), and no marriage between them is permitted." In examining his text we find that Kŭrtpirrap is evidently a division or equivalent of Gurogity, and that Kirtōk is an equivalent of Kappaty. In pursuing my ethnological investigations in that district of Victoria I found Mr. Dawson's statements correct.

These tribes, like those in the Wimmera River district, have a spirit-home, which is called *maioga* in some of the dialects, and *mung'-o* in others. All the clans have the same maiōga, which consists of an island a short distance off the coast of Victoria, about half way between Warrnambool and Portland. The native name of this island is Dhinmār, but it is known on the map as Lady Julia Percy Island. On the shore of the mainland facing the island there are some large rocks, into the base of one of which the ceaseless rolling of the billows has worn a cavelike recess, respecting which the natives have a superstitious belief that it is in some way connected with Dhinmār.

Every deceased person, when buried, is laid with his head pointing towards this island. His spirit then provides itself with a firebrand, consisting of a piece of dry cherry tree, because this wood emits a peculiar odour whilst burning, which has the power of warding off danger from the bearer. The spectre then proceeds to the shore where the rock is situated, where he divests himself of any clothing or trinkets he may be wearing on his body, and disappears over the intervening sea to Dhinmār. The spirits of all the clans and phratries go to this island, which they occupy in common, the same as they did in their native hunting grounds. There they remain until reincarnated.

Sociology of the Tribes of Eastern Victoria.

If we assume a line drawn from Geelong through Castlemaine and Pyramid Hill until it meet the Murray River;

thence up that river to its source in Forest Hill; thence from Forest Hill to Cape Howe; and thence along the sea-coast back to Geelong. Then all the tribes who inhabited the region included approximately within these limits had a marriage system of which I shall now give as full a summary as the space available in this journal will permit.

In 1898 I communicated to the Anthropological Society at Washington, U.S.A.,[1] a short account of the intermarrying laws and inaugural ceremonies of these people, but during subsequent journeyings among the remnants of the tribes referred to, evidence has accumulated which enables me now to speak more definitely than was formerly possible.

As in all other Australian tribes, marriages are regulated by a system of betrothals, which are made by the elders after a child is born, and not infrequently before that event. For example, they wish to determine what woman is the proper wife for a boy A. The old men know who is the father of A, whom we may designate B; from this they find C the father of B, or A's grandfather in the paternal line.[2] Next they discuss who was a sister of C, whom we shall denominate D. Then, a daughter of one of D's children will be the correct wife for A. That is, a brother's son's child mates with a sister's son's child. This is the regular or direct rule of marriage.

If C's son's child be allotted a spouse who is D's daughter's child, the result is the marriage which I have tentatively distinguished as "rare," when dealing with the Ngeumba tribes in earlier pages.

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[1] "The Victorian Aborigines—their Initiation Ceremonies and Divisional Systems," American Anthropologist, Vol. xi., pp. 325 – 343, with map.

[2] At the Wonggoa ceremony of initiation described farther on, the sacred bullroarer is exhibited to the novices under the title of their "father's father."

Although a youth may be allotted a wife from either one of the branches mentioned, he must be limited to that particular lineage. For example, if he be assigned a spouse in the "direct" order, he cannot be permitted to obtain another wife from the "rare" line of descent. He may, however, be allowed more than one wife, but they must all come from the same lineage, if there should be any more women available in that direction. This law applies to all the tribes dealt with in this treatise.

In making the betrothals, the old men endeavour as far as practicable, to arrange that the brothers and sisters in certain families shall intermarry with the brothers and sisters in certain neighbouring families, whether in the same or in an adjoining tribe. This has the effect of binding the two families together by ties of kinship, and of strengthening their claims to consideration in the tribal councils. It also adds to their importance at the great gatherings which take place for initiatory ceremonies, barter and other purposes.

Let us take the birth-place of A of the above example as a starting point, and call it "No. 1." In order to get a foundation to work upon, we will assume that owing to marriages in prior generations, the man C of our example had a wife betrothed to him in a district, say fifty miles north of No. 1. It may be only a few miles away, or it may be a hundred or farther still—the distance being immaterial. In due time, he brought his wife home to No. 1, and his sister D was taken away to the northern family by the brother of C's wife.

After a while, C's son B of our example, went, say, fifty miles east to claim his allotted wife, and brought her to No. 1. B's sister, however, was taken away by the brother of B's wife, to her home in the eastern triblet. D, as we have seen, went away northward and bore a son who may be called E, who is brought up in the northern tribe, and belongs to it. On reaching manhood, E goes into a tribe, fifty miles westward, and brings home to his own country his betrothed wife. E's sister, however, is taken away to the west in exchange. By and by E's wife presents him with a daughter, whom we shall designate F. Then the boy A of our example is betrothed to the girl F, and he will go up northward to claim her later on, and bring her home to No. 1. The brother of F will also claim A's sister, and take her away to his own district.

It will be seen by the foregoing examples that the sons remain in their father's tribe or family, but the daughters are taken away into other tribes in return for wives for their brothers. This may be further illustrated by supposing that one family, X, has three sons and three daughters, and another family, Y, has their progeny divided in the same way. The elder son of the X family marries the elder daughter of the Y family; the second son marries the second daughter, and the third son marries the third daughter. Again, the elder son of the Y family takes the elder daughter of the X family in exchange for his own sister, and his two brothers take the second and third sisters in the same way.

It could of course happen that one family might have all sons, and therefore have no daughters to give in exchange for wives for them,—or they might have all daughters, which would land them in the same predicament,—but this is got over by the following rule of aboriginal society. Supposing there are four brothers, all married and have families. Then each of the four brothers will call all the children his, and the children will in like manner call each of the four men father. The aggregate of these children would probably be equally divided as regards sex, so that the girls could be given in exchange for wives for the boys. The children of several sisters would in a similar manner call each woman mother, and each mother would look upon all the children as her own. It must, however, be borne in mind that each man, his wife and their own actual progeny form one family and camp by themselves. The broader terms of kinship just referred to being used merely as a matter of courtesy and friendship.

In all the tribes of the eastern half of Victoria,[1] the boys and girls alike inherit the same totem as their male parent; thus, if the father be a kangaroo, the sons and daughters will be kangaroos too, irrespectively of the totem of the mother. Marriage between individuals of the same totem is strictly interdicted; for example, a man who is an opossum cannot marry a woman who is an opossum. It appears, then, that the individuality of the wife, as well as that of her totem, is lost. In the first place she is taken into the tribe of her husband, her children are born there, and belong to that tribe, and take the totem of their father. The woman of course retains her own totem as long as she lives. In a community such as this, one can readily understand how clans or small triblets could be formed or develop. Not only do the sons remain in their father's family or tribe, but their children are all brought up there and learn to speak their father's dialect, as stated in the description of the *Wonggoa* ceremony in later pages of this treatise.

By studying the genealogy given a few pages back, it appears that A obtained a spouse from the same family or clan which supplied his paternal grandfather with a wife, and that his sister went away there in exchange.[2] If the

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[1] For the dialects of these people, see my "Aboriginal Languages of Victoria," Journ. Roy. Soc., N.S.W., Vol. xxxv., pp. 71 - 106; also "Notes on Native Dialects of Victoria," Vol. xxxvii., pp. 243 - 253.

[2] In 1900 I described the sociology of a Gippsland tribe known as *Kurnai.* On that occasion I followed the genealogy through the father's cousin, instead of tracing it, as now, through the father's father, which although amounting to the same thing, is more explicit. See "The Origin, Organisation and Ceremonies of the Australian Aborigines," Proc. Amer. Philos. Soc., Philadelphia, Vol. xxxix., pp. 560 - 562 and 577, with map showing the boundaries of the several aboriginal nations of Australia.

C, B and A of our example had moderate families, a good few people would be added to No. 1 district in three generations. But this is not all. C, B and A probably had each several brothers who all had similar families to themselves, which would still further reinforce the population of that locality. In these families where the totem is handed down, as we have seen, from father to son in perpetual succession, all the men mentioned would belong to the same totem.

After a long time, the members of this family might consider themselves strong enough to defend their own hunting grounds, and would become an independent triblet. If they all belonged to the kangaroo totem, they could appropriately be distinguished as the kangaroo clan. If the clan from which C and A obtained their wives were all of the musk duck totem, they could be called the musk duck clan. Again, the eastern people where B of our example exchanged his sister for a wife for himself, might be all crows, and would be denominated the crow clan, and so on. The name "totemic clans" may be used to distinguish triblets constituted in this way.

For some reason, the kangaroo triblet might divide into two or more smaller totemic clans and the musk duck people the same. Some of the kangaroo men might go to one clan for a wife and some to another, as in the examples a few pages earlier, where the men went from No. 1 to the north, east, west, etc. In this way all the clans, although dispersed over a considerable territory, would be united by bonds of kindship which would fuse them into one great nation.

A girl who has been betrothed to a certain man may die before he gets her, and therefore, to neutralize the chances of a man not obtaining a wife, more than one girl is usually betrothed to the same youth. On the other hand, one girl may be betrothed to several young men. If the man to whom she is betrothed dies before he is old enough to claim her, then she becomes the wife of one of the others. When the parties to the alliance attain puberty, it is necessary that the old men shall again meet and settle the point as to who shall marry whom, because nothing can be done without their ratification.

It must be remembered that until a youth has graduated in all the inaugural ceremonies of his tribe, and has been admitted to the rights and privileges of aboriginal manhood, he cannot claim his promised wife, or be present at any of the councils or deliberations of the men.

Moreover, when a man goes to claim his allotted wife, he is required to stand out with his shield, while a certain number of spears are cast at him by the girl's brother. If he be dexterous enough to ward off the missiles without receiving a wound, and so prove himself a warrior, he can take his promised spouse, but if not, he must go away with his people a bachelor as he came. This is not such a serious ordeal as it appears at first sight. If the claimant does not prove himself worthy of the girl, then it follows that her brother cannot obtain the sister of the young man whom he has wounded. It generally happens, therefore, that when the brother is throwing the spears referred to, he takes good care that they shall fall wide of the mark. There are occasions, however, where the brother has some other girl in view, or has a "down" upon the suitor, and in such case does his best to injure him. This custom has probably given rise to the stockmen's yarns about "marriage by capture."

It has been said above that the woman and her totem are absorbed by the tribe into which she marries, but this must be received with some qualification. An old proverb says, that "blood is thicker than water," and there is no place where this is more real than in a blackfellows' camp. Her brothers know where she is, and will not forget her totemic claims. A boy's mother's brother is an important personage in all native assemblages, for whatever purpose they have met. He is there to see that justice is meted out to his sister's son, as well as to take part in passing him through the initiation and other qualifying ceremonies of his tribe. And in communities where the progeny inherit the totem of the mother, a youth and his maternal uncle are fellow totemsmen.

The chief difference in the sociology just described, and that of the tribes of Western Victoria, consists in the fact that among the latter the totems are perpetuated through the women, which renders the development of totemic clans impossible. In Western Victoria the wives are taken away from their own people into the families of their husbands, as in all Australian tribes, but the children take their phratry, totem and other designations from their female parent; consequently, we find all the divisions scattered indiscriminately throughout the territory of the entire community or nation.

Before quitting the subject of sociology, it may be as well to record in this place that I was the first author to discover and report the existence of tribes in north-west Queensland possessing eight divisions in their social structure. In 1898 I pubished a table illustrating this organisation on the Nicholson River.[1] In the following year, 1899, I tabulated another set of eight intermarrying sections, found among the Inchalachee tribe on Barkly's Tableland and the sources of the Gregory River in Queensland.[2] In

[1] "Divisions of Some North Queensland Tribes," Journ. Roy. Soc. N.S. Wales, Vol. xxxii., pp. 251 – 252. The American Anthropologist, Vol. i., N.S., p. 596.

[2] "Divisions of Aboriginal Tribes of Queensland," Journ. Roy. Soc., N. S. Wales, Vol. xxxiii., p. 111.

1899 I also published the sociology of some tribes on Sturt's Creek, Ord and Fitzroy Rivers, Western Australia, which was the first time the eight-section system had ever been reported in that State.[1] That article was followed by another in 1900, "defining the geographic limits of that portion of Australia which is occupied by aggregations of tribes distinguished by having eight intermarrying sections in their social structure." Moreover, among the tribes adopting the "eight-section system" just referred to, in Queensland, the Northern Territory, and in Western Australia, I was the first to observe and publish the marriages which are provisionally distinguished as "alternative," "rare," and "exceptional."[3]

In a communication to the Anthropological Society of Paris, in 1901, when referring to the different systems of Australian sociology, I stated: "Mais qu'il existe deux, ou quatre, ou huit divisions de toute la communauté, les principes fondamontaux qui réglent les mariages entre les divisions du groupe, et l' ordre de succession de la postérité sont identiques en tout."

Language of Mothers-in-Law.

Throughout the central and south-western districts of Victoria, and in the south-eastern corner of South Australia there is a hybrid tongue or jargon in use, comprising a short code of words, by means of which a mother-in-law can carry on a limited conversation in the presence of her son-in-law, respecting some of the events of daily life. I observed jargons of this kind among the Woiwurru, Bunwurru, Wuddyāwurru, Thaguwurru, Tyapwurru, Dhauhurt-

[1] *Op. cit.*, p. 112.

[2] "Wumby'a Organisation of the Australian Aborigines," American Anthropologist, Vol. II., N.S., pp. 494–501, with map.

[3] American Anthropologist, Vol. II., N.S., (1900), pp. 494–501; Queensland Geographical Journal, Vol. XVI., (1901), pp, 69–90.

[4] "Organisation Sociale des Tribus Aborigènes de l' Australie," Bull. Soc. d' Anthrop. de Paris, Tome II., Serie 5, pp. 415–419.

wurru and Bungandity tribes when studying and preparing the grammars of these languages which I have already published in New South Wales and America.

Mr. James Dawson also observed this "lingo" as he calls it, among the Peekwurru and Chaapwurru (my Tyapwurru), people.[1] Mr. E. M. Curr says, "A father-in-law converses with his son-in-law in a low tone of voice, and in a phraseology differing somewhat from the ordinary one."[2] This jargon may have had its origin in the law forbidding a youth to learn the language of the friendly tribe into which he was relegated to be instructed in the national observances and traditionary lore.[3] Perhaps a sort of hybrid speech was invented to enable him to converse with those around him, or within hearing of his potential mother-in-law. Compare the foregoing with my "Yauan, or Mystic Language of the Kamilaroi," communicated to the Anthropological Institute of Great Britain.[4]

Among some of the tribes of New South Wales and the north-eastern parts of Victoria, I have observed that when a man is conversing with his wife's mother's brother, he speaks in a tone very little higher than a whisper, and his uncle addresses him in a similar undertone.

The Wonggoa or Wongupka Ceremony.

The following pages contain an account of the initiation ceremonies of the native tribes who originally occupied that portion of North-eastern and Central Victoria situated on the Upper Murray, Mitta Mitta, Kiewa, Ovens, Buffalo, King and Broken Rivers. These rites were also in force on the upper Goulburn, Yarra and Saltwater Rivers. Although these parts of Victoria have been settled upon

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[1] "Australian Aborigines of Western Districts of Victoria." (1881), p. 29.

[2] "The Australian Race," (1886), Vol. III., p. 461.

[3] See the last paragraph of the "Wonggoa Ceremony," *infra*.

[4] Journ. Anthrop. Inst., Vol. XXXIII., pp. 269 - 270.

by Europeans for very many years, nothing at all has hitherto been done to obtain a comprehensive account of the initiation ceremonies of the native tribes who were formerly spread over it. The aboriginal languages of the people had been equally neglected until I undertook the congenial task of studying and expounding their grammatical structure.[1] The particulars herein reported were told to me by native men who had passed through the ceremonies.

When it has been determined to call the people together for the purpose of inaugurating the youths of the tribes into the privileges and duties of manhood, messengers are despatched to the different sections of the community, informing them of the time and place of the intended gathering. A suitable camping ground capable of accommodating all the tribes who are expected to be present, is selected near some river, creek or lagoon, in a part of the tribe's domain in which there is sufficient game to furnish food for all the people during the continuance of the ceremonies. In the vicinity of this main encampment, a circular space, known as the *gu-ang'-a*, is cleared of all timber and grass, and the soil scraped off the surface in making it level is used to form a low mound or embankment around its outer margin.

When a messenger arrives near the camp to which he has been sent, he waits till late in the afternoon, because at that time the men have usually returned from their day's hunting, and then approaches the single men's quarters close to which he sits down. Some of the people go to him and bring him into the *ngulubul*, where the headmen of the tribe are then brought together. The messenger now states where he has come from and produces the *muddyigang* or

[1] "The Aboriginal Languages of Victoria," Journ. Roy. Soc. N.S. Wales, Vol. XXXVI., pp. 71 - 106.

bullroarer and other emblems of his authority, and tells them the time and place of the general assembly. Two men are generally sent together, for the sake of company, but the one who is charged with the message is generally of the same totem as the sender, and he delivers it to a man of that totemic family in the tribe which he has been directed to muster. Moreover, it is indispensable that the messenger shall be a man who has passed through all the inaugural rites of his tribe.

The messenger remains with this tribe until the time arrives to start for the appointed meeting place. All the men, women, and children are then mustered up, and the journey commences. When they reach a point within a few miles of the main camp, a halt is made, and they paint their bodies with coloured clays in accordance with the style customary in their tribe, after which the journey is resumed—the men in the lead, with the women and children following. On the approach of the strangers, the men of the local mob, together with the men of previous contingents who have arrived at the main camp, stand outside the guanga circle, with their weapons in their hands. The new arrivals march on in single file in a meandering line, carrying their boomerangs. They enter the ring and march round and round until they are all within it in a spiral fold, with the novices whom they have brought with them in the centre. The women and children, with leaves in their hands, are standing in close proximity. The headmen now call out the names of camping-places, hills, water-holes, totemic animals and so on, in their native country. The names of shady trees, blossoming and fruit trees, are also mentioned. The men likewise call out the names of the genitalia of both sexes. While they are making these proclamations, they point their boomerangs towards their own country, and stamp their feet.

After all the ceremonial connected with the reception of the strangers is disposed of, they disperse, and erect their quarters on the side of the general camping ground facing towards their own territory. Several days, and in some cases weeks, may intervene between the arrival of the first mob and that of the last contingent, and in order to occupy and amuse the people during this time, corroborees are held every fine night by the light of the camp fires. As soon as the last tribe has arrived, the headmen assemble at the *ngulubul*, and having consulted each other, they determine the day when the novices shall be taken charge of for the purpose of initiation. The band of men who shall have control of the procedure in the bush are also chosen at this meeting.

When all the invited tribes have reached the common meeting ground, a series of special corroborees commences. The first of this series takes place on the evening of the day of the arrival of the last mob. At this dance, while the women are beating their folded skins as usual, an old man taps a couple of sticks together and stamps one foot on the ground, and utters the grunt-like exclamations, "Rirt! yeh! wah!" Next day there is another dance, when the old man changes the exclamation to "Yeh! yeh! wirr!" At the dance which takes place the same evening, the old man shouts "Birr! wah! wirr!" Different words are employed at each dance in prescribed order. On the evening preceding the breaking up of the encampment, the old man calls out "Bui! yeh!" On hearing this, everybody knows that is the last dance of the carnival. At the conclusion of the dance some of the men pretend to quarrel, and others run apparently to quell the disturbance, which suddenly ceases, and then all hands retire for the night.

Next morning all the people are astir at daylight, and the proponents for initiation are mustered out of the entire camp at some convenient spot, where they are painted and invested with the brow-band, waist-belt and apron. Strings made by cutting narrow strips of the skin of the ring-tail opossum, with the fur on, and twisted, are bound round the biceps and fore-arms of the novices. It is believed that this binding causes the muscles of the arms to develop. A guardian is now assigned to each boy. Such guardian is one of the brothers, actual or titular, of the women from among whom the novice could obtain a wife in accordance with the laws of the tribe.

The novices are next conducted into the *guanga*, where they stand with their heads bowed, surrounded by a cordon of men. Before the boys are taken into the ring, each mother secures a portion of her son's apron, *ngore*, and swings it round her head as she gesticulates and jumps about. A large fire, which has been burning in the guanga all night, has reduced itself to a heap of hot embers and ashes. The mothers of the novices, and all the other women, with the children, are also gathered up a little way from the ring, where they are made to lie down, and are covered with bushes, grass or rugs. A sufficient number of men are appointed to keep guard over them, so that they may see nothing of the next performance.

A number of men have provided themselves with green boughs having a dense foliage and a stem about two or three feet in length. They catch hold of these boughs by the stem and hold them up over the novices where they are standing in the *guanga*, thus forming a thick leafy canopy above their heads. At a given signal from the chiefs, a contingent of active men selected from every tribe present, then pick up bark shovels, *bundurra*, shaped something like a tennis racket, and commence throwing the hot ashes from the fire above referred to, over the bough canopy. The boys underneath are surging round and round in a compact body, whilst the men hold the boughs close together overhead, trying to ward off as much as possible of the falling coals and ashes. The men and the boys shake their shoulders, and jump, for the purpose of dislodging any of the fiery shower which may descend upon their bodies. This fire throwing ordeal continues until all the ashes and embers have been distributed.[1]

The heads of the novices are then covered with rugs and they are marched away by their guardians till they get quite out of sight of the *guanga*. They arrive at a place where a line of holes about the size and shape of a human foot and a few inches deep, has been dug in the soil, with a layer of leaves strewn upon the bottom. Two holes are dug for each novice who is to be operated upon.[2] The boys are now turned rapidly round and round until they become giddy, after which they are placed standing with their feet in the holes. Each guardian then comes behind the boy he has in charge, and kneeling down, puts his head between his legs, so that the boy sits on his shoulders. Another man stands along side, and places bis hands over the boy's eyes, so that he may not see or recognise the man who takes out his tooth. A small piece of tough stick is placed across the lad's mouth to prevent his shutting it. During these proceedings a *muddyigang* is sounding in close proximity. The tooth extractor must be selected from among the men of one of the strange tribes. He pretends to accept the office reluctantly, whereupon an old chief pats him on the back with the open hand, and encourages him to undertake the important task. A fresh "dentist" must be appointed for each novice in the same manner.

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[1] Compare with my account of the *Bunan*, in which, on the morning of taking the novices away, they are exposed in front of a fierce fire, until dazed and stupified by the heat.—"The Bunan Ceremony," American Anthropologist, Vol. IX., (1896), pp. 335, 336. Proc. Geog. Soc., Brisbane, Vol. XV., p. 68.

[2] Sometimes only one pair of holes were dug, and the novices were placed in them in succession while the tooth was extracted.

The man entrusted with the dental operation, then steps up and with his finger nail pushes back the gum from the tooth to be extracted. Sometimes a headman walks along and rubs the boy's gum with a large quartz crystal for the ostensible purpose of loosening the tooth and making it draw out easily. The extractor then places one end of a small wooden chisel against the front of the tooth and gives it a smart blow on the other end with a mallet, which forces it out.[1] More than one blow is often required to dislodge the tooth, which is then taken out of the lad's mouth with the man's fingers, and the gum pressed together. As the tooth is held up to public view, all the men, who are standing around, shout wirr! wirr! and call out the names of places in the novice's native country, as well as the totems of his family. A man near by swings a bullroarer. The blood which flows from the wounded gum must be swallowed by the boy—he cannot spit it out. The tooth is then handed to the lad's mother's brother, or to his mother's mother's brother, should he be living.

When all the lads have been operated upon, the guardians assist them to withdraw their feet from the holes, which are then filled up. The mallet and chisel are either burnt or are driven into the ground. The novices are then taken away to a resting place in the bush, where they sit down on leaves spread on the ground. Here they remain motionless, with their hands held to their sore mouths, and the rugs still on their heads so that they can see nothing of what is going on around them.

All the able-bodied men start away and leave the novices in charge of some infirm old fellows, and men who have been maimed by accidents or fights. These feeble protectors commence lamenting among themselves, so that the novices can hear all that is said, something as follows:

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[1] In some tribes both upper incisors were punched out.

"We are unable to take these youths through the bush and provide food for them. Our great-grand-fathers used to go about in canoes on the dry land as easily as on the water; perhaps they will come and help us." Just then a man, a little distance off, gently swings a bullroarer, so that its intermittent sounds apparently just die away upon their ears. The eldest man says to the others, "That is the distant ripple of the paddle of my father's father's large canoe; let us go and meet him and he will take us anywhere we wish to go."

They now assist the boys to rise, and all of them go forward for some distance, when they encounter the men who had gone away from them a little while previously. The old men pretend to be very much surprised at this opportune and unexpected meeting; and amid much apparent rejoicing the novices are given into the care of the same guardians who had charge of them before. It should be explained here that when the men went away ahead, as stated above, it was for the purpose of giving them time to paint their bodies and get their weapons and other belongings together, to enable them to perform their share of the rôle in the bush.

Men and boys now journey on till they come to a creek or waterhole where they intend to camp. A bough yard of a crescent shape is made, and leaves strewn upon the ground within it, on which the novices are placed sitting, with their heads bowed; and a fire is lit to keep them warm. If a novice wants anything he is not allowed to ask for it, but must make a sign to the guardian who has charge of him. The men set to work and dig several lttle holes, *papal'wa*, about the size of a wash-basin, and bend a small green rod, with some leaves attached, over each hole. The ends of the rod are inserted in opposite sides of the hole, the rod forming a vertical arch, the centre of which is a few inches above the level of the surrounding surface. These holes are then filled with water carried from the creek in native vessels. Some rush-grass is cut and spread flat on top of the water, where it floats.

All the novices are now brought up to the *papalwas*, where they crouch down and rest their elbows on the bank, and bend their heads and necks over the rods, while they each suck a mouthful of water through the net-like covering of loose rush-grass floating on the surface. They must not swallow the liquid, but keep it in their mouths, and rise to their feet. All the men likewise take a mouthful of water from the holes in the same way. Men and boys now approach the fire already mentioned and squirt the water out of their mouths upon it—as many as possible squirting at the same moment. The men then jump round and sing:

"Bingalga wanba warrana! yeh! woh!"

This chant is repeated over and over again for some time, and when it is finished the novices are allowed to drink a few mouthfuls of water by crouching down beside the *papalwas*, or water pans, as before. They are also given some human ordure and animal flesh. In a little while both boys and men go to rest for the night.

If the fire above referred to was extinguished by the water blown from the mouths of the men and boys, it was a bad omen, and portended that perhaps some evil would happen to the party whilst engaged upon their duties in the bush, or that some of the novices might divulge the secrets later on, and be punished with death for doing so. But if the fire blazed up again after a short time, it was a sign that everything would turn out right.

The following morning the party go out hunting, accompanied by the novices and their guardians. When stoppages are made in the bush, the boys are placed sitting upon green boughs spread upon the ground, and are not allowed to do anything. During the afternoon one of the men, who is remarkable for a rotundity of stomach, goes on ahead, and with the assistance of some friends who accompany him, disguises himself as a woman, and lies down in a sheltered place. His friends then stick spears into the ground all around him. Presently the rest of the party, apparently by chance, pass along that way, and pretend that they suppose the person lying within the circle of spears is a woman about to give birth to a child. The novices are brought forward to see the woman, and a number of men dance round outside the spears, singing:

Bandhanggorba wirralgiñ ngaia.

The dancing and singing only lasts a short time, and then all the party proceed with their hunting. On arriving at the place which has been agreed upon as their camping ground for the night, a yard is made for the novices in the usual manner. Between this yard and the quarters of the men, a space is cleared of the loose surface rubbish, and a fire lit to provide the necessary illumination. After the evening meal has been disposed of, the novices are conducted out of their yard and are put sitting down in front of the fire, while the men go through various burlesque representations. These performances consist for the most part of imitating animals, or of scenes from the daily life of the people, and are all accompanied by much merriment and obscenity. Some of the animals selected are the totems of those present, whilst others are connected with the myths and superstitions current among the different tribes.

During the next day, the burlesque of "Thunder," *murimuriwa*, is enacted. The novices are brought up to a place where several men are kneeling in a row, with pieces of bark in their hands. These pieces of bark are about two feet six inches long and about six inches broad at the widest part. The outside man at one end of the row hits the ground in front of him forcibly with his bark, and all the men utter a low, rumbling noise and strike the ground in succession. When this "peal" reaches the other end, the outside man there hits the ground with his piece of bark and is followed by the other men back to the original striker. This performance is repeated several times backwards and forwards and is intended to represent the rolling of distant thunder.

Some of the old men address the novices, saying "Your great-grandfathers are coming by and by to take you along in their canoes on the dry land." Presently the booming sound of the bullroarer, *muddyigang*, is heard and the loudness increases till it is quite close. The guardians call out as if addressing some one, "Wait a while! the lads will get into the canoes directly." Almost immediately the rugs are lifted off the boys' heads, and they are told to look at the men swinging the muddyigangs. Each guardian then says to his novice, "There is your grandfather." The swingers now advance and place a bullroarer under the arm of each novitiate, who is at the same time cautioned against revealing what he has seen and been taught during the sojourn in the bush. Each novice is cautioned by a warrior belonging to one of the strange tribes.

The reader will now be taken back to that portion of the narrative where we left the women and children covered over at the guanga. As soon as the men and novices get out of sight of the camp, the covering is removed by some old men who have remained in charge of them, and they are set at liberty. The mothers and female relatives of the novices then scrape together all the ashes and coals which had been thrown over the youths in the way described in an earlier page, and form a heap in the centre of the *guanga*. Each mother has a reed spear on the end of which she fastens the portion of her son's ngorē which she had secured that morning, as stated, and then inserts the other end of the spear into the mound of ashes, on the side which faces her native country. All the spears thus decorated with ngorēs, are now standing vertically, or nearly so, in the heap, and the mothers and other near relatives dance and jump around, singing the songs customary on such occasions.[1]

If any man belonging to the party who have charge of the novices in the bush, has occasion to go back to the women's camp on a message or for any other purpose, as soon as he appears in sight two of the women run to meet him, each carrying a reed spear with the ngorē attached. They hold the spear over the man's head and swing it in such a way that the dangling ngorē describes a circle all round his head, about a foot distant from it. Then the women run back to the guanga and stand their spears in the mound of ashes as they were before. If there are two or more men they are each saluted in the same way, after which they march up to the camp and explain the business upon which they have come.

The mothers of the novices eat practically the same kind of food which is given to their sons in the bush, and must remain silent the same as their sons. They sing the prescribed songs every morning at dawn and every evening at dusk ; and whilst standing singing they lift burning sticks from off the fire and wave them repeatedly towards the direction in which they suppose the camp of the novices to be situated. The novices, their mothers and their potential wives are all painted alike, according to the pattern of the tribe to which they respectively belong. Each tribe has its own distinguishing style of painting at these ceremonies. The mother of every novice has a woman to look after her

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[1] See my "Aboriginal Songs at Initiation Ceremonies," Queensland Geographical Journal, Vol. XVII., pp. 61 - 63.

and give her food. This guardian is generally one of the sisters of her husband, or one of her own sisters. Each mother has a small fire which she keeps alight all the time, and she heaps the soil or sand up around it so that it cannot be seen at a distance.

We will now resume the account of the proceedings in the bush at the point where the novices were shown the bullroarers, as described a few pages back. Next morning the neophytes are taken to a place where there is a patch of open and moderately level ground, from which the grass has been removed. Within this space is a sheet of bark, stripped from a gum tree, on which is cut the rude outline of a man about half life-size, representing Dharamulan, a mystic personage connected with the initiatory rites. Sometimes this figure is formed by heaping up the loose earth into the required shape; and in portions of the region herein dealt with there are other drawings on the ground, some being heaped up, whilst others are cut into the soil.

Lying on the top of the human figure are two real bullroarers,[1] one being the *muddyigang* or larger kind, and the other the *yirraga-minnunga*, which is supposed to be the wife of Muddyigang. The novices are brought up and shown the image of Dharamulan, with his two descriptions of bullroarers, and are invited to carefully observe them. The men then dance round and sing:—

Dharamulan ngunning-a-wa
Nundhunna, yeh! yeh! yeh!

After this exhibition, the youths are warned against revealing anything which has been said or done in the bush, under terrible penalties of being cruelly murdered, or being

[1] Among the Yarra and Saltwater River blacks—the Wurrundyirra-baluk—where the Wonggoa Ceremony also extends, the bullroarer is called *berber'ogan*. I got this name from "Billy Berak," a Woiwurrung blackfellow.

seized with fearful maladies from which it is impossible to recover.

One evening after dark the men play the opossum game, *dumpul.* Several men of different stature ascend a tree with dense foliage within sight of the camp fire. This is done unknown to the novices. By and by the other men say "Let us see if there are any opossums in that tree?" and commence throwing sticks up among the branches. Some of the men in the tree mimic the call of opossums and micturate down upon the ground in imitation of a habit of those animals. The men then descend the tree, one after another, at intervals of a few minutes. A hunter stands at the base of the tree, and as each "opossum" comes down he apparently hits it on the head with a stick and it falls upon the ground. During the performance the audience make remarks upon the size and appearance of each animal "killed"—that it is large, small, fat, and so on. The last "opossum" to descend is the biggest of the lot, and as the hunter knocks it on the head, it falls on its back exposing the genitalia, and all hands call out, "That is an old buck!"

Different burlesques and songs take place every day and every evening, but their essential characteristics are the same. Among these performances for the instruction and amusement of the company are mimic plays of the locust, native companion, kangaroo, porcupine and other animals.

At all times when marching along through the bush care is taken that the boys shall not walk under a leaning tree, nor between two trees the branches of which press against each other, because their future growth might thereby be impeded, or some other bad luck befall them. If a novice's belt works loose and falls to the ground, it must not be picked up and given to him again. His guardian takes off his own belt and gives it to the boy, and takes in exchange the one which fell off. And if it be necessary to cross a watercourse or swamp when out hunting, the novices are carried over on the men's shoulders.

Whilst the men and novices are away in the bush, if any of the men at the women's camp wish to go out to see them, they shout *bu-u-u*! when they arrive within hearing, and the bush mob answer them in the same way. They march on, uttering the same sound, and are answered again and again until they get close enough to the men's camp, where they are met by the old chiefs, and state the purport of their visit.

Every aboriginal camp is kept free of excrementitious matter. When any of the people attend to a necessity of nature, they make a hole in the ground and cover the deposit over with earth. This is perhaps not so much on account of cleanliness as from their superstitious fear of anything belonging to them being picked up by evil spirits, or enemies prowling about the camp, at night or any other time.

When the ceremonies in the bush are over, the novitiates are brought back to the confines of the women's camp, where a wall or screen of boughs has been erected, and a fire lit at the butt of a tall tree close by. When the men and boys get within about a mile of this place, they form into a sinuous line, and advance in a kind of jog. All the novices are in the front, painted and having a forked, leafy bough fastened on each shoulder. Each boy's mother's brother runs in front of him, with his guardian on one side. On arriving within sight of the bough screen, the mothers and aunts go out to meet their sons, each carrying a bunch of twigs in her hand. A mother and her sister take their places one on each side of her son and jog on with him. They each strike him lightly on the hips with their twigs, and shout "*yer! yer!*" as they move onward. When the novices arrive in front of the fire, they come to a stand,

and the mothers and aunts take up their places farther back. Men who are in attendance place green bushes on the fire—the women and novices throwing their boughs on top of the rest. As soon as the bushes have burnt sufficiently to create a dense smoke, the novices are held in it by their guardians until they are partially suffocated. They are then conducted to a place prepared for them not far from the men's quarters. They are now called Narramang, and can go out hunting with the men.

Early next morning the catechumens are again marched away by their guardians and the old men, for the purpose of receiving further instruction, and are kept in the bush for such time as may be fixed by the elders. At the end of the prescribed period they are again brought back to the vicinity of the women's camp and are required to stand in a dense smoke. They are then released and are placed sitting on a seat prepared for them. This seat, *karkaria*, consists of two long logs of wood laid side by side, with leaves thickly piled up on top, for the lads to sit upon. Their mothers have placed netted bags containing food beside the seats for their sons' use. The old women and the mothers of the boys are looking on a short distance off, but the young women must turn their faces the contrary direction.

Every novice must spend a further term of probation among some of the visiting tribes. It is also necessary that they must attend one or more additional *wonggoa* gatherings before they can become thoroughly acquainted with the different parts of the ceremonial, and be admitted to the higher grade. The novitiates are kept under the control of their seniors for a considerable time, being longer for the younger boys than for those verging upon manhood. During this period they must not learn to speak the dialect of the people among whom they are sojourning, because every boy is required to perpetuate the speech of his forefathers. A youth is generally sent to spend his probationary term in the tribe from which he is to get his wife by and by, when the old men are satisfied that he is entitled to that privilege. A portion of the scarring of the youth's back, arms, and chest, is executed during this time, and he is instructed in the dances, songs, and folklore of the people. The position, extent and pattern of the scarring is regulated by the custom of the tribe to which the novitiate belongs. When a youth has been scarred he is called *yenyannga*. See "Mūmbirbiri or Scarring the Body," *supra.*

I have elsewhere described the Kannety ceremony of initiation, practised by the aborigines of the south-western districts of Victoria from Geelong westerly to the South Australian boundary. I have also published full details of the Wonggumuk ceremony, which is in force in portions of the central and northern districts of that State.

The Tyibbauga Ceremony.

In the course of some months, or it may be a year or two, or perhaps several years, after the youth has passed through all the grades of the Wonggoa ceremony, he must submit to the further rite of *Tyib-bau-ga*. The interval which elapses between the two inaugural courses is entirely in the hands of the old chiefs, being regulated by the boy's age. It is not necessary to form a circle upon the ground, like the *guanga*, neither is it imperative to convene the whole community, as in the ceremonial of the *Wonggoa.* But it is generally considered politic to consult with the leading men of some of the neighbouring tribes, who may desire to witness the proceedings, or perhaps bring a few boys of their own to be initiated, Messengers, who must be men who have passed through all the rites connected with the ceremony, are despatched to arrange the preliminaries, and when the time arrives the people proceed to the place appointed.

It not infrequently happens that while a batch of novitiates are passing through the *Wonggoa*, and before the tribes disperse, such of the young men present who have submitted to the requisite course of instruction at previous meetings, are taken charge of by the headmen, and are admitted to the final degree of *tyibbauga*. This is done to avoid the trouble and delay of mustering the people again. It will in some respects be more convenient to describe the procedure respecting one of the novices only, asking the reader to remember that they are all treated alike. The following details were related to me by a man who had been thus initiated.

The candidate for initiation is taken from the single men's camp early in the morning, unknown to the women. A rug is thrown over his head, and he is escorted by some strange men to a retired spot a little way out of sight. Here a fire has been lighted beside which are lying ready for use several bundles of the dry outer bark shed in the spring time by the upper branches of some forest trees. A man steps up to a youth and catches hold of the hair on one side of the head whilst another man singes it off, little by little by applying a lighted taper made of the bark just referred to. This is done carefully and takes a good deal of time—just sufficient blaze being applied to remove the hair without injuring the boy's skin. The hair on the other side of the head is singed off in the same manner. Along the middle zone of the skull, from the forehead to the back of the head, a strip of hair, about two inches wide, is left intact, and is curled into a ridge. Both sides of the head from which the hair has been removed are then daubed with pipeclay mixed with common earth. The hair in the armpits, and the pubic hair, is also singed off. If any of the youths have an inceptive beard it is similarly dealt with.

It should be explained that the hair on the sides of the boy's head is not wholly consumed, like that growing on the other parts of the body. The operator separates it into small wisps or coils, which he holds out horizontally, one at a time, and then applies the taper near the roots, thus severing the hair from the head. The whole is then wrapped up with green leaves and tied round with string made of opossum fur. This is attached to the desiccated tail of a native dog, and hung upon a neck-lace which is worn by the *guguba* or maternal uncle of the lad's mother.

The youth's body is greased and white stripes of paint drawn upon his back, and from his forehead down his nose, chest and stomach, extending right down to the end of his penis. A belt is put round his waist, and green, leafy boughs fastened in it to represent an apron or *burrandity*. A forked green bough is fastened on each shoulder.

By the time these preparations have been completed it is well on in the afternoon, and the novice is kept in a quiet place out of the way of traffic. Most of the men and women are away hunting, and return to the main camp about an hour before sundown, and commence preparations for the evening meal. When everybody is busy dressing and cooking the results of the day's hunting, the graduate is brought out suddenly and runs in amongst them, shouting Hoh! hoh! yeh! yeh! waho! He jumps and shakes his legs like the men do at corroborees. In one hand he carries a piece of smouldering bark, around the proximal end of which green twigs are tied. In the other hand he holds a club or other weapon, with which he occasionally taps the burning bark, making sparks fly in all directions.

He promenades from one group of hunters to another all about the camp, gesticulating and shouting in the same way. He then withdraws to the place prepared for him near the men's quarters, where his guardian and a few old chiefs look after him for the night. He sleeps with the forked boughs on his shoulders, but next morning he casts them away. His guardian then provides him with a bag, *dhulang'munna*, made of kangaroo skin, with a loop made of string attached, so that it can be slung over the shoulder. His head is freshly plastered with clay, and the painting of his body is also renewed.

The graduate passes the loop over one shoulder, letting the dhulangmunna hang under his arm on the opposite side. In this bag he carries excrement of dogs and other filth. He starts away at a sort of jog, shouting, and goes to a camp in which is a girl who has been betrothed to him. She steps forth and puts some stinking fish, maggotty flesh or the like, into his bag.

He passes on to another camp where a man or woman will perhaps call out "Tyibbauga! fetch me some water." He answers, "waho!" and taking the vessel offered to him, scampers off to the creek or water-hole and brings back a small quantity of water with dirt in it. The person refuses this, and then the novice goes and brings good water. Several different persons may make the same request, and be similarly responded to.

Some one will ask him for food and he offers them some of the evil-smelling commodities out of his bag, or perhaps he brings them a few bare bones. Or he may offer them stones, leaves, or grass. An old man may want him to bring some firewood. He goes and gets a small stick about as thick as a man's finger and a foot or two long, which he carries on his shoulder, pretending to groan under its great weight and throws it on the fire.

Some days he carries in his bag a live "sleepy lizard" or a snake out of which the poison fangs have been taken by means of a stick. In passing women and children sitting down he casts the reptile in amongst them, which scatters them hither and thither. He is not permitted, however, to catch hold of a woman, or to interfere with any of her work. Another time he collects a few rotten toadstools, pieces of putrid meat, pounded charcoal, or human excreta, and proceeds on his rounds. He will raise a loud lamentation, and on the people running to him to see what is the matter, he pelts them with the contents of his bag. Perhaps he has in his bag a live opossum from which all the fur has been plucked. He suddenly liberates the animal, which runs away among the spectators.

If he finds a little boy going about by himself, he picks him up and runs towards a water hole with him, pretending he is going to drown him. On being pursued by the child's mother, or another woman, he lets him drop, and goes on. Whilst travelling through the camp he is constantly gesticulating in an indecent manner, and if he has to comply with any necessity of nature, he does it wherever he happens to be at the moment, in view of everyone.

If the graduate sees some men sitting at a camp, he will challenge them to come and wrestle with him. If they are roasting a small animal on the coals, he may rush up and upset it into the dirt, or cast filth upon it, or perhaps he will take hold of it and put it into his bag.

If a number of women or girls are bathing in a river or waterhole near the camp, he sneaks up close to them under cover of some bushes, and suddenly dashes out shouting and gesticulating to make them believe that enemies are assailing them. Several men run to the rescue, pretending they think some wild blacks have attacked the women, and the graduate disappears.

The guardian renews the painting of the novice's body and the sides of his head every morning and sees that the contents of his bag are satisfactory. He also provides the youth with a burning brand, composed of two pieces of dry bark placed side by side, which he carries in his hand, enveloped in green leaves. As soon as this bark smoulders away, it is replaced. The novice usually carries a weapon, as a shield, a club, a spear, a tomahawk ; it is the guardian's duty to supply him with these.

Young women who are eligible to the graduate in marriage, encourage him by replenishing his bag, and potential brothers-in-law afford him every opportunity of displaying his buffoonery. At intervals during all the peculiar ceremonial practises of the graduate, above described, he calls out "Hoh! Hey! Waho!" whilst perambulating the camp. Sometimes he jumps and quivers his legs ; at other times he goes at a jog, swinging his body from side to side ; or any comical attitude in which he has been carefully drilled by his guardian. Where there is a chance of introducing the obscene or phallic element, it is taken advantage of.

It is part of the ordinary routine of the ceremony that a number of demands shall be made upon the novice during his peregrinations. Every man or woman who wishes to assist him in consummating the prescribed ritual calls out "Tyibbauga!" and is answered by the shout "Waho!" The order is then given and it is the duty of the novice to comply with the requests of the people, or at any rate make a pretence of doing so.

The guardian or sponsor of the graduate is somewhere whithin view all the time, and when the evening approaches he takes his ward back to their own camping place, where he attends to all his wants and "coaches" him for the duties of the next day. These itinerary performances, with variations, continue from day to day until the hair, which was singed off, begins to grow again. None of the performances above described are ever enacted by the youth during the night time, but are confined exclusively to the day.

When the council of old men considers that all the necessary procedure has been gone through, the perambulation of the camp is discontinued, and the youth is taken to the single men's quarters, where a place has been assigned to him. He is not allowed to go into the women's camp, nor must he converse with any woman whom he meets. The guardian and his people then give presents of spears, rugs and other articles to the graduate's father and his people; and the latter in return make gifts to the guardian's friends, at a meeting which has been held for that purpose. The graduate has now attained the final step in the initiatory course, and after a time he will be allowed to claim the bride who has been betrothed to him, and exercise the rights and burdens of tribal membership.

The Dolgarrity Ceremony.

Another form of initiation ceremony, called *Dol-gar-rity*, of which the following is a condensed description, was practised among the tribes who formerly roamed over the north-western districts of Victoria from the Avoca River[1] westward to the South Australian boundary, and extending from the Murray River southerly to the main range. The following particulars were gathered by me in the native camps.

The preliminaries connected with convoking the neighbouring tribes at an appointed meeting place were substantially the same as those adopted in the Wonggoa, but there was no circular enclosure like the *guanga* at the main encampment. There was, however, a level portion of ground cleared of all loose sticks and rubbish, for the purpose of dancing on.

As soon as all the tribes who are expected in answer to the summons of the messengers have made their appearance the chief men of each contingent consult together, and fix the day on which the principal function of the meeting

[1] For the language of these people, see my article on "Die Sprache des Tyeddyuwurru-Stammes der Eingebornen von Victoria," Mitteil. d. Anthrop. Gesellsch. in Wien, Bd. xxxiv., S. 71 – 76.

shall commence. They also choose the boys who are to be operated upon, but this information is not communicated to the women. When the eventful morning arrives, all the people get up at daybreak, and congregate in a central portion of the camping ground. All the boys are mustered out of the whole camp and are put sitting in a row on green boughs or pieces of bark spread on the ground for the purpose. Several men who have been selected to take charge of the boys are standing opposite, and have been carefully instructed by the chiefs what boys are to be picked out from among the large number who are sitting in the row in front of them. The time of life at which a youth is considered ready for the ordeal is determined by the first appearance of hair on the pubes and chin.

Each man has a small quantity of pipe-clay, in a liquid state, concealed in his mouth. One of these men, pretending to discern a stranger in the distance, says to his comrades "Who is that coming yonder?" Another man answers, "Probably some one to see the boys." This causes the youths to turn their heads rearward to look at the supposed new comer. As soon as they do so, each man puts his forefinger into his mouth and pulls it out covered with pipe-clay; and on the boys again facing round to the front, the men step up to them, and with their fingers draw a white line down the faces of those who have been chosen, from the forehead to the chin. This is a signal to the women, as well as to all the other people in the camp, that the youths thus marked have been taken possession of by the elders, and the remainder of the boys in the row are then dismissed.

The men who have been deputed to act as guardians to the novices now take charge of them and paint their bodies with red ochre and grease—the hair of their heads being combed with pointed sticks and decorated with white feathers. When all is ready a number of men armed with spears surround the boys and their guardians, shouting and beating their weapons together, and all of them march away. The mothers of the novices, as well as the other women present, make a pretence of resistance by gesticulating frantically and throwing small sticks over the heads of the men, but do not attempt to follow them.

Rugs are then thrown over the heads of the graduates and they are conducted about a quarter or half a mile into the bush, and put sitting down on bushes, in charge of a few feeble old men. The strong agile fellows go forward a short distance, for the purpose of painting their bodies and otherwise preparing themselves for their duties. The novices being now alone with the old men, the latter pretend to discuss with each other, so that the boys can overhear them, something to this effect: "All the active young men have gone away and left us poor old fellows to provide for these youths. We cannot climb trees to catch opossums or similar animals or procure honey. Neither can we run after game upon the ground. What shall we do?" Then they chant a melancholy song to suit the occasion, and some of them pinch the ears of the dogs to make them howl. This has a very depressing effect upon the poor novices who are sitting motionless, with the rugs still over their heads, so that they can see nothing of what is going on around them. Presently one of the old men says, encouragingly, "Never mind, we will do our best to obtain food for the boys and ourselves. We can climb leaning trees for opossums, and perhaps catch a few fish, or procure some yams and grubs." After a while they help the novices to their feet and lead them along till they reach the place where the other men went to a short time before. They induce the novices to believe that they have accidentally come upon their friends again. Each graduate is now given into the charge of the man who is to act as his guardian and sponsor throughout the remainder of the proceedings. The guardian must not belong to the novice's own people, but is selected from one of the visiting tribes into which the lad could lawfully marry later on.

The whole party now starts away and proceeds to a secluded locality previously agreed upon, perhaps some miles distant, where a camp is formed and the graduates are placed lying down on a layer of green leaves upon the ground, and are covered over with cloaks or grass—their guardians remaining with them. A fence of boughs is erected around where the boys are lying, to protect them from the wind. This yard resembles a horse-shoe in shape, with the open end to leeward, and all the men make their own camps in close proximity. Between the quarters of the novices and those of the men a space is cleared of all sticks and grass, and one or more fires lighted beside it. In the evening, after the youths have partaken of their allowance of food, they are placed sitting in a row near this prepared spot, and the men go through various semidramatic performances, consisting of imitating the characteristic movements and calls of different animals, and indulging in many obscene gesticulations which are usually practised on similar occasions, described by me in treating of the inaugural rites of other tribes.

At the close of the evening's functions, all hands lie down to rest. During the night the boys are not allowed to sleep soundly. The guardians keep continual watch, relieving each other in turn. Just as a lad drops off to sleep he is roused up again. Next morning the men go out in quest of game, but the guardians remain with the boys all day and prevent them from going to sleep. That evening shortly after dark, a number of young men, under the direction of the elders, provide themselves with large green boughs, and run past where the novices are lying, shaking and rustling the boughs, thumping their feet on the ground, and uttering humming sounds in imitation of the roaring of the wind. If any small saplings are growing near, they are snapped off with a crash by some of the men. This rushing past may be repeated several times, to make the lads believe a violent tornado is blowing. When the "storm" ceases, men and boys seek their night's repose, but the latter are awakened at short intervals, as before.

On the following day the depilation of the graduates is commenced. The boys are carried out of the yard and placed on their backs on couches of green bushes. They are so worn out by having been kept awake so long that they are in a state of semi-slumber and take but little notice of what is done to them. A man sits down beside each novice and begins pulling out the hair from the pubes, under the arms and the incipient beard. When one man becomes tired he is replaced by another; or two men may be employed on the same youth. Beeswax or gum is used upon the ends of the fingers to facilitate catching the hair, which is pulled out singly. The men of the novitiate's own tribe do not take part in the hair-plucking operation—this duty devolving upon the men of some of the strange tribes present. The pluckers must be men who have been initiated in the same way at previous gatherings, and are the potential brothers-in-law of the respective novices who are assigned to them. The youth is not allowed to see the face of the man who pulls out his hair, but must keep his eyes closed.

Some of the headmen of each tribe sit on the ground near by directing the proceedings, and a bullroarer, *bumbir-bumbir*, is sounded in the vicinity. The hair pulled out of each youth is kept carefully by itself, and is given into the charge of one of his relatives, in the same way that the extracted tooth is disposed of in other districts. When the plucking out of the hair has been completed, the novices are raised to their feet by their guardians and other men, amid the plaudits of the assemblage. Each graduate is then painted, and is invested with a brow-band, *mullengaran;* a man's waistbelt, *ngeyir;* an apron, *pain-dyip.* Strips of the skin and fur of a ring-tail opossum are fastened round the biceps and the fore-arm—each arm being bound in three or four places. Kangaroos' teeth are fixed in the lad's hair, and a neck-lace, *dyakurn*, made of pieces of reed on a string, is placed around his neck. The novices are then cautioned in an impressive and earnest manner against divulging the details of what they have passed through to any person except the initiated.

Next morning after breakfast the men start out hunting, taking the graduates with them. The latter are freshly greased and painted, and carry a small green bush under each arm. When one of the novices becomes thirsty, he is allowed to crouch down on his elbows and toes at the margin of a pool or stream, and suck up the water into his mouth through a hollow reed which is given to him. The guardian stands alongside and places his foot under the boy's throat, for the purpose of making the swallowing of the liquid difficult and slow, so that he may not drink too much.

During the day the novices are brought within view of a kangaroo, wallaby or other animal lying dead upon the ground. Several men are walking about it, imitating eagle-hawks and making the peculiar whistling call of that bird. Upon being disturbed, they run along swaying their arms up and down to represent the flapping of the wings of these large birds to enable them to raise their heavy bodies from the ground when they commence to fly away from their prey. Sometimes this performance is varied by the men representing crows instead of eaglehawks. In such case, the action and cry of the crow is mimicked.

One evening by the light of the camp fires, a man takes a small stick about fifteen or twenty inches in length, and binds a piece of the pelt of some animal, newly skinned, on one end, which he inserts into his anus, the free end of the stick having previously been lighted in the fire. The man now moves back into the darkness, swaying his rump with the fiery caudal appendage from side to side, in imitation of the bird known as the "willy-wagtail." Several men may engage in this performance and sing the prescribed song.

A week or more may be spent at these camping places in the bush, the time being regulated by the weather and other considerations. The programme of performances changes every day, and each dramatic entertainment has its own appropriate song, which is chanted by the men engaged in it, or by the old men sitting near the fire. The graduates are shewn the larger bullroarer, *bumbir-bumbir*, and also the smaller one, *mattyamuk*, who is the wife of the former.

In the remainder of the ceremony, from this point onwards to the end, the procedure closely resembles the corresponding portions of the Wonggoa, already described, and will therefore be passed over. The graduates have to pass through this ordeal of depilation at not less than two or three different meetings of the tribes for that purpose before they can be admitted to full membership, and be called *birnapkil*.[1]

Notes on the Initiation of Girls.

During several interviews with an old woman of the Wuddyāwurru tribe respecting the language and customs

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[1] Compare the foregoing summary with my description of the "Initiation Ceremonies of the Barkunjee Tribes," who adjoin the people herein dealt with.—Journ. Roy. Soc., N.S.W., Vol. xxxii., pp. 241 - 255, with map of territory. See also my "Multyerra-Initiations-zeremonie," Mitteil. d. Anthrop. Gesellsch. in Wien, Band xxxiv., S. 77 - 83.

of her people, I obtained the following information respecting the initiation of girls. At the first sign of the menstrual flux, the girl is taken charge of by an elderly female, who is not her mother, and is removed into the adjacent bush. They are accompanied by some young matrons who help the old woman in her duties. After painting the novitiate, her arms are decorated with strings cut from the skin of the ring-tail opossum, with the fur on. These strings are bound round the upper arm about midway between the shoulder and the elbow and also round the thick part of the forearm. The strings are not wound tightly on the arm, but like any other bandage which closely fits the limb bound, they cause the arm to swell after wearing them for some time.

The old dame, assisted by those who are with her, builds a fire by laying wood upon the ground and applying fire until it is well ignited. Green bushes are then laid on top of the fire, and on top of this covering of bushes earth and sand are thrown to prevent the wood from blazing up, and to augment the issue of smoke. Two of the women present help the novice to get on top of this smouldering heap. When she has remained in the smoke for a considerable time, the old woman hands the girl a yamstick, with which she jumps off her smoking pedestal.

In the meantime, a hut or shelter has been erected of boughs, into which the novice is put by herself and she sleeps there all night—the other women sleeping a few yards away. Next day the smoking ceremony is repeated in the same manner, morning and afternoon. This procedure is continued until the novitiate is cleansed. The bandages are then removed from the girl's arms and she is painted as before. A girdle manufactured from the fur of animals is now put round her waist, from which depends a narrow apron, *ngurraty*, made of emu feathers, covering her pudendæ. When the novice has passed through this ordeal she is called *ngurramdurragurk*, an initiated woman, and may be claimed in marriage by the man to whom she was assigned from her childhood.

Among the Yota-yota and adjoining tribes on the Murray River, the ceremony of "making young women" is called *dhuddiwai*, and may be described shortly as follows: When a girl reaches puberty she is taken away some distance from the camp by an old female relative. A moderately large fire is lit, and when it burns quite down, the embers and ashes are scraped off. Green leaves are then strewn thickly upon this warm ground, and the girl is placed sitting on top of the leaves until she is clean, being looked after by the old women who are there. The first flux is called *durguggimuty*, but a woman during her monthly period at any time thereafter is called *gartyibulla*. When the novice passes through this ceremony she is known as *dhuddiwai*, and is painted like the other women of the tribe.

On the Mitta Mitta and Ovens Rivers the following is a brief outline of the procedure as told to me by an old native: At the first appearance of puberty, the girl is taken out of the camp by some old women, and her body is anointed all over with opossum fat and ground charcoal. The fresh skin of a ring-tail opossum is procured and cut into very narrow strips. These strands, with the fur remaining upon them, are then twisted until they become small, rounded strings, resembling cords. The arms of the girl, both above and below the elbow, are then bandaged with a few coils of this string. She is now lifted into the fork of a sapling or tree, from six to eight feet above the ground.

A fire is lighted at the butt of the tree, on the windward side of it, and a number of green boughs laid upon it. Presently a dense smoke is produced, which ascends up around the girl, the quantity of fume being regulated so that it shall not suffocate her. This lasts for some hours, when the novice is removed to a camp close at hand, where she and her companions remain for the night. The same ceremonial is repeated for a day or two longer, or until the old women are satisfied that their object has been attained. A waist-belt is now given to the girl, to which is attached a small apron, *dyabeng*, which hangs down in front. She is now qualified to become a wife.

After a married woman has a child, she and her babe must be smoked by her old women friends, before she can appear in the main camp. See also "Childbirth," *ante*.

Aboriginal Mythology and Folklore.

Under this head will be recounted a few of the fabulous or romantic stories current among the aborigines of New South Wales and Victoria, which have been written down by me from the mouths of the old men and women from time to time. The folklore of any primitive people is always valuable, as showing the bent of the human mind in its earliest development, in accordance with the different surroundings and conditions of life. Many native stories are a mixture of legend, folklore and superstitious belief, and could perhaps be classed under one or other of these designations. I shall not, however, trouble with any classification at present, beyond trying to include specimens of the different kinds of tales.

Throughout their folklore we find evidences of the proclivity of the native mind to account for any specialities of animal structure or peculiar habits, as well as the remarkable forms of lakes, rivers, trees, hills, and other natural phenomena. In perusing all the different classes of tales, we find ourselves revelling in a new field of wonder and beauty—the fairy land of Australian romance and poetry.

Mythologic ancestors and fabulous monsters—a class of genii—form a conspicuous element in their legends. Some of these magical beings reside in the mountains, others in dense scrubs, others in the clouds. Some have their abode in deep waterholes, others live in the trees, others again have bodies which glow like burning coals. Some of them have the power of altering their shape, or of increasing or diminishing their size, at pleasure. Some of them can vanish into the air, whilst others disappear under the ground. All of them, with a few exceptions, are more or less maleficent. Whether in human shape, or as monstrosities, these creatures of aboriginal fancy or exaggeration were possessed of supernatural powers; and many of their habits were different from those of the present race. Some of them could form water-courses; some could cleave mountains asunder and make hills from the material; others had the power of causing springs to burst forth. Some were assisted in their work by means of magical weapons and wonderful dogs.

Obscenity is a prominent characteristic of all Australian folklore. It is persistent in their rock pictures, in their initiation and other ceremonies, as well as in their dances and songs. Where the indecent element has been eliminated by missionaries and others, the peculiar manners and character of the people have lost much of their real personality. Human ordure also has its place in their mythology, as well as in their most important ceremonies. It is supposed to possess many virtues, among which may be mentioned the power of speech, to personify the individual who deposited it. It also enabled a man to catch whatever he was pursuing, by the magical effect of its odour. Human fat also holds an important place in native enchantments.

If the various ceremonies of the aborigines can be called a religion, it amounts to no more than a mystery and a craft, in which the old sorcerers and warriors are the chief personages. Sometimes a sorcerer was supposed to intercept the fleeting spirit of a dying person and so save his life. Others professed to chase away supernatural enemies by their menaces and gramarye. Others pretended they could ameliorate the cold of winter by casting hot coals towards certain stars. Some professed to be able to cure disease by enchantment. Others again claimed to have the power of bringing rain and causing the food supply to increase by means of magic arts.

Stories similar in character to those recounted in the following pages are found in every tribe throughout all the Australian States. Necessary local variations are introduced in different districts, to accord with divergent practices and modes of living, but the radical elements are the same. Moreover, the animals which took part in these folk-tales, everywhere in Australia had the same phratries, sections, clans, etc., as the people of the tribe where the tale is current.

In every part of Australia which I have visited, the bat and the night-jar hold a peculiar place in the superstitions of the people and figure largely in their stories. The former is the friend of all the men and the latter of all the women. In some tribes the woodpecker (tree-creeper) is substituted for the small night-jar. Rev. L. E. Threlkeld was the first to discover and report these specific totems of the two sexes. In his grammar and vocabulary published in 1834 he states:—"*Tilmun*, a small bird the size of a thrush is supposed by the women to be the first maker of women, or to be a woman transformed after death into that bird ; it runs up trees like a woodpecker. These birds are held in veneration by the women only. The bat, *kolung-kolung*, is held in veneration on the same ground by the men, who suppose the animal (bat) a mere transformation."

Baiame.—A little better than half a mile westerly from the railway station at Byrock, on the Western Railway

Line, 460 miles from Sydney, town of Byrock, parish of Bye, county of Cowper, there is an outcrop of granite, about an acre or more in extent. It is irregular in shape and does not project more than a few feet above the surrounding country, which is practically level. The aboriginal name of this granitic outcrop is *Bai*, a word signifying the semen of men and animals.

On various parts of the exposed surface of the rock there are a number of patches of a reddish-brown colour, the staining being due to oxides of iron introduced by natural agencies. These stained patches vary in size from a few inches to several feet. They are of different forms, and the imagination of the natives has assumed certain ferruginous outlines to represent hunting and fighting weapons, utensils, tracks of men and animals, sacred instruments, and other objects connected with their daily life. I made a rough survey by compass and pacing of the positions of some of the most important of these delineations, and submit the following descriptions of them.

Near the northern extremity of the rock is a small hole in which water collects in rainy weather and also during every thunderstorm which falls, and remains for a considerable time. This little "rockhole," called in the native language *wuggarbuggarnea*, was a great camping place of the aborigines when this part of the country was first occupied by European settlers. And there is still residing, in close proximity, the remnant of the old Ngēumba tribe, accompanied by a few friendly aborigines from the surrounding country.

Baiamē, the principal hero in the mythology of these people, is said to have had his home at this rock in the faraway past. He dug the water hole with his stone hatchet, and everytime it became blunt during the operation, he whetted it on the surface near him. The pictorial stains on the rock are believed to have been caused by Baiamē laying down his magical weapons and other articles of his equipment at different places upon it, the impressions of which cannot be effaced.

About half a chain north-easterly from the rock-hole is a natural depression in which sand and drifted soil collect. This is supposed to have been the hole in which Baiamē cooked his game and other articles of diet. S. 45° E. from the cooking-hole, and thirty-five links distant, is a very good figure of a bullroarer (*muddhiga*), eighteen inches long and nine inches across the widest part. Continuing the same south-east bearing for a farther distance of 140 links brings us to the imprint of a prodigious fighting club, six and a half feet in length by nine inches wide, called *dhurtubirra*. Starting from this club and going south for two hundred and fifteen links we come to a figure which has some resemblance to a monstrous boomerang, nine feet and a quarter long by eighteen inches in width. Again starting from the dhŭrtubirra or club on a bearing of S. 40° W. we find another boomerang-like formation, two feet nine inches long and nine inches wide.

Close to rock-hole wuggarbuggarñēa, is a narrow, coloured streak, trending in a westerly direction for several yards, which is said to be one of Baiamē's spears. On a bearing of N. 25° W., from the rock-hole, at the distance of 25 links is a *gululla* or native bag carried by the men, three feet long, with a string attached for swinging it over the shoulder.

On another portion of the rock is a tolerably good representation of a human footmark, two feet long and nine inches across the widest part. It is the right foot, and has five toes, the great-toe being about twice the length of the others.

Here and there at wide intervals on the rock surface are grooves worn by the actual grinding or sharpening of stone hatchets, similar to the grinding places reported and illustrated in my article.[1] These grooves have been made by the present and past generations of natives, who have lived and hunted in the neighbourhood. A portable stone carried by the natives in their bags, and used for whetting any of their stone weapons, is called *giwai*. At other places there are hollows in the rock where Baiamē is believed to have pounded nuts and ground grass-seed for the purpose of making cakes.

There is a long straight crack in the rock, varying from two to three feet in width, and about a foot and a half deep, commencing at the rock-hole and bearing S. 25° E. for about two chains and a quarter to the smaller boomerang above described, and onward for a little way farther. This is said to be the trail along which Baiamē dragged his fire-wood and larger game. It also served the purpose then, as at present, of conducting storm water into the rock-hole. Further imaginary portrayings include tracks of dogs and other animals, the moon, stars and different objects, which I had not time to examine.

Several miles from Byrock, near Coronga Peak woolshed, on the road going to Wilgaroon, there is a tank or dam which has been made for watering stock. On the left of the road in this locality, and not far from the tank, is a large rock called *Gu-lum'-bur* in the native speech. On this rock are some ferruginous stains similar to those already described, which are said to be the marks of Baiamē's rump where he sat down to rest himself, his foot, his hand, etc. At what is now the great copper mines at Cobar there was formerly a cave or hole in the rock, which was one of the camping places of Baiamē in the days of long

[1] "Some Stone Implements Used by the Aborigines of New South Wales," Journn. Roy. Soc. N. S. Wales, Vol. xxviii., pp. 301 – 305, pl. 43, fig. 3.

ago. This hole sloped inwards, and there was red ochre on its sides. Kūbbŭr in the native word for red ochre, and has been corrupted to Cobar by the white people. The old aborigines told me that before the copper mines were worked, there were footmarks, boomerangs, bullroarers, and other delineations on the rocks. The ore of copper visible on the surface was believed to be Baiamē's excrement deposited during his residence in the cave.

It is related that Baiamē started from Cobar after a wild bee, on the feet of which he had put bird's down. He followed the insect all the way to a large rock at Wittaguna, in a cleft of which was the honey comb, which Baiamē succeeded in securing. There is still a bee's nest in that rock, but ordinary mortals cannot reach far enough into the crack to get at the honey.

Baiamē then went away northwards and formed a camp in the solitudes of a forest. All the large trees lean towards the camp from all surrounding points,[1] but the small shrubs and berry-bearing trees grow straight up. Hanging from the branches of the larger trees are bullroarers which are always sounding. [Wongaibon and Wirraidyurri Tribe.]

Dhurramulan.—Dhurramulan was a sort of half brother or near relative of Baiamē's. His name is made up from *dhurru*, thigh, and *mulan*, one side, the whole name meaning leg-on-one-side, as he is said to possess one leg only. He is also called *ngullagelung*, from *ngulla*, a tree, because he lives in the trees. He had a voice like the rumbling of distant thunder. It fell to his lot to separate the youths from their mothers and teach them the Burbung ceremonies. Dhurramulan had a fire or oven in the bush, in the bottom

[1] Compare with my "Journey to Kurrilwan," the fabled home of Baiame among the Kamilaroi tribes. Folklore of the Australian Aborigines, (Sydney, 1899) pp. 15 - 19.

of which were stones, which were kept continually hot. The novices were brought to this place, with rugs cast over their heads, so that they could see nothing of what was going on around them. Dhurramulan caught a boy and hit him on the back of the head, which caused one of his front upper incisors to fall out. The tooth, by Dhurramulan's gramarye, then became a *gunabillang*, or rock crystal, a sacred stone used in these ceremonies of initiation. He then cast the lad into the fire and scorched all his hair off. Sometimes he burnt the boy to ashes, and being a great sorcerer, was able to restore him to human shape. He fed the lads on wallūmbil, a small wood lizard, which they were obliged to eat raw. He also gave them his own excrement to eat, and when they were thirsty, they drank his urine.

Eventually, Dharramulan went into different kinds of trees, where he still resides, excepting during those times when the initiation ceremonies are in progress. A piece of wood, cut from any tree will make a *muddhiga* or bull-roarer, which is also frequently called Dhurramulan, on account of its humming sound, which represents his voice. On the boles of some trees in the bush, generally between the base and the first branches, there are circular or irregular protuberances, some of which project outwards half a foot or more. On the top surface of many of these excrescences there are fairly flat or level places, on which Dhurramulan is said to have a fancy for sitting or lying to rest himself when he comes out of the tree. These protuberances or calabashes are called *dhunnang* by the Wir-raidyuri people, and some of the old men told me that they have sometimes found the upper side of a *dhunnang* worn smooth by Dhurramulan's repeated occupation. Like some other Australian heroes, he has the magical power of changing his shape, and making his body smaller or larger at pleasure, from the size of a little lizard or bird, to that of a giant.

Miscellaneous Superstitions.—The Darkiñung people had a mythic malevolent creature resembling a man whose body had a red glow like burning coals, who had his abode in rocky places on the sides and tops of mountains. Fathers used to warn their sons to keep away from such spots. His name was Ghindaring, and his image was marked upon the ground at their initiation ceremonies, with a vessel containing human blood laid upon his breast.[1]

Gu-ru-ngaty is the name of an aquatic monster among the Thurrawal and Gundungurra tribes. He resides in deep waterholes, and would drown and eat strange blacks, but would not harm his own people. He usually climbed a tree near the water, from which he kept a look out. If he saw a stranger approaching, he slid down and dived into the water, without making a splash, or leaving any ripples on the surface. As soon as the individual began to drink, he was caught by Gurungaty.

Mūmuga is another fabled monster of the Thurrawal, possessing great strength and residing in caves in mountainous country. He has very short arms and legs, with hair all over his body but none on his head. He cannot run very fast, but when he is pursuing a blackfellow he evacuates all the time as he runs, and the abominable smell of the ordure overcomes the individual, so that he is easily captured. If the person who is attacked has a fire stick in his hand, the stink of Mumuga has no effect upon him.

The Wongaibon natives believe that a spirit or wicked person named Gurugula hovers about in the clouds and in the air overhead. If he smells the fat of any animal,

[1] See my "Burbung of the Darkiñung Tribe," Proc. Roy. Soc. Victoria, Vol. x., N.S., p. 3; also "The Darkiñung Language and Vocabulary," Journ. Anthrop. Inst., Vol. xxxiii., pp. 271 - 281.

especially of fish, being burnt in the fire at night, he gets very angry. In order not to provoke Gurugula, all cooking is done in the day time; and even then the people are careful not to let any fat burn during the process. The Thurrawal and Thoorga people have a similar story. The effect of such a superstition as this would be to preserve the fat for greasing their bodies and other purposes.

Gūram'bugang is the Thurrawal name of a small, smooth-skinned dark-coloured lizard seen among rocks and about logs. Women and children are forbidden to injure this animal. If a man gets a piece of grit, an insect, or other irritating substance in his eye, he catches the lid in his finger and thumb and moves it up and down, opening and shutting the eye, repeating in a singing tone:

Bindi, bindi, gurambugang
Dill, dill, dill!

The meaning is, "Wake up, wake up, guram'bugang"—*dill* being merely a request to the injured eye to open. The man continues to repeat these words and moving the eyelid, till the object falls out of the eye.

If children throw sticks, stones, or any missile at a bat, *Kubbugang*, it will cause their thumbs to become short. If they point at that animal, to show its location to anyone, they must point with the thumb, and not with the finger. [Thurrawal tribe.]

Among the Ngeumba tribe, women and children of both sexes must not look at the birds known as swifts, *pulluru*, which fly high in the air, or silliness would be the consequence. These birds are believed to be the harbingers of rain, but if the women look up at them, it would prevent the rain coming. The swift is a Kubbi and belongs to the guaimundhun caste.

In the legendary period it was unlawful for women to converse with dogs, the consequence being somewhat similar to the fate of Lot's wife. The following are some examples:—Among the Wirraidyuri tribes there is a story that on one occasion during the period the youths were away in the bush going through the course of initiation, a dog left the party and went away back to where the women were camped. They asked the dog where their sons were and what they were doing, and he told them, whereupon all the women and children were transformed to stone. This happened near Lake Cudgellico, where there are some rocks of different sizes, which at a distance, and good stretch of imagination, bear some similarity to women and children sitting down.

The natives of the south-east coast of New South Wales have a legend that two women were out in the bush, gathering *burrawang* seeds for food, which they placed in their net-bags, *kurama*. During the day they met a dog carrying a mullet, *murra-murra*, and asked him where he caught it. Upon his answering their question, they were immediately changed into stone, together with their bags of burrawangs and their yamsticks, *gauulang*. Rocks bearing a fanciful resemblance to these women are pointed out at a place on the hills between the Kangaroo Valley and the coast.

If very bad thunder and lightning occur during the night, the old men hold burning sticks in their hands and call out to *Merribi*, the thunder, to go away to another place which they name, and request him to take the lightning with him as a torch, to show him light to fish for *bulundyulung*, a small black fish. [Thoorga tribe.]

Upon the death of a native in the Wimmera district of Victoria, the clever old men and relatives of the deceased sit up through the night and watch the corpse. They suddenly observe the *muruk* or ghost appearing at the body, but do not see whence it came. After a short stay it goes away towards the *miyur* of its clan. The *muruk* of the slayer also comes to look at the corpse. The old men see him approaching stealthily, and after looking at the body he retraces his steps and disappears in the direction of his own hunting grounds. Having ascertained by this means whom to retaliate upon, they patiently wait for an opportunity to avenge their comrade's death. See "Pirrimbir" expedition in this treatise, *ante*.

Among the natives at Byrock, New South Wales, when anyone is dangerously ill, the old wizards proceed a little distance from the camp towards the setting sun and go through some incantations for the purpose of inviting the spirits of the sick person's friends to come and see him. One old man lies down on the ground and the others form a circle around him several yards distant, so that they can chase the spirits toward the man on the ground. The object of the ceremony is to intercept the shade or warrūngun of the invalid when it is trying to run away towards the west. If the old man succeed in capturing the spirit in some green leaves which he holds in his hand, and take it to the sick man, he will recover; if he fail to catch the spirit, the patient will die. The spirit is called warrūngun.

The Kamilaroi people say that after death, their spirits or internal parts, called *Gundhaddyiba*, go away up the Barwon River and live under the mountains at the sources of that stream.

On the Upper Lachlan River, flying foxes were supposed to be clever fellows who, in the days of long ago, used to travel about spying out the location of their enemies. They could make themselves small and hang on the branches of trees, so that any one who saw them would think they were only loose pieces of bark. Upon becoming flying foxes they continued their old method of camping.

Some of the Wirraidyuri tribes had the following ceremony for making rain. An old man took the rump of an emu, the bone of a kangaroo's leg and a white stone, all tied together. He then dived into a hole of water, carrying the parcel with him to the bottom, for the purpose of saturating it with water. On coming to the surface again, he swayed it backward and forward toward the west, muttering incantations all the time. If he happened to see a fragment of cloud coming up, he put the apparatus into the waterhole near the bank, and waited for the rain.

The Wongaibon people call the mirage *kullugu-kulli*, literally, shingleback's water, because it is believed to be a mythic or magical water which supports the *kullu* or shingleback, a kind of lizard which always lives out on the arid plains far from water. Some of the Wirraidyuri tribes thought the mirage was the smoke made by the fires of supernatural beings, when cooking their game out on the plains.

In the Thurrawal tribe the following observance was in vogue for bringing down showers. A *muyulu* or doctor got a piece of kurrajong bark, which he laid on a log and beat with a stick till it became soft and flexible. Then he took some stringybark and pounded it in the same way and wrapped it around the kurrajong bark, and bound the whole with string. This parcel was placed in a water hole, and was believed to have the power of causing rain.

Another superstition which is firmly rooted among all Australian tribes, is that of transmigration or reincarnation. Ever since the time when New South Wales was first settled by Governor Phillip, we have heard of the inveterate belief of the blacks that they would reappear in the form of other men after death. Buckley, the white man who spent so many years with the wild natives of Port Phillip, Victoria, is said to have owed his life to their assuming that he was one of themselves who had come to life again. A similar belief was discovered at Port Lincoln, South Australia, in 1846, by Mr. Schürmann, who says, "they certainly believe in the pre-existence of the souls of black men."[1]

It is stated in Rev. G. Taplin's work, that among the Nimbaldi tribe, about Mount Freeling in South Australia, a spirit called Muree, which may be either a male or a female, meets a black woman, and throws a small waddy, *weetchu*, under her thumb nail, or under the great toe nail, and so enters the woman's body. In due time she gives birth to a child.[2]

Rev. Duncan Mackillop reports that on the Daly River, Northern Territory, the souls of children are supposed to to be shut up in certain hills, scattered over the country, and are given out when an infant is to be born.[3] Superstitions substantially the same in character as those above referred to, in various forms to suit surrounding circumstances, have been observed in every part of Australia where investigations have been made.

Dyillagamberra, the Rainmaker.—The natives of the south-east coast of New South Wales have a legend that a mystic personage named Dyillagamberra once lived among them. When he went away from them he travelled up the valley of the Tuross River, and at short intervals dug holes or springs, some on the sides of the hills and others on the tops. This was to secure a supply of water for his people, and the waterholes still remain. He made these lagoons and springs all the way till he got to a mountain the natives call Barrity'-burra at the head of the Tuross River.

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[1] "Native Tribes of South Australia," p. 235.
[2] "Folklore, Manners, etc., South Australian Aborigines," (Adelaide, 1879), p. 88.
[3] Trans. Roy. Soc. South Australia, Vol. XVII., (1893) p. 262.

There is a deep lagoon or large waterhole at the foot of the mountain, said to contain all kinds of fish which frequent either the sea or the fresh water. In this lagoon there is plenty of *nyiwun* (congevoi) attached to the rocks around the margin or projecting above the surface of the water. A large rock overhangs one side of the lagoon, and away in one of its dark corners is the camping place of Dyillagamberra, who lives upon the fish and congevoi.[1] On the hillside, above the waterhole, the ground is strewn with different kinds of shells, such as oyster shells, cockle-shells, mussel shells and the like.

In time of drought, if two or three old men go to this lagoon and ask Dyillagamberra to make rain, he pours immense quantities of water out of the hole, and causes a flood in the Tuross river, accompanied by great rain. When asking Dyillagamberra to cause showers, the old men go through certain ceremonial incantations, and throw a stone into the lagoon to produce a surface ripple. They also mention the locality and the people affected by the drought. Sometimes the rain comes so suddenly that the people have to seek shelter in caves, or in hollow trees, or under large logs. Occasionally the showers are accompanied by hail.

How the Wongaibon obtained Fire.—In the far-away past the aborigines had no fire, but had to cook their meat in the sun. After a while it was observed that two old women, *gimma*, the kangaroo-rat, and *yummar*, the bronze-wing-pigeon, always had sweet, tender meat to eat. They had a small bag in which they carried the fire, shut up in a nut of the needle-bush or *thinku*. These women used to go out into the bush by themselves and cook whatever game they caught, and put the fire out. Different members of the tribe tried to find out what was done by the two women in the bush, but all to no purpose, because they

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[1] *Colocasia macrorrhiza.*

were too vigilant. At last the night owl, būllūr, undertook to watch them. This bird is the colour of the bark of trees and sits motionless, so that it is very hard to see him as he sits on the upper side of a branch.

Būllūr went away ahead, making a wide detour, and climbed a tree near a waterhole where the women used to go. By and by they made their appearance, carrying a fine fat iguana, and camped under the tree in which the man was watching. They gathered some sticks and grass and took the needle-bush nut out of their bag. The fire came out of the nut and kindled the wood, and while they were cooking the iguana, one of the women stood waving her hands to and fro above the fire, to keep the smoke from ascending, while she sang:

Ngullu ngulludhur būtthu bŭddha.

As soon as the meat was cooked the fire was again put into the nut, after which the women had a hearty meal which made Bullur's mouth water. When the day got cooler they started back to the camp, and as soon as they were out of sight, Bullur followed their example. When he reported the details he had observed regarding the fire, a council was held and it was decided to hold a big corroboree, and invite the two fire-women to favour it with their presence. It was hoped that the women might be seized with a fit of laughter, or become so absorbed in the performances, as to relax their attention to the bag containing the fire, and thus give some dexterous fellow a chance to snatch it up and run away with it.

When all the people had assembled on the corroboree ground, the chief actors were painted in different colours and performed in their most mirth-provoking style; but it was all unavailing. The *gimma* and the *yummar* sat stoically beside each other, with the precious bag held between them, as if it had more claims upon their attention than all the hilarity which was going on in front of them. Then some renowned dancers from an adjoining tribe were asked to come and try if they could provoke the risibility of the two old women. The pelican, *wirraia*, and the black-and-white magpie, *kurruwur*, came to the camp and executed some wonderfully farcical performances, but their joint endeavours were equally ineffectual.

The old men considered the acquisition of fire of such great importance to their people that they decided to ask still another tribe to send some of their most laughter-exciting players. In response to this invitation two comical characters volunteered—the black cockatoo, *bilir*, and the shingleback, *kulu*. After some preliminary manœuvres by less distinguished men had been disposed of, the shingleback danced along, to and fro, on the point of his tail, evacuating as he did so. This made a decided impression on the two women, and arrested their attention, but they still remained tolerably self-possessed. The black cockatoo now jumped along among the performers, with his lower bowel protruding through the anal orifice, and ordure mixed with blood running down his tail. This exhibition proved irresistible to the women, who broke out into uncontrollable laughter and rolled over on the ground.

This was the opportunity so long sought for. The sparrow-hawk, *girriki*, picked up the women's bag and ran away a little distance, where he upset its contents upon the ground. This liberated the fire, which spread in all directions among the dry grass. The sparrow-hawk followed the fire and "sang" to encourage it to go faster. By his magic he produced a whirlwind which accelerated the spread of the flames. As it blazed along, he put some of it into every tree of the forest, both soft wood and hard wood, so that fire can now be obtained by rubbing the two kinds of wood together.

W—Oct. 5, 1904.

Ever since that corroboree the black cockatoo has reddish stains on the feathers which grow on the under side of his tail. Evidence of the glare of the flame also appears on the back and head of the sparrow-hawk.

How water was obtained by the Kamilaroi people.—On the Mehi and Gwydir Rivers, in the Kamilaroi country, the natives say that in olden times there was no water on the surface of the ground. The people had to depend upon showers, the dew, and such moisture as they could procure from roots of trees and vines. The iguana, *yurundiali*, however, knew of a spot where there was a hole in a rock, at which he used to quench his thirst and then place a stone over the top of it, so that it was hidden from the eyes of passing strangers.

His fellows often noticed greenish layers or deposits, such as usually float on the surface of water, about the iguana's jaws and on his head, when he came into camp, but they could get no explanation from him. He always looked sleek and contented, and never went in quest of vines or similar substances. Attempts had frequently been made to watch him when he went out hunting, but he was too adroit to let anyone see him drinking. The sandpiper, *billidhu*, at length volunteered to go out and see if he could discover the iguana's secret.

Next day the iguana started away by himself, and so did the sandpiper. This bird has a habit of running along a little way, and stopping suddenly, as still as a statue. Then he makes another short run, and comes to another abrupt standstill. He learnt this habit from dodging about after the iguana, and has kept it up ever since. He kept his eye constantly on the iguana, and every time that animal looked in his direction, he came to a sudden stop, and was easily mistaken for a dried stick projecting from a log, or for the stump of a sapling. After a while the iguana climbed a tree and pulled a young opossum out of a hollow spout, and after some exertion swallowed it.

Then the iguana changed his direction and went towards a stony ridge. As he walked along he gazed around him suspiciously and frequently, which increased the billidhu's watchfulness. On nearing a flat rock, he approached it cautiously and slowly, pretending he was tracking some animal. The billidhu now kept coming nearer and nearer, and every time the iguana turned his head towards him he stood still. The iguana finally halted and began removing the loose stone which covered the water, which enabled the billidhu to come quite close. A last look around satisfied the iguana that no one was within view, and he dipped his mouth into the water to take a draught. By this time the billidhu was alongside, and raising his tomahawk cleft the iguana's skull open. As the billidhu had not the talismanic secret of shutting down the water, it flowed out and filled all the hollow places, so that everybody had plenty of water, which has continued till the present time.

The Dhiel and her Water-trough.—The *dhi-el* is a small night jar, which remains in the hollow spouts of trees during the day, and comes out in the night time, feeding upon berry-bearing shrubs. This bird was a woman—a being of mystery—in the far-away past and had two dogs, the soldier ant and the leech. She generally camped some distance back from watering places, and carried water for her own use in a native trough, or *kuddyil*, of magical proportions and manufacture. Dhiel was very friendly to all the people of her own sex, but would kill and eat boys and men. When a girl attained the age of puberty, she was taken by some old female relatives into the bush, where she was treated in accordance with the regulations briefly described under the head of "Initiation of Women" in earlier pages of this work. Dhiel always assisted on such occasions.

It chanced on a day that two blackfellows who were out hunting became very thirsty and went to her camp to ask for a drink. She replied that there was very little water in the kuddyil, and suggested that they had better both dip their heads into it together, so that each might get some. As soon as they did this, the kuddyil closed up around their necks and made them fast. The soldier ant immediately commenced to sting their bodies, and the leech which was in the trough began to bite their tongues, while Dhiel herself beat them with her yamstick. When they were dead, she roasted them, and she and her dogs fared sumptuously for many days.

After a while, when the two men did not return to their own camp, two of their friends went in quest of them into the dry hinterland. In the afternoon they were sorely pressed with thirst and approached Dhiel's camp to beg a drink of water. She received them with the same duplicity as the former pair, and they met the same fate. Several searchers went out, and were similarly disposed of by Dhiel and her dogs. At last the crow determined to go out by himself, in the hope of finding out what mysterious disaster had befallen his comrades. He, like his predecessors, got thirsty and went to Dhiel's camp to ask for a drink. She told him there was just a little water in the bottom of the kuddyil and invited him to put in his head and drink. He carried a charmed shield and when he bent his head into the trough, he held the shield in front of him, reaching from his chest to his chin. The leech jumped at his tongue and the kuddyil attempted to shut upon him as usual, but the magical shield prevented it.

The crow became very angry and ran after Dhiel to kill her. She ran, screaming, first round a *dhurri* or white emu-bush; then around the *yerriai*, or apple bush; next the *dhikku*, or black emu-bush; then the mulga tree; and lastly the grey box. The crow at length overtook Dhiel and killed her, as well as her dogs, and broke the enchanted kuddyil to pieces with his club. Dhiel's voice went into all the trees around which she was chased by the crow. At the initiation ceremonies the blackfellows use a *munibear*,[1] or small bullroarer which is manufactured from the wood of any of the trees above mentioned. When the old women at the *Burbung* ring hear the munibear sounding in the adjacent bush, they say to each other, "That is our *kutthainga* or playmate, calling out to us." [Wirraidyuri Tribe.]

Yandhangga.—Another kind of fabulous being is Yandhangga, a small man, with a long beard flowing down to his waist. He has a stone tomahawk naturally formed on his right elbow, with which he kills blackfellows and procures game. On this account he carries everything in the left hand. After killing a man, he skins him and makes a bag out of the pelt for carrying water into the dry sandhills and ridges where he goes hunting. If a blackfellow is walking along and observes Yandhangga, he will probably begin thinking to himself what a queer looking man that is. Yandhangga will then call out to him, "What are you saying about me?" The blackfellow will reply that he said nothing. Thereupon Yandhangga tells the man what his thoughts were, where he is from, and the names of his relatives. After that he kills and skins him; but if the man is some distant connection of his own, he allows him to proceed. I was unable to learn whether the blacks ascribed this supernatural knowledge of Yandhangga to his reading the man's thoughts, or whether it was supposed to be due to his omniscience. [Wongaibon Tribe.]

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[1] See my "Burbung of the Wiradthuri Tribes," in which I have described the munibear and its uses, Journ. Anthrop. Inst., Vol. xxv., p. 298, pl. 26, fig. 39 (May 1896).

The Moon and its Halo.—Two women were carrying the moon, *giwa*, seated on a pole between them, across the Culgoa River. In midstream the moon was either thrown off, or tumbled off the pole into the water and was washed down and drowned. After a while he came to life again, and went out into the mulga country near the Warrego River. He stripped a lot of bark off leopard-wood trees, and his reflection can be seen on the bark of this kind of tree ever since. He carried all the bark which he had stripped a long way, to a place on what is now known as the Multaguna run, and made a large camp for himself. He saw a mob of blacks and invited them to come and see him corroboreeing.

He had his bark propped up with forks all round the corroboree ground, and asked the people, men and women, to come inside the ring of bark. One man was outside and the moon said to bring him in also. A woman who had just given birth to a baby was sitting down a little way off, and *giwa* told them to fetch her to the corroboree too. After he had "opened the ball," he said, "Now, all of you must keep your eyes cast on the ground and don't look at me for a little while." He then went round and pulled down his leopard-tree bark quickly, which fell on top of the people, crushing and smothering them all.

The halo, or large ring sometimes seen around the moon during a moist state of the atmosphere, represents the ring of leopard-wood bark under which the people were suffocated. The scene of the catastrophe is now a small lake on Multaguna Station. All the details of this story would occupy many times the space I have been able to afford in this article. [Kurnu Tribe, Darling River.]

Two Young Men and the Moon.—Giwa the moon had two young relatives who had been trained to know some magic. He was a heavy, corpulent old man, not able to hunt much himself, so he had several dogs to help him. His dogs were the bull-dog ant, the brown snake and some others. The two young fellows mostly accompanied the old man and assisted him in procuring food, but he did not treat them well. If they caught a number of opossums and brought them to the camp, Giwa used to cook them, split them open, and eat the fleshy parts of the legs and all the choice portions of the bodies himself, giving the young men the back-bones and the heads. When they brought home a buck opossum for themselves, old Giwa waited till their backs were turned, and cut off the opossum's scrotal pouch with its contents, healing up the wound by his magic, and then insisted that the animal was a doe, which, consequently, the youths were forbidden to eat, by the tribal laws.

Owing to his continual greediness the lads determined to separate from the old man, but were rather afraid of his powers as a wizard. They used to lie behind him in the camp, and, because he could not turn round easily, he called out "Are you fellows there ?" and they answered "Yes." He rather suspected they would leave him, so he asked this question frequently. At last they started off early one morning, but before doing so they defecated copiously on the ground a little way from the old fellow, and by their gramarye conferred the power of speech upon the deposit, to enable it to respond to Giwa's queries. Every time the moon enquired "Are you fellows there?" the ordure replied in the affirmative.

The young men came upon an emu, which they speared and carried on the top of a flat rock which protruded a few feet above the surface of the ground. Having lit a fire on the rock, they commenced cooking the emu, but suddenly remembered that this bird was taboo to them, and consulted as to how this difficulty could be surmounted. Being clever fellows, they could pitch their voice so that it could be heard a longer distance than the speech of ordinary mortals. They called out to their aged relative to come and see them, and he at once got up in surprise to find them gone. The ordure was now silent and Giwa started off in the direction whence the call had come.

When the youths saw him coming, they had recourse to their magical functions and caused the rock on which they were standing to rise perpendicularly out of the ground about twenty feet. They then called out "Look, grandfather, what we have here," raising the emu into view. He told them to throw it down to him, upon which they cut off a slice from the fattest part of the body, and cast it to Giwa. He caught it in his hands, but seeing it was mostly fat, he threw it back to the lads.

This was a piece of artfulness on the part of the youths. The flesh of the emu is forbidden to young people, who cannot eat it till given to them by an old man. When Giwa threw the portion of emu to the boys, they greased their mouths with the fat, and ate the morsel of flesh which was attached to it. They were now released from their taboo, and could eat the animal which they had roasted.

They now asked Giwa to go and cut a sapling to lean against the rock, so that he could climb up and join them in the feast. He accordingly estimated the length of the pole he would require, and went into the forest to get it. While he was away the youths caused the rock to rise some ten feet higher, consequently, when Giwa brought his sapling it did not reach the top. The boys suggested that he should go and find a longer pole, and in his absence they again added to the height of the rock. Giwa went away the third time to cut another pole, and succeeded on this occasion, because the rock had not increased in height during the interval.

Giwa prepared himself for the ascent, but on looking round at his dogs, he asked the youths what he should do with these. They suggested that he should put them in his shoulder bag and bring them with him. He adopted their advice, and commenced climbing the pole, but owing to handling the emu fat as stated above, his hands were greasy and slippery. However, after much struggling, he managed to reach within a few feet of the top, when the youths caught hold of the pole and turned it rapidly round. This had the effect of causing Giwa to lose his hold, and he fell heavily to the ground on his back, killing his dogs and injuring his spine. As he lay there, he sang a song while the youths were enjoying their feast on the top of the rock. This song has to be sung to the present day, when anyone is allowed to eat emu flesh for the first time. Giwa walked with a great stoop for some days after his fall, which is the reason that the new moon always appears bent. [Wongaibon Tribes.]

The Yaroma.—This is a creature closely resembling a man, but of greater stature, and having hair all over the body. Its mouth is large, which enables it to swallow a blackfellow whole, without mastication. There are generally two of these monsters together, and they stand back to back, so that they can see in every direction. Their method of locomotion is by a series of long jumps, and at every jump their genital appendages strike the ground, making a loud, sudden noise, like the report of a gun, or the cracking of a stockwhip.

Yarromas have short legs and large, long feet, of a different shape to the feet of a human being. When one of these monsters is heard in the vicinity of a native camp during the evening, the people keep silent and rub their genitalia with their hands, and puff or spit in his direction. Some of the headmen or doctors shout out the name of some locality a long way off, and the Yaroma is supposed to depart to that place. If they cannot be dispersed by this means, the men take sticks which have been lighted in the fire—a stick in each hand—and strike them together to throw out sparks. This usually causes the Yaroma to disappear into the ground, making a flash of light as he does so. If a man be pursued by a Yaroma his only means of escape is to jump into a waterhole and swim about, because these creatures cannot wet their feet. They have long teeth which they sharpen on rocks in the high ranges; and some of the old men aver that they know of rocks where there still remain marks of this grinding.

On one occasion, a blackfellow went under a large fig tree to pick up ripe figs, which had fallen to the ground, when a Yaroma, which was hidden in a hollow place in the base of the tree, rushed out and catching hold of the man, swallowed him head first. It happened that the victim was a man of unusual length, measuring more than a foot taller than the majority of his countrymen. Owing to this circumstance, the Yaroma was not able to gulp him farther than the calves of his legs, leaving his feet protruding from the monster's mouth, thus keeping it open and allowing the air to descend to the man's nostrils, which saved him from suffocation. The Yaroma soon began to feel a nausea similar to what occurs when a piece of fishbone or other substance gets stuck in one's throat. He went to the bank of the river close by and took a drink of water to moisten his throat, thinking by this means to suck into his stomach the remainder of his prey, and complete his repast. This was all to no purpose, however, for, becoming sick, the Yaroma vomited the man out on the dry land. He was still alive, but feigned to be dead, in order that he might perhaps have a chance of escape. The Yaroma then started away to bring his mates to assist him to carry the dead man to their camp. He wished, however, to make quite sure that the man was dead before he left him, and after going but a short distance, he jumped back suddenly, but the man lay quite still. The Yaroma got a piece of grass and tickled the man's feet, and then his nose, but he did not move a muscle. Finally he got a bull-dog ant and made it sting the man's penis, but he never flinched. The Yaroma, thinking he was certainly dead, again started away for help, and when he got a good distance off, the man, seeing his opportunity, got up and ran with all his speed into the water close by, and swam to the opposite shore and so escaped. [South-east coast of N. S. Wales.]

Wallanthagang.—Wallanthagang was a small man-like creature, but very thick-set and strong. He wore a lot of pretty feathers in his hair, and carried a large bundle of light spears. He obtained his food by catching parrots which he speared in the feet, so that their bodies might not be damaged for eating. He frequented the thick tea-tree scrubs and brush in the swamps near Cambewarra mountain, in the Nowra district, because parrots are usually very numerous about there. He had a bag slung over his shoulder in which he carried these birds. Only one of these men are ever seen at the same time, and his camp fire has never been observed, nor any place where he had been camping or resting. The clever old blackfellows can sometimes hear one of these animals calling out yau! yau! yauh! If a blackfellow met Wallanthagang in the bush he would not speak, unless first addressed. He would then imitate what the man said, as if trying to learn the language. The blackfellow would probably think this boy-like personage was poking fun at him, and give Wallanthagang a clout. He would then rush at the blackfellow, and catching hold of him, throw him up several feet into the air, and let him fall heavily upon the ground. This would be repeated many times in quick succession, until the man became very sick at the stomach and quite helpless. Wallanthagang would now carry the man to a bull-dog ants' nest, and lay him down on top of it, so that these insects might sting him until he recovered. [S. E. Coast of N. S. Wales.]

The Wawi and Song-makers.—The Wāwi is a serpent-like creature which lives in deep waterholes, and burrows into the bank, where he makes his den. He has a wife and children who camp close to him, but in a different place. A "doctor" or clever man can go and see the Wāwi, but must not go near his family. When a man is going on a visit to this monster he must paint his body all over with red ochre. He then follows after the rainbow some day when there is a thunder-shower; and the end of the rainbow rests over the waterhole in which is the Wāwi's abode. The man then dives under the bank, where he finds the Wāwi, who conducts him into his den and sings him a new song for the corroboree. The man repeats the song after the Wāwi until he has learnt it sufficiently, and then starts back to his own people. When they see him returning, painted red and singing, they know he has been with the Wāwi. The bard then takes a few of the other clever men with him into the bush and they strip pieces of bark off trees, and paint different devices upon them with coloured clays. The pieces of bark ornamented in this way are taken to the corroboree ground, and all the men dance, and sing the new song. This is how new songs and dances are obtained. The Wāwi has the magic power of varying his size from a few inches up to prodigious proportions. The black streak in the Milky Way, towards the Southern Cross, is one of the ancestors of the Wāwi. He encourages snakes and adders to bite the black people. [Wirraidyuri Tribe.]

Achievements of the Brambambults.—In the distant past there lived in the north-western districts of Victoria two warrior youths, who were brothers, named Bram-brambulaty,[1] which in the aboriginal tongue means, Two-Brams. These words the natives have shortened into Brambambult, which is more euphonious and is the name by which the heroes are mostly spoken of. They are sometimes called Barm-barm-bult. I have collected a few examples of the principal exploits of these mythic warriors, as told to me by some old natives. It has been found necessary to abridge the narratives very largely, and to omit portions of them altogether, in order to bring them within reasonable limits for publication in this article:—

1. *The Ngindyal.*—The ngin′-dyal was a bird-like animal, having the shape and feathers of an emu, but of enormous proportions, and was moreover, a great magician. She had her nest at Wombagrŭk, containing only one egg, on which she sat. She used to kill and eat all the people she could catch. One day a crow came prying about, and the ngindyal ran after him in a furious manner. The crow fled across the country and ran into a cave or hole in the side of a mountain, and came out at the other side. The ngindyal rushed at the hill and struck it with her foot, which split it in two, forming what is now known as Rose's Gap. The ngindyal continued on through the cleft in the mountain and was graining rapidly on the crow till he came to another mountain which was passed over in a similar manner. The chase was continued until the crow reached his own *miyur* or spirit land at Dyŭrnera,[2] whither the ngindyal had not the power to intrude, and turned back to her nest.

Shortly afterward the crow left his *miyur*, and returned to his ordinary hunting grounds. It chanced on a day that

[1] See my "The Aboriginal Languages of Victoria," Journ. Roy. Soc., N. S. Wales, Vol. xxxvi., p. 84.

[2] Dyurnera is the fabled water of the clan Wanguguliak, to which the crow belongs. See "Sociology of the Tribes of Western Victoria," in earlier pages of this work.

he met the Brambambult brothers near what is now Jeparit, and told them all about his adventure with the ngindyal. They begged of the crow to come and show them the place, and the three of them started off, but they had a long distance to go. The crow did not care to risk another meeting with the ngindyal, so when he had gone part of the way, he said to the Brambambults, "I'll stop here while you two go on to where I have told you of." But the brothers asked the crow to come on a little way farther. They made this request, not because they wanted his assistance, but because he was helping them to carry their large load of weapons.

The three travelled on again, and presently the Brambambults saw in the distance what they thought was a bright star shining. The crow said "That is her eye; she is there, sitting on her nest." The Brambambults left the crow there and advanced on the foe. The younger brother went round to the farther side, when the ngindyal spied him and got up to have a better view. By this time the elder brother was quite close and hurled a spear, which caught the ngindyal in the breast. She immediately turned round and rushed at him, which gave the younger brother an opportunity of throwing a spear, which wounded the ngindyal in the body. She then bestowed her attention upon the junior assailant which allowed the elder brother a chance to cast another spear.

They kept throwing spears alternately until the ngindyal was considerably subdued by pain and loss of blood, and then drove her before them towards what is now called Horsham Plain. When wity-gurk, the lark, saw the ngindyal coming, pursued by the Brambambults, he came out, carrying a bough in front of him, to hide himself from observation. When he reached within range, he cast a spear with all his force, which struck the ngindyal in the chest and killed her. The Brambambults were somewhat annoyed with the lark for depriving them of the honour of slaying the ngindyal; but as a common enemy had fallen, they did not quarrel about it.

The Brambambults then split each feather of the ngindyal down the middle, casting one half of the feathers on the right hand side and the other half on the left, making two heaps. One of these heaps of feathers was converted into a cock and the other heap into a hen, of the present race of emus, which are incomparably smaller than the ngindyal. It was also arranged by the sorcery of the Brambambults that all future emus should lay a number of eggs, instead of one only. The splitting of the feathers above mentioned is still easily observable in the feathers of all emus, which are double, or consist of two independent shafts.

All the people then journeyed away to Wombagrŭk to get the egg on which the ngindyal had been sitting. Although every body tried their best, none of them could lift the egg, till *babim'bal*, a sort of wattle-bird, came. He picked it up and put it into his bag, and carried it to Horsham Plain, where it was cooked and made a great feast. The nest in which the large egg lay is said to be still visible at Wambagrŭk. The ngindyal now occupies the black patch in the constellation of the Southern Cross, and the crow was changed to α Argus, at a respectful distance from his ancient pursuer.

2. *Ngaut-ngaut.*—Ngaut-ngaut lived out in the Mallee country of Western Victoria, and belonged to the Ngurrumba-nguttya people, in the far-off legendary age. He used to kill blackfellows and suck their blood. It was impossible to hurt him with a spear or any other weapon, except in the tongue, which was the only vulnerable part of his body. The two Brambambults went out to punish

him, and caused a spring to break out at a place called Gurabo, where he used to frequent. Having obtained the leg bone of a kangaroo, they ground the smaller end of it to a sharp, keen point, and placed this weapon, point upward, under the water close to the bank. Then they changed themselves into two dead trees—one on either side of the spring.

One very hot day Ngaut-ngaut came up and looked at the water, but he was suspicious. He came again next day and stood between the two trees, with a hand on each. He shook one of the trees, saying "This is you, Brambambult;" then shaking the other tree, he said, "And this is your brother." Receiving no answer, he shook the trees more forcibly, and could hear bits of the rotten core rumbling down inside, the same as one can hear if a dead, hollow tree be struck heavily with the back of an axe. This satisfied him that they were really trees.

But Ngaut-ngaut still thought there might be enemies lurking about, so he went some distance away to search for them. The Brambambults then began to "sing" quietly to themselves to make him more thirsty, and he came back and shook the trees again with the same result. He went away the third time, but not so far, because his thirst was increasing, owing to the necromancy of the Brambambults. On returning the third time, he put his mouth close to the water, but changed his mind and did not touch it. Then he went away again, but only a little distance. This was repeated a few times to satisfy himself that there was no danger near. He now lay down on his hands and knees and dipped his mouth into the water to drink. The hidden bone spike immediately shot up like a living thing and went through his tongue into his head, killing him on the spot.

3. *Wirnbullain.*—Duan, the flying-squirrel, followed a kangaroo from somewhere near Stawell, and it ran away northerly down the Wimmera River, forming the present watercourse. The kangaroo grazed a long time about Lake Hindmarsh, eating the grass quite bare, and formed the lake. It went on and grazed about Lake Albacutya where another lake was formed in the same way. From there it travelled on to Lake Wonga, where it was overtaken and killed by Duan. While he was cooking the kangaroo, Wirnbullain, the tarantula, came up and commenced fighting with Duan. The latter was getting the worst of it and climbed up into a tree out of the way. Wirnbullain commenced gnawing the base of the tree, and cut it down with a few bites.

When Duan felt the tree falling, he bounded or flew into another tree close by. Wirnbullain proceeded to cut this tree down too, and Duan flew into another one. Then Wirnbullain called his two daughters to come and stand at the butt of the tree in which Duan had taken refuge, until he himself cut down all the surrounding trees for some distance. Wirnbullain next commenced cutting down the tree occupied by Duan, and as there were no more trees close enough for him to fly into, he was caught by Wirnbullain and his daughters, who killed him. They carried his body to their camp, as well as the carcase of the kangaroo which he had caught and feasted on them for several days.

The Brambambults were nephews of Duan—his sister's children. When Duan did not come back to his camp in a reasonable time, these two young fellows, accompanied by their mother, Dōk, the frog, started away along his tracks. On reaching Lake Hindmarsh, they left their mother there, because she was tired. Going farther on, they met some ants, *mara*, carrying Duan's hair. He wore long hair and used to dress it with red ochre. The younger Brambambult at once recognized the hair and began to cry, because he knew that his uncle must be dead. The elder brother bade him be of good cheer, that they would by and by ascertain the truth of the matter.

The two brothers wandered on and tracked their uncle to Wonga Lake, where they discovered portions of his body. Upon seeing the trees lying on the ground, which had been cut down by Wirnbullain, they at once knew who had killed their uncle. They then tracked Wirnbullain to Pine Plain, where they found him with his two daughters. They killed the father and took his two daughters for wives. These girls, however, inherited their father's dexterity in felling trees, which scared the game away when out hunting. If one brother went away round a kangaroo and turned it towards the other brother, who was waiting to spear it, then, just as he was about to launch the weapon, the women would cut down a tree, and the noise of its falling startled the kangaroo, which ran away.

After suffering this annoyance and disappointment from their wives for some time, the Brambambults one day went up to the two sisters, who carried bags across their loins for holding such fruits and yams as they could gather. They pretended that they wanted the women to carry their shields for them, and asked them to turn their backs while they placed the shields in the bags. As soon as this was done, the men chopped the women in the back of the neck and killed them. All tarantulas have had the mark of a shield on the lower part of their backs ever since.

4. *Dyuni-dyunity.*—The Brambambults went to see their brotber-in-law, Dyu-ni-dyu-nity, the night owl. On reaching the camp, Dyuni-dyunity was out hunting, but his two little sons were there, playing with something which resembled the shoulder blade of a kangaroo. The Bram-

bambults asked their little nephews what bone that was? and they replied, "This is our mother's shoulder blade; our father and we ate the flesh off it this morning for breakfast. Father killed our mother some days ago." The Brambambults became very wrath, because their sister had been murdered and eaten, but they kept it to themselves.

After pondering over the outrage for a while, they asked their nephews to build up a hut, consisting of nothing but dry wood and boughs, and make a small door in one side of it. They told the boys that the building was for their father to sleep in that night, when he returned from his hunting, as it looked like rain. The Brambambults then went away and pitched their camp some distance off.

By and by Dyuni-dyunity returned and enquired of his sons why they had built the hut. They replied that their uncles had been to see them, and pointed out their camp fire in the distance. This alarmed Dyuni-dyunity and he said he would kill the younger Brambambult before long. He started out hunting next morning and brought home human flesh. It was his custom every day to search about for blackfellows, whom he killed and secured the daintiest parts of their bodies, which he carried to his camp for himself and his boys. He cooked some of the flesh and sent a portion by his sons to the Brambambults' camp, but they refused it, saying that they had plenty of meat of their own. Moreover, they told the lads that they were going right away the same afternoon, into another part of the country, and asked them to tell their father so. This was a ruse to throw Dyuni-dyunity off his guard and make him feel confident in his security while he slumbered through the night. But the Brambambults only moved into a patch of scrub, where they hid themselves.

That evening the Brambambults, who were clever wizards, caused a heavy downpour of rain, which made

Dyuni-dyunity and his children seek shelter in the hut which had been erected, and all of them went sound asleep. During the small hours of next morning, after the rain had ceased, the Brambambults went cautiously to the camp of their brother-in-law, and found them all slumbering. They carefully and noiselessly lifted the two lads and carried them out of the hut—the elder Brambambult carrying the elder boy and the younger Brambambult taking the younger—and placed them lying on the grass out of the way of danger. Then they set fire to the inflammable material of which the hut was constructed, and it was soon enveloped in flame.

Dyuni-dyunity did not feel the heat for some time, because he had very long hair all over his body. When at length he became aware of his position, he sprang to his feet and picking up one of his clubs, struck out all around him, thinking that his enemies the Brambambults might be within reach of his blows. His club came in contact with the poles supporting the building and displaced them, causing the fire to burn all the fiercer. It had, in fact, the same effect as what we call "poking the fire." Presently the whole burning mass fell down on top of Dyuni-dyunity, suffocating him and consuming his body.

The Brambambults carried their two nephews away to their own camp, where they all slept till after sunrise. The boys were then told to go to their father's camp for breakfast, but when they reached it there was nothing but cinders and burnt bones. The boys, who had much of their father's cruel nature in them, then returned to Brambambult's camp, and told the younger brother that they would kill him and take out his liver, to furnish them with breakfast. The elder brother then said, "These boys will probably try to kill us some day in revenge for their father." They accordingly fell upon the lads and destroyed them.

The site of Dyuni-dyunity's camp, where the conflagration took place is still pointed out by the natives, about a day's journey northwards from Cow Plain. There is a rocky outcrop, mixed with calcareous fragments which are said to be the charred bones of Dyuni-dyunity.

5. *Gartuk.*—Another time the Brambambults came to the camp of Gartuk, the mopoke, a Guro-gity man, who was a great hunter and had several dogs of different kinds, one of which was the sparrow-hawk. They asked Gartuk if he had any flesh to give them, as they were hungry. He falsely replied that he had plenty of does, but no bucks. The Brambambults were not at this time released from their taboo of female animals, and consequently could not eat the meat which Gartuk churlishly offered them. The Brambambults were vexed with Gartuk for his want of hospitality, and started away. In a short time they discovered a tree, in the fork of which was a recess, *dyattyar*, containing some water, of which they had a good drink.

It may be explained that some trees, at about ten or twenty feet from the ground, or higher than that, are forked into two large branches. If this fork is split slightly open by a wind-storm while the tree is growing, the wood around the injured part decays and rots, forming in course of time a cavity into the centre of the bole of the tree. During rainy weather the water runs down the branches into this hollow part and fills it till it runs over. Such water remains for a long time, being replenished by every shower. A tree of this kind is readily distinguished by bushmen, owing to the discolouration of the bark caused by the overflowing of the water from the cavity down the outside of the bole of the tree.

The brothers now returned to Gartuk's camp and invited him to come with all his dogs and have a drink. Arrived at the tree, they told him to take his dogs under his arms, so that both he and they could get a share of the water. When the hunter and his dogs got into the dyattyar, the Brambambults by their enchantments made the entrance to the recess close up, shutting them all inside. The brothers journeyed on, and left them there.

After a time, during which Gartuk had eaten his dogs to sustain his own life, Babim'bal, a bird like the wattle-bird, and his brother Bimbin, the woodpecker, came wandering about the tree and heard Gartuk calling out for help. Babimbal was anxious to release his friend from his confinement, but wished to exercise sufficient care not to injure him by a chop of his tomahawk. Tapping the outside of the tree at a certain place, he asked Gartuk if he should chop a hole there. Gartuk replied, "No, that is my belly." Babimbal tapped on another part of the bole and enquired if it would be safe to chop at that spot, and got the answer, "No, that is my eyes." Other interrogations elicited the replies "That is my back," "That is my knees," and similar warnings.

By this time the patience of the rescuers was exhausted. Bimbin chopped into the tree and accidentally cut Gartuk on the stomach, the scar of which accounts for the white place on the Mopoke's belly to this day. At the same time Babimbal, who was a very strong fellow, split the tree down from above with heavy chops of his hatchet, so that all the rotten wood, and earthy matter inside of the bole rolled down on Gartuk's head. The large bunch of feathers on the Mopoke's head is due to the mass of rubbish which fell upon his skull on that occasion.

When Gartuk recovered, he pondered over how he should be revenged upon the Brambambults. Some days after this event he saw a cyclone coming. He ran to his camp and got a large bag, made of kangaroo skin, into which he let the cyclone rush, and tied it up securely. Another cyclone came in a few day's time, which Gartuk bagged in the same way. He waited until a third hurricane blew, and he secured it in another bag, which he placed with the rest.

Then Gartuk wanted to know where his enemies were, and learnt that they were camped near Mukbilli. So he started away carrying his skin bags. On getting within view of Brambambult's camp, he opened his three bags simultaneously and liberated all the cyclones. The elder Brambambult caught hold of a dog-wood tree and told his brother to get a secure hold of a wattle tree. Dōk, a frog, the mother of the two youths, went into the ground. By this time the triple-cyclone was upon them, and the two trees were swayed and twisted in every direction. The wattle tree was torn out of the ground and carried into the air, taking the younger Brambambult with it. The dog-wood tree withstood the hurricane.

When the fierceness of the storm had passed, the elder brother let go his hold of the tree and Dōk came out of the ground. Upon searching about they could find no trace of the younger boy. The mother took hold of one of her teats and squirted out some milk, to determine the direction in which her son had been swept by the hurricane. The elder Brambambult then started off along the course indicated by his mother's milk, and came to a place where his brother had been fishing for eels, but had changed himself into a small red-gum tree owing to the nankeen bird making such weird noises. When the elder brother saw the tree he recognized his brother by the way he was standing, being similar to his attitude when he stood as a tree to watch Ngaut-ngaut. Upon speaking to the tree, it regained the human shape, and the two brothers went back and met their mother.

At some time subsequent to the events related in the foregoing pages, the Brambambults took their place in the heavens as α and β Centauri, whilst the mother, Dōk, was transformed into α Crucis. The mother and her two sons belong to the clan and miyur Pattyangal, and phratry Gamaty.

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In the following bibliography are given the titles of ninety five different articles written by me on the ethnology of the Australian aborigines, during the past ten years. The original articles enumerated were contributed to some of the leading Societies in Europe, America and Australia, who open their Journals to anthropological subjects. The names of the different Societies are given in the list, with the volumes and pages where my papers appear. In giving the customs of the Australian aborigines the widest publication, my aim throughout has been to induce a student here and there to embark upon this interesting work.

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PRELIMINARY OBSERVATIONS ON RADIO-ACTIVITY AND THE OCCURRENCE OF RADIUM IN AUSTRALIAN MINERALS.

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[*Read before the Royal Society of N. S. Wales, October 5, 1904.*]

LITERATURE.

PROFESSOR H. Becquerel, as is well known, was the first to observe what is now called radio-activity in uranyl-potassium sulphate. Schmidt[1] extended the observations to thorium minerals. Madame Curie,[2] who independently made the same discovery, has published values of the radio-activity of thirteen minerals[3] of high uranium and thorium content, as measured by the ionisation produced in an air gap. Sir W. Crookes[4] looked for radio-activity by a photographic method in his collection of minerals, especially among the barium ones; but found only euxenite, alvite, arrhenite, sipilite, and hiebnite to be active. These minerals contain either uranium or thorium. No instance of the comparatively intense activity of minerals containing these elements, has been found in their absence. The Hon. R. J. Strutt[5] examined the activity of samarskite, fergusonite, pitchblende, malacone, monazites, and zircon by a different method, depending on the rate of decay of the activity of the gas given off when the minerals were heated.

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[1] Wied. Annal. 65, p. 141, 1898.

[2] Comptes Rendus, 126, p. 1601, 1898.

[3] Thèse présentée à la Faculté des Sciences de l' Université de Paris.

[4] Proc. Roy. Soc., 66, p. 409, 1900. [5] *Loc. cit.*, 73, p. 193, 1904.

American uranium bearing minerals were examined by B. B. Boltwood[1] for radium, and it was found that in uraninite, gummite, uranophane, and samarskite, the radium present as indicated by the emanation method was proportional to the uranium content. This does not appear to hold, for the uraninite and samarskite examined by Strutt, for the former was only half as active as the latter, and this would scarcely be the ratio of the uranium in the two minerals. More recently[2] he has studied the radio-activity of natural waters. Radium has been found by Obalski[3] to occur in a cleveite and in a bituminous substance from Quebec, containing uranium as an impurity. Elster and Geitel[4] have detected radio-activity in fine mud from the Italian watering place Battaglia. Radio-activity was detected in natural gas by E. F. Burton.[5] An examination of the radio-activity of Russian muds was made by J. Borgmann.[6] A radio-active gas was found in the soil and water near New Haven, U.S.A., by H. A. Blumstead and L. P. Wheeler.[7] Later Mr. Blumstead[8] published an account of atmospheric radio-activity.

M. F. Pisani[9] has recently examined by photographic methods a large number of diverse types of minerals, in all about 77, and found that in every case those containing uranium or thorium were active; exceptional cases were certain specimens of fluorspar, which from his results appear to act comparatively strongly on the photographic plate. Specimens of fluorspar from the same districts were tested in our apparatus and gave negative results.

[1] Amer. Journ. Sci., 18, p. 97, 1904. [2] *Loc. cit.*, p. 378.
[3] Eng. and Min. Journ., March 17, 1904.
[4] Phys. Zeitschr., v., p. 11, 1903,
[5] University of Toronto Studies—Physical Science Studies.
[6] Nature, 70, p. 80, 1904.
[7] Amer. Journ. Sci., 16, p. 328, 1903, and 17, p. 97, 1904. [8] *Loc. cit.*, 18, p. 1.
[9] Bull. Soc. Franc. de Minéralogie, part 1, 27, p. 58, 1904.

M. G. Bardet[1] arranges a number of the more common uranium and thorium minerals in a comparative table, according to the activity exhibited photographically. R. W. Brocke[2] has published a comparative table of activities measured by a simple type of electroscope.

Experimental Methods.

A preliminary examination of a number of the minerals was made photographically, and the active ones were readily detected. No disagreement was found between the photographic and the electrical methods. Since the β and γ rays are the photographically active ones, it is an unsafe method, as Rutherford has pointed out, to rely on alone. Our results as stated in the table, were obtained by the use of a C. T. R. Wilson's[3] electroscope, consisting of a rectangular brass box, with a narrow gold leaf, insulated throughout with sulphur, and made by one of us in the Engineering Laboratory. The plate potential used was about 209 volts (as measured by a static voltmeter of the Physics Department), which gave the maximum sensitiveness. The case was preserved throughout at a constant sensitive angle of tilt. The movement of the gold leaf was read by means of a microscope moved by a screw thread. The leaf was connected to the upper of two insulated brass plates 11 cm. in diameter separated by a 5 cm. air gap, and surrounded by a metal case which was earthed. The lower of the plates was kept at a positive potential of 300 volts, by means of a battery of test tube accumulators, which was found sufficient to produce a saturation current. On this plate the mineral was placed in a circular lead dish of 5 cm. diameter, 3 mm. in depth—a fresh one being used for each mineral.

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[1] Bull. Soc. Franc. de Minéralogie, part 1. 27, p. 63, 1904.

[2] Engineering and Mining Journal, June 2, 1904.

[3] Proc. Camb. Phil. Soc., 12, part ii., 1903.

As Madame Curie found that the activity of uranium oxide U_2O_5 was constant for a period of five years, we compared the current passing when the mineral was tested with that from uranium oxide, the same standard specimen being used for each comparison. This was done by observing the time with a stop clock, which the leaf took to fall through the same distance, first with the mineral then with the U_2O_5. In all cases the minerals were finely ground, and the lead dish completely filled and levelled off.

In examining the emanation from several specially selected minerals, about 40 grams of the finely powdered substance was heated in a porcelain tube in an organic combustion furnace to the highest attainable temperature. The tube was pumped out whilst thus heated, allowed to fill and air drawn over from the other end, and again pumped out. The gas from the Sprengel pump was collected over mercury, and transferred to a partially evacuated metal vessel, of about 800 cubic centimetres capacity, with a central insulated wire. The gas in the vessel was brought to atmospheric pressure by the addition of air. The walls of the vessel were kept at a positive potential of 300 volts, and the current through the gas to the wire, attached to the gold leaf of the Wilson electroscope, charged it positively with resulting fall of the leaf.

Measurements were taken over a period of four days and the results plotted. Decay of the radio-activity of the emanation to half its initial value in four days indicates, as shown by Rutherford and Soddy, the presence of radium. Our instrument was not suited for measuring the decay of the thorium emanation. In this work Rutherford's "Radio-activity" was found most useful, especially the chapter on methods of measurement.

Results.

A large collection of minerals was examined, and as expected, only those containing uranium or thorium were found to have measurable activity. The apparatus readily detected an activity of $\frac{1}{200}$ that of U_2O_5. Among the minerals tested and found to be inactive the following are worthy of mention:—

Columbite, Barrier Ranges, N.S.W.
Stibiotantalite, Greenbushes Tin-field, W.A.

Zircons	Various localities.
Tellurides	
Bismuth ores	
Tin stones	
Barytes	

As will be noticed in referring to the following table, only two occurrences of uranium minerals have been recorded, so far as we are aware, in Australia. In both cases specimens at hand, up to the present time, are too small to admit of complete investigation. The first is a *euxenite* occurring with stream tin at the Marble Bar Tin-fields, W.A., and is derived from the degradation of Pre-Cambrian gneiss. The other specimen is a *torbernite*[1] occurring in small flakes adhering to decomposed eruptive rock of intermediate character, and was collected by one of the officers of the Mines Department at the cobalt mine, Carcoar. The association of cobalt and uranium ores at Joachimsthal in the Bohemian Erzgebirge, at Schneeberg in Germany, and occurrence of slightly radio-active silver cobalt ores at Temiscmaringue in Canada has already been remarked by R. W. Brock.[2] This circumstance, however, is regarded by the authors as accidental.

[1] Records Mines Dept. N.S.W., Vol. iv., p. 20.

[2] *Loc. cit.*

TOTAL ACTIVITY AS DETERMINED BY IONISATION PRODUCED IN AIR-GAP.

Mineral.	Activity.	Locality etc.
Black oxide of Uranium, U_2O_5	100	Taken as standard.
Torbernite	highly active	Carcoar, N.S.W. (insufficient for comparative test)
Euxenite	highly active	Marble Bar Tinfields, W.A. (insufficient comp. test)
Gadolinite	·88	Cooglegong River—Greenbushes Tinfield, W.A.
Monazite	11·30	Pilbarra, W.A.
Fine river sand with gold, tinstone, etc.	8·49	Tumberumba, N.S.W.
Zircon sand with monazite ...	·60	Tooloon River, N.S.W. Contains ·45% thoria.
Concentrated beach sand ...	7·39	Broken Head, Richmond River, N.S.W.
Ditto, ditto	1·82	Ballina, Richmond River, N.S.W.
Concentrated river sand ...	8·00	Tasmania.
Monazite	5·47	Torrington, N.S.W. A large well developed crystal used.
Ditto	3·25	Torrington, N.S.W.
Ditto	4·92	Cow Flat, Torrington, N.S.W contains ·3% thoria.
Ditto	3·11	20 miles W. of Torrington, contains 1·5% thoria
Ditto	4·46	Ditto, contains 1·8% thoria.
Ditto	3·31	Various samples from the Gulf Mine, Emmaville. Contains ·6% thoria.
Ditto	3·00	
Ditto	3·41	
Ditto	3·13	
Ditto	2·50	
Ditto	4·50	Paradise Creek, Emmaville, N.S.W.
Foreign Minerals.		
Pitchblende	354·05	Joachimsthal } Given for comparison.
Samarskite	47·10	Sweden } Given for comparison.
Thallium blende	3·75	Locality unknown. Activity may be due to the probable association of uranium minerals.

The Australian minerals whose activities have been recorded in the table are with one exception monazites. These *monazites* frequently occur in the tin fields throughout Australia, and on account of their thoria contents have lately become of commercial importance. Monazites are found to a less extent in situ, at Torrington in a decomposed granite, and at Warialda embedded in a lode of bismuth carbonate.

New South Wales varieties[1] are of a hyacinth colour, well crystallised, and exhibit two good cleavages. The Pilbarra *monazite* in which we have identified the presence of radium[2] is darker in colour than the N.S.W. specimens, and cleavages are not so well defined. It is found in the tin wash in association with euxenite and gadolinite. It will be noticed in referring to the figures in the table that no relation can be traced between radio-activity and thoria contents. This points to the presence of some other active substance in addition to the thoria.

The *gadolinite* from the Cooglegong River, W.A. was collected by Mr. B. F. Davis, B.Sc., and is described[3] as occurring both with the stream tin in alluvial deposits and in lode formations in Pre-Cambrian gneiss. In the paper cited an analysis is given, and it is stated that Prof. Norman Collie found 1 bubble of helium in the gases obtained by heating 10 grams of the mineral. This is the first authentic case in which radio-activity has been noticed in gadolinite.

Examination for Radium.

The method adopted was that used by Hon. R. J. Strutt depending on the decay of the emanation. A preliminary experiment was conducted on 5 grms. of Canotite[4] from Colorado, U.S.A. Its emanation was found to be strongly active, the rate of decay determining it to be due to radium. Three Australian minerals were next tested with the following results:

Gadolinite from West Australia (38 grams tested) gave no radium emanation. In view of the fact that helium is intimately related to radium, this result is extremely interesting, as the gadolinite has been shown to contain helium.[5]

[1] Annual Report Dept. Mines, N.S.W. 1903 and Records of Australian Museum 1903.

[2] Vide postea. [3] Journ. Roy. Soc. N.S. Wales, 1902, p. 286.

[4] Since then B. B. Boltwood has published that radium emanation is obtained from this mineral.—Amer. Journ. Sci., 18, p. 97, 1904.

[5] Vide antea.

A similar instance is that of a meteorite from Virginia, examined by Strutt.[1] In this case, although the presence of helium was detected by analysis, the meteorite failed to give the radium emanation. In the gadolinite, although thoria is not mentioned in the statement of analysis, later investigation by Acting Professor Schofield showed that a small percentage is present, and the activity is probably referable to this.

Pilbarra *monazite* (31 grams tested) gave a definite radium emanation decaying to a half in very slightly under four days. The value of the radium activity cannot yet be assigned until more comparative data are obtainable.

Monazite from Paradise Creek, Emmaville, N.S.W. (25 grams tested) gave an emanation decaying in a very short time, and not measurable with our apparatus.

SUMMARY.

A number of Australian minerals have been examined for radio-activity by the ionisation produced in an air gap as measured by the most recent form of a C. T. R. Wilson electroscope. The activities are compared with that of black oxide of uranium. Radium was tested for in four of the minerals by heating them in a vacuum and testing the rate of decay of the radio-activity of the resulting gas.

A gadolinite in which Professor Norman Collie found helium to be present was radio-active, but no radium emanation could be detected. A number of monazites were radio-active, one from Pilbarra, W.A., gave the radium emanation. It is intended to continue this work shortly, when all results will be published in ampères.

For the suggestion of the research, carried out in the Chemical Laboratory, and for constant encouragement we wish to thank Professor David. We are indebted to the Department of Mines for a number of minerals, and especially to Mr. G. W. Card, A.R.S.M., for his cordial help in obtaining us specimens. Our thanks are also due to Acting Professors Schofield and Knibbs for encouragement and interest shown in the research.

[1] Proc. Roy. Soc., 73, p. 193, 1904.

POT EXPERIMENTS TO DETERMINE THE LIMITS OF ENDURANCE OF DIFFERENT FARM-CROPS FOR CERTAIN INJURIOUS SUBSTANCES.

By F. B. Guthrie, F.I.C., F.C.S., and R. Helms.

[*Read before the Royal Society of N. S. Wales, November 2, 1904.*]

Part III.—Barley and Rye.

The experiments which form the subject of the present communication were carried out last year and are in continuation of those already communicated to you with regard to wheat and maize.[1] They were conducted in precisely the same manner, and it will be unnecessary to go into the detail of the methods adopted which will be found in full in this Journal, xxxvi., p. 191.

The soil with which the pots were filled was a rich garden loam mixed with a nearly equal quantity of light sand. Each pot received a manuring of 10 grms superphosphate, and all were exposed to precisely the same conditions as to light, warmth, water, etc., throughout the course of the experiment. Check pots were filled and sown in exactly the same way, except that the deleterious substances were omitted.

III. Barley—*Experiments with Common Salt.*

Eight pots were filled with the soil together with a light manuring with superphosphate and the following quantities of common salt per 100 ℔s. of soil :—

No. 84,	·10	per cent.	NaCl.
,, 85,	·15	,,	,,
,, 86,	·20	,,	,,
,, 87,	·25	,,	,,
,, 88,	·30	,,	,,
,, 89,	·35	,,	,,
,, 90,	·40	,,	,,
,, 91,	·50	,,	,,

[1] This Journal, xxxvi., p. 191, and xxxvii., p. 165.

The pots were sown on December 3rd, 1902, with 13 grains of barley in each pot, the surface being covered as in the other experiments with a mulch of shredded coconut fibre and the soil kept moist during the experiment.

The following notes were made on December 13th with regard to the growth of the plants :—

In No. 84 the seeds had germinated well, but the growth had already been affected.

In Nos. 85 and 86, the plants had germinated weakly and the growth was very poor. In the remaining pots the seed had not germinated at all.

From these experiments it would appear that the limits both to growth and germination had been struck, the growth being affected by ·10 per cent. NaCl and the germination at about ·25 per cent.

Further pots were sown on July 30th, 1903, with the following quantities of salt :—

No. 92,	·05	per cent.
,, 93,	·07	,,
,, 94,	·10	,,
,, 95,	·15	,,

These were examined August 21st, 1903, when the following notes were made :—

No. 92, germination unaffected and growth unaffected.

No. 93, germination unaffected, growth very slightly affected.

No. 94, the germination had been slightly affected and the growth retarded.

No. 95, germination was weak and the growth was poor.

Examination of the pots a month later, September 29th, 1903, showed that in Pot No. 92, the growth was quite unaffected and the plants were growing vigorously.

In Nos. 93 and 94, the plants had recovered and were apparently as healthy as the control pots, whereas in Pot No. 95 the growth was affected.

From the above it is concluded that the germination of barley is affected by about ·1 per cent. NaCl, and entirely prevented by the presence of ·25 per cent. The growth is affected by as little as ·07 per cent. NaCl, but with this quantity and up to ·15 or ·20 per cent. the plants may recover under favourable conditions. With ·20 per cent. the growth is prevented.

Experiments with sodium carbonate.

Eight pots were filled with soil, manured with superphosphate and sown on December 3rd, 1902, with 13 grains of barley. Sodium carbonate had previously been added in the following proportions:—

No. 96,	·1	per cent.	Na_2Co_3
,, 97,	·2	,,	,,
,, 98,	·25	,,	,,
,, 99,	·30	,,	,,
,, 100,	·35	,,	,,
,, 101,	·40	,,	,,
,, 102,	·50	,,	,,
,, 103,	·60	,,	,,

The appearance of these pots on December 13th, when they were examined was as follows:—

Germination had not been affected in pots 96 and 97.

In pot 98 the germination had been slightly retarded, though all the seeds had germinated.

In the remaining pots the germination was less vigorous and in pot 103 the seeds did not germinate at all.

In pot 96, the plants were growing well. In 97 the growth was slightly affected, the effect increasing with increase of sodium carbonate up to pot 101. In this and the succeeding pots the plants had died.

In order to determine within narrower limits the point at which the growth commenced to show signs of being influenced by the presence of carbonate of soda, 3 additional pots were sown on July 30th, 1903, containing respectively:

No. 104	·1	per cent.	sodium carbonate.
,, 105	·15	,,	,,
,, 106	·2	,,	,,

On August 21st, 1903, when these pots were examined, the germination was unaffected in all three. In pot 104 the growth was quite vigorous and unaffected; in No. 105 the growth was slightly affected, and in No. 106 somewhat more so.

From the above it is concluded that germination of barley is not affected by quantities of carbonate of soda up to ·25 or ·30, and is absolutely prevented by ·60 per cent. carbonate of soda in the soil. The subsequent growth of the plant is not affected by quantities below ·15 per cent., at which point the effects of carbonate of soda are distinctly noticeable. ·4 per cent. and over prevent the growth of barley.

Experiments with ammonium sulphocyanide.

Six pots were filled and sown on December 3rd, 1902, as in the preceding experiments, the following quantities of ammonium sulphocyanide having been added previous to sowing:—

No. 107,	·001	per cent.	NH_4CNS.
,, 108,	·002	,,	,,
,, 109,	·003	,,	,,
,, 110,	·004	,,	,,
,, 111,	·005	,,	,,
,, 112,	·006	,,	,,

In all these cases the germination was unaffected and the plants were growing vigorously on December 13th in all pots except Nos. 111 and 112, in which the growth was affected.

Another series of 5 pots was sown on July 30th with freshly prepared ammonium sulphocyanide, as the solution of cyanide used in the above series had been in stock for some time, and it was thought probable that it had undergone decomposition :—

No. 113, ·007 per cent, ammonium sulphocyanide.
,, 114, ·008 ,, ,, ,,
,, 115, ·009 ,, ,, ,,
,, 116, ·010 ,, ,, ,,
,, 117, ·012 ,, ,, ,,

In none of these cases did the plants germinate, the results are consequently inconclusive and the experiments will have to be repeated.

Experiments with sodium chlorate.

Pots were filled as follows :—

No. 118, ·001 per cent. sodium chlorate.
,, 119, ·002 ,, ,,
,, 120, ·003 ,, ,,
,, 121, ·004 ,, ,,
,, 122, ·005 ,, ,,
,, 123, ·006 ,, ,,

All pots germinated well, except Nos. 122 and 123 in which the germination was much retarded and the plants very weak. On December 13th, the plants in Nos. 118 and 119 were growing well when examined. In No. 120 the growth was good, but the leaves had a tinge of yellow at the tips.

In 121 and 122 the growth was markedly affected, and in 123 the plants were dying. In these three last pots the leaves were distinctly yellow.

Three additional pots were sown on July 30th, 1903, with larger preparations of chlorate :—

No. 124, ·006 per cent. sodium chlorate
,, 125, ·007 ,, ,,
,, 126, ·008 ,, ,,

In none of these cases did the plants germinate.

It appears from the above that in the case of barley, germination is affected by the presence of ·005 per cent. sodium chlorate in the soil, and entirely prevented when ·006 or ·007 is present. The effect of this substance is apparent when ·003 per cent. is present, and when it reaches ·006 the growth of barley is prevented.

Experiments with arsenious acid.

Six pots received varying proportions of arsenious acid on December 3rd, 1902, as follows :—

No. 127,	·10	per cent.	As_2O_3
„ 128,	·20	„	„
„ 129,	·30	„	„
„ 130,	·40	„	„
„ 131,	·50	„	„
„ 132,	·60	„	„

All plants germinated fairly well, but the growth was found (December 13th, 1902) to have been affected by the smaller quantity of arsenic taken, No. 127 being very slightly affected. No. 128 slightly affected, and in No. 129 the growth of the plants was much affected, the effect being more marked with the increase of arsenic in the remaining pots.

Additional pots were resown on July 30th, as follows :—

No. 133,	·05	per cent.	As_2O_3
„ 134,	·06	„	„
„ 135,	·10	„	„

When examined on August 21st, 1903, the germination was practically unaffected in all cases, but the effect on the growth was already strongly marked in the case of No. 133. In No. 135 the growth was very strongly affected. By September 29th, 1903, when the pots were again examined, pots 133 and 134 had recovered and were growing vigorously though not quite as strongly as the control pot. In No. 135 however, the plants were almost dead.

The results with barley are tabulated below:—

Effect upon germination and subsequent growth of Barley of different percentages of injurious substances in the soil.

	Germination affected	Germination prevented	Growth affected	Growth prevented
NaCl	·1	·25	·10	·20
Na_2CO_3	·25	·60	·15	·40
NH_4CNS	inconclusive			
$NaClO_3$	·005	·007	·003	·006
As_2O_3	germination unaffected by ·6		·05	·10

IV. Rye—*Experiments with NaCl.*

Five pots were filled with soil, to which was added 10 grms superphosphate per pot, and the following quantities of sodium chloride:—

No. 136, ·05 per cent.
,, 137, ·10 ,,
,, 138, ·15 ,,
,, 139, ·20 ,,
,, 140, ·25 ,,

These pots were sown on August 6th, 1903, in the usual manner, the surface being covered with a mulch of shredded coco-nut fibre and the soil kept moist throughout the experiment. A check pot was sown at the same time.

The pots were examined in August 21st, when the following observations were made:—

In No. 136 the plants had germinated well but the growth was rather backward compared with that in the check-pot.

In No. 137, the germination was already affected and the growth considerably retarded.

In the remaining three pots both germination and subsequent growth were very markedly affected.

The pots were again examined on September 29th, 1903, when it was found that the plant in pots 136 and 137 had recovered and were apparently making as vigorous growth as the check-pot. In pot 138, however, the growth was strongly affected. In pot 139 the plants were nearly dead, and in No. 140 they were quite dead.

These experiments showed that germination of rye is already affected by the presence in the soil of ·1 per cent. NaCl, it was not however, prevented by amounts up to ·25 per cent. The subsequent growth of rye is affected by ·05 per cent., but under favourable conditions the plants may recover in the presence of sodium chloride up to ·1 per cent. With ·15 per cent. the subsequent growth is strongly affected and with ·20 per cent. the plants die.

In order to ascertain the amount necessary to prevent germination, a further series of four pots were sown on October 10th, 1903, with the following proportions of common salt:—

No. 141,	·30	per cent.	NaCl
,, 142,	·35	,,	,,
,, 143,	·40	,,	,,
,, 144,	·50	,,	,,

It was found on examining these pots on October 21st, that the germination in Nos. 141 and 142 had been strongly affected, and that in No. 143 the plants had hardly germinated at all, the germination being still more feeble in No. 144.

By December 4th, the plants in all pots were dead. Germination of rye is therefore prevented by ·4 per cent. NaCl and over.

Experiments with Na_2CO_3.

On 6th August, 1903, six pots were filled with the soil, 10 grms superphosphate to each pot, and the following quantities of sodium carbonate, and 13 grains of rye:—

No. 145,	·1	per cent.
,, 146,	·2	,,
,, 147,	·25	,,
,, 148,	·30	,,
,, 149,	·85	,,
,, 150,	·40	,,

The following notes were made on August 21st:—The germination was unaffected in pots 145 and 146; slightly affected in 147 and more strongly in the remainder. The early growth was slightly affected in pots 145, 146, 147, and more strongly affected in the remaining three.

On September 29th, the plants in 145, 146, and 147 had recovered and were growing as vigorously as the check-pots; in No. 148 the growth was strongly affected, in 149 the plants were very feeble, and in 150, very nearly dead.

In order to arrive at the point at which germination was prevented, three more pots were sown on October 10th as follows:—

No. 151,	·4	per cent	Na_2CO_3
,, 152,	·45	,,	,,
,, 153,	·50	,,	,,

On October 21st the germination in pot No. 151 was strongly affected; in pot 152 the germination was still more strongly affected, and in pot 153 the plants had hardly germinated at all. By December 4th, 1903, when the pots were again examined, the plants were all dead.

It is therefore, concluded that in the case of rye, germination is affected by the presence of ·25 per cent. Na_2CO_3, and prevented when ·5 per cent. is present. ·1 per cent. is sufficient to check the early growth of the plant, but under favourable conditions the plants will recover with quantities up to ·25 per cent., above this point, however, the subsequent growth of rye is affected, and in the presence ·4 per cent. the plants die.

Experiments with ammonium sulphocyanide.

The following pots were prepared and filled with soil as usual, manured and sown on August 6th, 1903:—

No. 154,	·004	per cent.	NH_4CNS.
,, 155,	·005	,,	,,
,, 156,	·006	,,	,,
,, 157,	·007	,,	,,
,, 158,	·008	,,	,,

The pots were examined on August 21st, when it was found that in all cases the germination was very weak and the young shoots had withered almost as soon as they appeared above ground.

The pots were consequently resown on October 10th with the following quantities:—

No. 159, ·001 per cent. NH_4CNS.
,, 160, ·002 ,, ,,
,, 161, ·003 ,, ,,
,, 162, ·004 ,, ,,

On examining these pots on October 21st, it was found that the germination was unaffected in all cases. Pots 159 and 160 were growing well, but the growth was affected in No. 161, and more strongly in 162, the leaves beginning to curl and the tips to wither.

On December 4th, when re-examined, all plants had apparently recovered and were doing well. The results therefore, with ammonium sulphocyanide are not conclusive and will require to be repeated. Germination appears to be affected by quantities above ·004 per cent. and the growth of the plants affected by ·003 per cent., with this quantity and up to ·004 the plants may recover under favourable conditions. Above ·004 the plants do not recover.

Experiments with sodium chlorate.

The following pots were prepared and sown on August 6th, 1903, sodium chlorate being applied in the undermentioned quantities:

No. 163, ·002 per cent. $NaClO_3$
,, 164, ·003 ,, ,,
,, 165, ·004 ,, ,,
,, 166, ·005 ,, ;,
,, 167, ·006 ,, ,,

The pots were examined on August 21st, when it was found that pots 163 and 164 had germinated well. In 165 the germination was slightly affected, and in 166 and 167 the germination was very weak—in pot 167 the plants hardly germinated. In all cases, even in pots 163 and 164, the subsequent growth was very feeble and the plants were nearly dead. In pots 166 and 167 the plants were quite dead.

Two more pots were therefore sown on October 10th with smaller quantities of $NaClO_3$ in order to determine the point at which the growth commenced to be affected.

No. 168, ·001 per cent. $NaClO_3$
,, 169, ·002 ,, ,,

These pots were examined in October 21st, when both had germinated well. In pot 168 the growth was unaffected and in No. 169 the growth was slightly affected. By December 4th, when the pots were again examined, the plants in both cases had recovered and were growing well.

From these it is concluded that germination is unaffected by $NaClO_3$ in the case of rye by quantities below ·004 per cent., the presence of ·006 per cent. preventing germination. The subsequent growth of the plants is affected by ·002 per cent., but under favourable conditions the plants can recover. Growth is prevented by ·004 per cent.

Experiments with arsenious acid.

The following 5 pots were filled with soil, manured and sown on August 6th with varying quantities of arsenious acid :—

No. 170, ·05 per cent. As_2O_3
,, 171, ·10 ,, ,,
,, 172, ·20 ,, ,,
,, 173, ·30 ,, ,,
,, 174, ·40 ,, ,,

When examined on August 21st, the following appearances were noted:—In pots Nos. 170 and 171 the plants germinated freely. In 172 the germination was retarded. In 173 and 174 the germination was very feeble, and in No. 174 the plants had hardly germinated at all. The plants were growing well in No. 170, but the growth was already affected in No. 171, and in the remaining pots the plants were very feeble and in 173 and 174 nearly dead.

Subsequent examination of the pots on October 10th showed the plants in No. 170 to be growing normally and equal to the check-pots. The plants in No. 171 had recovered and were apparently quite as healthy as those in the check-pots. In No. 172 the growth was affected (stunted) and in 173 and 174 the plants were dead.

The conclusions drawn are that germination in the case of rye is unaffected by quantities of arsenic below ·2 per cent. With ·2 per cent germination is affected, and about ·4 or a little over prevents germination. The subsequent growth of rye is not affected until the amount of arsenic in the soil reaches ·15 per cent. at which point the effects of its presence are marked, and with ·30 per cent. the growth of rye is prevented.

The results of the experiments with rye are presented in the following table :—

Effect upon germination and subsequent growth of Rye of different percentages of injurious substances in the soil.

	Germination affected	Germination prevented	Growth affected	Growth prevented
NaCl	·10	·40	·15	·20
Na_2CO_3	·25	·50	·25	·40
NH_4CNS	inconclusive			
$NaClO_3$	·004	·006	·002	·004
As_2O_3	·2	above ·4	·15	·30

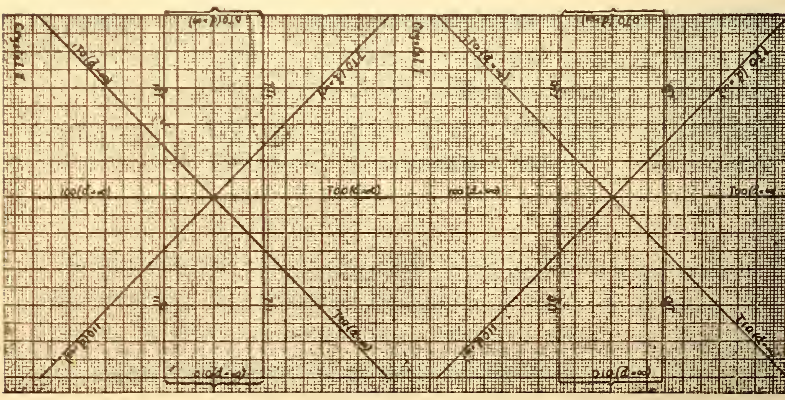
THE OCCURRENCE OF ISOLATED AUGITE CRYSTALS AT THE TOP OF THE PERMO-CARBONIFEROUS UPPER MARINE MUDSTONES AT GERRINGONG, N. S. WALES.

By H. G. FOXALL. (Communicated by Prof. T. W. E. DAVID, B.A., F.G.S., F.R.S.)

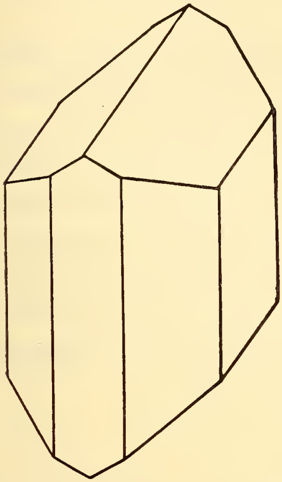
[*Read before the Royal Society of N. S. Wales, November 16, 1904.*]

THESE crystals occur in great numbers embedded in a matrix of tuffaceous mudstone about half a mile south of Black Head, Gerringong. A few crystals also occur in a similar formation to the north of Black Head, but they are not so numerous there. In the former locality the crystals are found right on the shore-line, most of the specimens collected being found actually below high-water mark. They are very perfect and evenly developed, and can be picked out clean from the matrix, In many cases they are twinned on the 100 face.

At the suggestion of Professor David, crystallographical and chemical examinations were made of these crystals in the Geological and Chemical Laboratories, respectively, of the University of Sydney. The results are given below, as



well as two gnomonic projections showing the forms present on the crystals.



Out of about fifty specimens collected only two gave satisfactory results on being measured with the goniometer. The general habit of these crystals is shown in the accompanying figure. The forms developed in the prism zone are the pinacoids [100] and [010] and the prism [110]. The other forms appear to be in one case the dome [011] and in the other case the pyramid $[\bar{1}11]$. On the other crystals the faces other than those on the prism zone were dull, apparently by reason of being corroded by the sea-water.

The measurements were made on a Goldschmidt two-circle goniometer and the results have been tabulated, together with the angles given by Goldschmidt for diopside in his "Crystallographische Winkeltabellen." In addition to the forms recorded, several very small and dull faces are present on some of the crystals which could not be measured accurately, but which seem to belong to the forms [021] and [121] or $[\bar{1}21]$ and $[\bar{2}21]$ according as the larger faces are [011] or $[\bar{1}11]$. The differences between the theoretical angles for these forms are so small, however, that it is impossible to distinguish between them when the faces are so dull as in the present case. If the correct orientation of the crystal were known this ambiguity would of course disappear, since it would be evident whether the faces were on the back or the front of the crystal. It is impossible, however, to determine this orientation excepting in the two crystals above mentioned, owing to the small differences between the ordinates of the [011] and the [$\bar{1}$11] forms.

With regard to the chemical analysis, it will be seen that the mineral is free from alkalis, and contains small quantities of TiO_2, Cr_2O_3, and MnO. It is rather high in Al_2O_3, and iron oxides are present in fairly large amounts. In this part of the work I must express my indebtedness to Mr. H. S. Jevons and Professor Schofield for the use of apparatus and reagents necessary for the accurate performance of the analysis, and also to Mr. T. H. Laby of the Chemical Laboratory for several important hints as to the methods of procedure.

CRYSTAL I.

Form	Measured Angles.		Goldschmidt's Values		Difference.	
	ϕ	ρ	ϕ	ρ	ϕ	ρ
110	43° 36′	90°	43° 33′	90° 00′	+03′	00′
,,	43 38	90			+05	00
100	89 53	89 39	90 00	90 00	−07	−21
,,	90 00	90 00			00	00
0$\bar{1}$0	0 00	90 00	0 00	90 00	00	00
011	25 52	33 14	25 43	33 11	+09	+03

CRYSTAL II.

Form.	Measured Angles.		Goldschmidt's Angles		Difference.	
	ϕ	ρ	ϕ	ρ	ϕ	ρ
110	43° 32′	89° 52′	43° 33′	90° 00′	−01′	−08′
,,	43 39	90 00			+06	00
100	89 57	90 00	90 00	90 00	−03	00
,,	90 03	89 57			+03	−03
010	0 00	89 48	0 00	90 00	00	−12
$\bar{1}$11	25 08	33 00	25 07	33 04	+01	−04

Chemical Composition.

SiO_2	47·21
Al_2O_3	11·12
Fe_2O_3	5·50
FeO	5·11
MgO	8 97
CaO	19·73
Na_2O	abs.
K_2O...	abs.
H_2O (100° C.) ...	0·41
H_2O (+100° C.) ...	1·25
TiO_2	0·79
Cr_2O_3	0·13
MnO	0·29
	100·51

The APPROXIMATE COLORIMETRIC ESTIMATION of NICKEL and COBALT in PRESENCE of ONE ANOTHER.

By R. W. Challinor.

[Communicated by Acting Professor J. A. Schofield, F.I.C., F.C.S., A.R.S.M.]

[*Read before the Royal Society of N. S. Wales, December 7, 1904.*]

Maumené about 1851 appears to have first observed that the colours of solutions of Ni and Co are complementary, his experiment being quoted by Rudolph Wagner in 1854.[1]

Dr. C. Winkler in 1866[2] published a method, founded on Maumené's observation, for the colorimetric estimation of Ni and Co, but the method does not seem to have been used, probably owing to his experiments being few in number and the method somewhat complicated.

Dr. Wolcott Gibbs[3] made use of the complementary colours of the Ni and Co solutions, to remove the colour from a solution of either metal when testing for Mn in its presence by the PbO_2 and HNO_3 method.

W. Gould Leison[4] also used the same method to avoid the colour interference when estimating Ni or Co by titrating the oxalates with $KMnO_4$.

J. Shüller[5] estimated Ni in Ni steels by removing iron and comparing the Ni solution with a Ni solution of known Ni content. He states that steel containing under 1% Ni gives too faint a colour for estimation by this method.

1 Journal für Practische Chemie, 61, 129.
2 *Loc. cit.*, 97, 414.
3 Amer. Journ. Sci., Series 2, Vol. xiii., p. 204.
4 Chemical News, Vol. xxii., p. 210.
5 Chem. Zeit., 1897, xxi., pp. 243 - 244.

Dr. Winkler used solutions of various strengths and various salts, and assumed in all cases that the colour imparted by one part by weight of cobalt neutralizes that given by three parts by weight of nickel. His maximum error is ·0052 gram of either metal in ·34 gram of the mixed metals or about 1·5%, but his experiments were not very numerous.

The method described in the following pages, which differs somewhat from that employed by Dr. Winkler, was adopted as the result of a number of preliminary experiments and observations, some of which will be mentioned in order to better follow its development. The tubes used for comparing the colours of the solutions (except those with MacMillan's apparatus) were Nessler tubes of 50 cc. capacity, the height from 0 to 50 cc. mark being 10·9 cm., placed side by side on a glass plate over a white paper reflector inclined at an angle of 45°. The colours were observed by looking down through the solutions.

Preliminary Experiments.

To observe the effect of dilution on the colours of the nickel and cobalt solutions with the object of finding the most suitable strengths to use; two solutions, one twice the strength of the other, were placed side by side in tubes and viewed vertically, so that the colour seen was due to the same weight of metal in each tube. A number of experiments showed that in each case the more dilute solution appeared if anything a little lighter in colour than the other. (*i.e.* with solutions containing about ·1 gm. to ·3 gm. of metal in 50 cc.)

In another series, two solutions containing the same weight of metal in each were used; to one water was added 5 cc. at a time till it was 10 times more dilute than the other, the two being compared after each addition of water, with the result that the dilute solution always appeared a trifle paler in tint than the stronger one.

A series of trials were also made with *MacMillan's colour testing apparatus.* This apparatus is devised for the determination of carbon in steels (Eggertz test) and consists of two tubes with reservoir tops into which slide two smaller tubes, enclosed in a wooden box and supported over an opal reflector. The standard solution and solution to be examined are placed respectively in the larger tubes, and the smaller tubes are lowered till they rest on the bottom; when viewed vertically they now appear white. The standard tube is then raised till a suitable tint is obtained and is clamped, the other tube is likewise raised till the tint is the same as standard and also clamped. A vertical scale between the tubes shows the relative depths of the columns of liquid which give the same colour and from this the amount of carbon is calculated.

Some 22 standard solutions containing different proportions of nickel and cobalt in 10 cc. were prepared with the idea that if the solution under examination was first of all matched in colour with one of these standards and then compared with it in the apparatus as above mentioned, the amounts of nickel and cobalt present could be calculated. After comparing about 20 of the standard solutions with each other, under various conditions, the idea was abandoned as the results were far from satisfactory, owing chiefly to the variety of colours produced when nickel and cobalt solutions are mixed in different proportions.

Other experiments showed that when cobalt and nickel solutions are added to each other a neutral tint is produced, and the change in colour near this tint is found to be sharpest when the total weight of nickel and cobalt in 50 cc. of solution, using these particular tubes, is not more than ·05 gram., and that at this strength dilution does not appear to affect the colour of either nickel or cobalt solution separately.

As it is proposed to apply the method of estimation to the mixed metals deposited by electrolysis and nitric acid is the most suitable solvent, nitrate solutions of both cobalt and nickel were prepared and used in the subsequent experiments; it is also assumed in all cases that the sum of the weights of Ni and Co present are known.

The measuring vessels used in the preparation of $Ni(NO_3)_2$ and $Co(NO_3)_2$ solutions of accurate strength were all calibrated at 15° C.

Preparation of Solutions.

Ni precipitated by electrolysis from Co free $NiSO_4$ (Kahlbaum's)

Co first precipitated as cobaltinitrite from $Co(NO_3)_2$ which was found to contain a trace of Ni, followed by solution in H_2SO_4, addition of NH_4OH and $(NH_4)_2SO_4$ and electrolysis.

The precipitated metals were dissolved in HNO_3, evaporated over waterbath almost to dryness, dissolved in water and diluted to definite volume.

$Ni(NO_3)_2$ $\frac{N}{2{\cdot}5}$ solution

2·7366 grams of Ni in 234·7 cc. water

·01166 grams of Ni in 1 cc. water

$Co(NO_3)_2$ $\frac{N}{5}$ solution

·6973 grams of Co in 119·07 cc. water.

·005856 grams of Co in 1 cc. water.

Standard.

The preliminary experiments showed ·05 – ·06 gm. of the mixed metals to be the maximum amount permissible in solution to produce a suitable neutral tint, stronger solutions were of a drab tint and prevented a sharp change being noticed. The solution of standard tint was made as follows:—

$Co(NO_3)_2$ solution placed in nessler glass and $Ni(NO_3)_2$ run in till it was quite free from pink or green colour.

Thus 2·56 cc. Co solution	=	·015 grams	=	23·45% Co
required 4·2 ,, Ni ,,	=	·04897 ,,	=	76·55% Ni
		·06397		

It was then diluted to 50 cc.

The method used in the first series of determinations was as follows:—A solution containing a known weight of the mixed metals as nitrates was given, colour noted, and if necessary it was diluted to a definite volume and a measured quantity taken, so that after titration the total weight of mixed metals in solution would be about the same as that in the solution of standard tint.

The nickel or cobalt solution of known strength was then added from a burette till the colour was nearly neutralised, then diluted to 50 cc. in the nessler tube, and finally brought to same tint as standard by the addition of more nickel or cobalt as required; they now contained as nearly as possible the same proportion of nickel and cobalt, and since the amounts are known for the standard solution they may be calculated for the other.

Example—

Weight of mixed metals in solution given = ·05835 gm.

Colour—pale green

Volume of $Co(NO_3)_2$ solution required to bring it to the standard tint = ·45 cc. = ·00263 gm. Co

Total mixed metals in 50 cc. = ·06098 gm.

The standard contained 76·55% Ni

$$\frac{\cdot 06098 \times 76 \cdot 55}{100} = \cdot 04668 \text{ Ni}$$

Ni + Co = ·05835

Ni found = ·04668

Co = ·01167

	Given	*Found*	*Error*
Ni	= ·04664	·04668	+ ·00004
Co	= ·01171	·01167	− ·00004

FIRST SERIES.

	Mixed metals	Colour	Ni or Co added		Total metals in 50 cc.	Given	Found	Error	Percentage error on weight of mixed metals
	Grams		cc.	Grams	Grams				
1	·05835	greenish	·45 Co	·00263	·06098	Ni ·04664	·04668	+ ·00004	·07
						Co ·01171	·01166	− ·00004	
2	·05203	bright				Ni ·01982	·02043	+ ·0006	1·1
	½ taken	pink	3·55 Ni	·04139	·06741	Co ·03221	·0316	− ·0006	
3	·05016	pale	1·4 Co	·0082	·05836	Ni ·04431	·04467	+ ·00036	·72
		green				Co ·00585	·00549	− ·00036	
4	·02922	pink	2·85 Ni	·03323	·06245	Ni ·01457	·01457	·0000	·00
						Co ·01464	·01464	·0000	
5	·05073	green	1·95 Co	·01142	·06115	Ni ·04781	·04758	− ·00023	·95
	+ 5 cc. 16	E. HNO_2				Co ·00293	·00315	+ ·00023	

Maximum error (No. 2) ·0006 gm. in ·052 grams = 1·1%

In the subsequent experiments the solutions used were made of a slightly different strength so that in colour effect one cc. of each were approximately equivalent to one another.

Nickel Solution.

Kahlbaum's Co free $NiSO_4$, electrolysed under the usual conditions and the precipitated Ni dissolved in HNO_3, evaporated almost to dryness on water bath and diluted to the required bulk. It contained

2·7449 grams Ni in 274·49 cc. distilled water
·01 ,, Ni in 1·0 cc. ,,

Cobalt Solution.

Kahlbaum's Ni free $CoSO_4$, electrolysed and the precipitated Co dissolved in HNO_3, evaporated almost to dryness on water bath and diluted to required bulk. It contained

2·0156 grams Co in 671·86 cc.
·003 ,, Co in 1· cc.

Solution of Standard Tint.

4 cc. Co solution = ·012 grams = 24% Co
required 3·8 cc. Ni ,, = ·038 ,, = 76% Ni

·050

Diluted to 50 cc.

SECOND SERIES.

	Mixed metals, grams	Colour	Ni or Co added		Total metals in 50 cc. grams	Given	Found	Error	Percentage error on weight of mixed metals
			cc.	Grams					
1	·05	pink				Ni ·032	·03152	− ·00048	·96
	½ taken		1·35	·0135 Ni	·0385	Co ·018	·01848	+ ·00048	
2	·05	light	2·5	·0075 Co	·0575	Ni ·044	·0437	− ·0003	·6
		green				Co ·066	·0063	+ ·0003	
3	·0501	green	2·9	·0087 Co	·0588	Ni ·045	·04469	− ·0003	·6
						Co ·0051	·00541	+ ·0003	
4	·05035	green	4·65	·01395 Co	·06430	Ni ·0490	·04887	− ·00013	·26
						Co ·00135	·00148	+ ·00013	
5	·05	pink				Ni ·014	·01352	− ·00048	·96
	¼ taken		2·55	·0255 Ni	·0380	Co ·036	·03648	+ ·00048	
6	·042	pink	·97	·0097 Ni	·0517	Ni ·03	·0296	− ·0004	·95
						Co ·012	·0124	+ ·0004	
7	·044	green	1·75	·00525 Co	·04925	Ni ·038	·0374	− ·0006	1·36
						Co ·006	·0066	+ ·0006	

Maximum error (No. 7) = ·0006 gm. in ·044 gm. = 1·36%

Effect of free HNO_3 on the Colour.

A number of experiments showed that the presence of much free HNO_3 had a decided influence on the colour of solution. The results of those given below show the maximum amount which may be present without affecting the colour.

Ni and Co solutions were mixed in the same proportion as that required to produce standard tint, diluted to 20 cc. with distilled water and compared with each other, then to one was added 16 E. HNO_3, 1 cc. at a time, to the other the same quantity of distilled water and again compared after each addition, with the following results:—

Aqueous Solution. H_2O added	HNO_3 Solution. HNO_3 added	Result.
20 cc.	20 cc. water	identical tints
1	1 cc. HNO_3	no apparent difference
2	2 „	ditto
3	3 „	ditto
4	4 „	ditto
5	5 „	?
6	6 „	a doubtful difference
7	7 „	a very faint pinkish tint
8	8 „	more pronounced pinkish tint
9	9 „	a faint pink
10	10 „	ditto, more marked
15	15 „	faint pink still more marked

From these results it appears that the presence of more than 5 cc. strong HNO_3 in the solution would have a decided influence on the estimation.

The next series of experiments were carried out under conditions similar to those which would be used in actual practice.

The given nitrate solutions were evaporated over water-bath with concentrated H_2SO_4 to get rid of HNO_3 diluted with water, $(NH_4)_2SO_4$ and excess of NH_4OH added, and solution electrolysed under usual conditions without any particular care, since the method used is only an approximate one. The precipitated metals were dissolved in HNO_3 evaporated to pastiness, diluted to definite bulk and a proportion taken for estimation. The following table shows the results :—

No.	Mixed Metals		Colour	Ni or Co added		Total metals in 50 cc. grams	Given	Found	Error	Percentage error on weight of mixed metals
	Given	Deposited by Electrolysis		cc.	Grams					
1	·1010	·1001	pink				Ni ·050	·04967	– ·0003	·3
	¼ taken			2·75	·0275 Ni	·05253	Co ·051	·05043	– ·00057	·56
2	·1185	·1176	drab	diluted matched	to 50 cc. this standard.		Ni ·09	·08938	+ ·00062	·5
	½ taken					·0588	Co ·0285	·02822	– ·00028	·2
3	·1010	·1006	pink				Ni ·050	·04838	– ·00162	1·6
	¼ taken			2·925	·02925 Ni	·0544	Co ·051	·05222	+ ·00122	1·2
4	·1000	·0996	green				Ni ·085	·08459	– ·0004	·4
	½ taken			1·95	·00585 Co	·05565	Co ·015	·01501	+ ·00001	·01
5	·072	·072	green	1·15	·00345 Co	·03945	Ni ·06	·05996	– ·00004	·05
	½ taken						Co ·012	·01204	+ ·00004	

Maximum error (No. 3) ·00162 gm. in ·101 gm. = 1 6%.

Reference to the preceding tables of results shows that when the solution was green the errors were as a rule smaller than when it was pink. The reason is obvious, assuming that the change in colour near the neutral point is equally sharp when equal volumes of either Ni or Co solutions are added. When the Co solution is used only one third of the weight of metal is being added as would be added if the same amount of Ni solution were used.

To further test this, another series of experiments were tried with varying quantities of Ni and Co. A known excess of Ni being added till the solution was pale green, it was then diluted to a definite volume and a portion taken and titrated back with Co solution to the neutral tint.

The results are shown in the following table :—

SERIES I.—Adding known excess of Nickel if necessary.

No. and Colour	Mixed metals given. Grams	Ni added to give green colour. Grams	Total Ni + Co Grams	Co added to match standard Grams	Total metals in 50 cc. Grams	Given Grams	Found Grams	Error	Percentage error on weight of mixed metals
1	·05	·18	·23	1·1 cc.		Ni ·005	·00484	- ·00016	·3
pink	¼ taken			= ·0033	·0608	Co ·045	·04516	+ ·00016	
2	·049	·08	·129	·8 cc.		Ni ·025	·02534	+ ·0003	·6
pink	¼ taken			= ·0024	·03465	Co ·024	·02366	- ·0003	
3	·0505	·02	·0705	·6 cc.		Ni ·037	·03632	- ·00068	1·35
pink				= ·0018	·03705	Co ·0135	·01418	+ ·00068	
4	·05	...	·05	2 6 cc.		Ni ·0495	·04985	+ ·0003	·6
green	½ taken			= ·0078	·0328	Co ·0005	·00015	- ·0003	
5	·0221	...	·0221	1·4 cc.	·0263	Ni ·02	·02001	+ ·00001	·05
green				= ·0042		Co ·0021	·00209	- ·00001	
6	·041	·055	·096	·45 cc.		Ni ·02	·02001	+ ·00001	·02
pink	½ taken			·00135	04935	Co ·021	·02099	- ·00001	

Maximum error (No. 3) ·00068 gm, in ·0505 gm. = 1·3%,

SERIES II.—Adding known excess of Nickel.

No. and Colour.	Mixed metals taken Grams	Ni added to give green colour. Grams	Total Ni + Co Grams	Co required to match standard tint Grams	Total metals in 50 cc. Grams	Taken Grams	Found Grams	Error Grams	Percentage error on weight of mixed metals taken
1	·031	·07	·101			Co ·021	·02105	+ ·00005	·16
pink	½ taken		·0505	·0021	·0526	Ni ·01	·00995	- ·00005	
	·022					Co ·021	·02095	- ·00005	·23
2	½ taken	·045	·056	·0039	·0599	Ni ·001	·00105	+ ·00005	
pink	the other					Co ·021	·02099	- ·00001	·05
	half	·037	·048	·00135	·04935	Ni ·001	·00101	+ ·00001	
	·01715					Co ·01665	·01656	- ·00009	·53
3	½ taken	·034	·04257	·00255	·04513	Ni ·0005	·00059	+ ·00009	
pink	the other					o ·01665	·01675	+ ·00014	·8
	half	·033	·04157	·0021	·04367	Ni ·0005	·00396	- ·00014	
	·02555					Co ·02505	·02486	- ·00019	·7
4	½ taken	·044	·05677	·00158	·05835	Ni ·0005	·00069	+ ·00019	
pink	the other					o ·02505	·0249	- ·00015	·6
	half	·05	·06277	·00345	06622	Ni ·0005	·00065	+ ·00015	

Maximum error (No. 3) ·00014 gm. in ·01715 gm. = ·8%.

In the above experiments the solution under examination was compared with a standard containing about the same total weight of nickel and cobalt, selected from a series of various total nickel and cobalt contents, *e.g.* ·03 gm, ·04 gm, ·05 gm, ·06 gm, ·07 gm in 50 cc., in the proportion of 76 % Ni to 24% Co.

The results are more uncertain when the amount of nickel present is as low as 1%. The large proportion of cobalt necessitates the addition of a correspondingly large amount of Ni before titration; the amount of metals originally taken must therefore be about ·01 gm. (see No. 6 in table) in order that the total weight of metals permissible (about ·05 gm.) in 50 cc. of solution is not exceeded.

The following table gives the results of experiments on solutions containing approximately 99% Co and 1% Ni.:—

No.	Mixed metals taken	Ni added to give green colour.	Total Ni + Co	Co required to match standard tint	Total metals in 50 cc.	Taken	Found	Error	Percentage error on weight of mixed metals taken
	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	
5	·05045								
½ used	·025225	·0895	·114725			Co ·04995	·05096	+ ·00101	2
	again	halved	·057362	·00135	·05871	Ni ·0005	·00051	− ·00101	
5*a*	·05045	·0895	·114725			Co ·04995	·05048	+ ·0005	1
		halved	·05736	·0015	·05886	Ni ·0005	·00003	− ·0005	
5*b*	·05045					Co ·04995	·04884	− ·00111	2
¼ used	·01261	·043	·05561	·0015	·05711	Ni ·0005	·00161	+ ·00111	
						Co ·01005	·00997	− ·00008	·8
6	·01015	·034	·04415	·000825	·044975	Ni ·0001	·00018	+ ·00008	
						Co ·01005	·01022	+ ·00017	1·7
6*a*	·01015	·036	·04615	·001125	·047275	Ni ·0001	·00007	− ·00017	
7	·0203	·078	·0983			Co ·0201	·01972	− ·00038	1·9
		halved	·04915	·00255	·0517	Ni ·0002	·00058	+ ·00038	
7*a*	·0203	·078	·0983			Co ·0201	·02017	+ ·00007	·35
		halved	04915	·00225	·0514	Ni ·0002	·00013	− ·00007	

The method finally recommended is as follows:—

Solutions required—

Standard $Ni(NO_3)_2$ solution containing ·01 gm. Ni in 1 cc.
,, $Co(NO_3)_2$,, ,, ·003 ,, Co in 1 cc.

Standard solutions of neutral tint containing various total weights of Ni and Co (in the proportion of 76% Ni to 24% Co) in 50 cc. *e.g.*,

·04 gm. standard.

Take of standard	Ni solution	3·04 cc. =	·0304	gm.	Ni
,, ,,	Co ,,	3·2 cc. =	·0096	,,	Co
			·04		

·05 gm. standard.

Standard	Ni solution	3·8 cc. =	·038	gm.	Ni
,,	Co ,,	4 cc. =	·012	,,	Co
			·05		

·06 gm. standard.

Standard	Ni solution	4·56 cc. =	·0456	gm.	Ni.
,,	Co ,,	4·8 cc. =	·0144	,,	Co.
			·06		

Dilute each to 50 cc.

After obtaining the weight of the two metals deposited electrolytically, dissolve in HNO_3 (16 E. HNO_3 diluted with an equal volume of water) by heating gently on hot plate, in a covered beaker. Evaporate nearly to dryness, take up in water and dilute to a known volume. (*a*) *If the solution is green* (indicating the presence of more than 76% Ni), take an aliquot portion containing from ·04 – ·05 gm. of the mixed metals, and add standard $Co(NO_3)_2$ from a burette till the colour (after diluting to 50 cc. mark) matches that of the standard solution containing the nearest total weight of mixed metals. (*b*) *If the solution is pale pink* (indicating more than 24% Co) take about ·02 gm., and if *decided pink* about ·01 gm., add a measured excess of standard $Ni(NO_3)_2$ solution till of a faint green colour and then standard $Co(NO_3)_2$ and match with standard solution as before. After calculating the weight of Ni present in this solution, deduct the amount of added Ni and this gives the weight of Ni in the portion of solution taken. The above proportions are for 50 cc. Nessler tubes 10·9 cm. high from 0 to 50 cc. mark.

If after titrating, the final weights of mixed metals present differ largely from those in the standard neutral solutions, repeat on a fresh portion so that the weight of mixed metals in each solution is approximately the same.

Example.

Weight of Ni + Co in solution = ·022 gm.
Colour—pink
Diluted to 50 cc.
25 cc. taken = ·011 gm. Ni + o
Standard Ni $(NO_3)_2$ solution added to give green colour } = 3·7 cc = ·037 gm. Ni
Standard Co $(NO_3)_2$ solution required to bring to standard neutral tint } = ·45 cc. = ·00135 gm. Co

Total metals in 50 cc. = ·04935 gm. Ni + Co

Then 76% of ·04935 is Ni.

$$\frac{\cdot 04935 \times 76}{100} = \cdot 03751 \text{ gm. Ni}$$

Ni added = ·037

Ni in the 25 cc. of solution taken = ·00051
2

„ 50 cc. „ „ = ·00102 gm.

Co + Ni = ·022 gm.
Ni = ·00102 „

Co = ·02098 „

Probably increase of accuracy would be obtained if a colorimeter were used in which the colours to be compared could be brought into juxtaposition.

In conclusion I desire to express my warmest thanks to Professor Schofield for pointing out this work and also for the kindly interest he has shown during the course of these experiments.

NOTE ON A COMBINED WASH-BOTTLE AND PIPETTE.

By J. W. HOGARTH.

(Communicated by Acting Professor J. A. SCHOFIELD, F.C.S., A.R.S.M.)

[*Read before the Royal Society of N. S. Wales, December 7, 1904.*]

DURING some chemical work in which it was desirable to dissolve a precipitate, with which the work was concerned, in a known volume of acid, the want was felt of a vessel possessing the combined advantages of a measuring vessel and wash-bottle. It was not originally intended to have devoted a separate article to the description of the apparatus which is described below, but because the work for the time being has been stopped, it was deemed advisable to now make mention of the vessel. Ordinarily when it is wished to dissolve or wash a precipitate with a known volume of solution, a measured quantity of the hot or cold liquid is poured into the filter containing the substance to be dissolved or washed, in which manner it is not possible to stir up the precipitate and thereby offer as large a surface as possible to the action of the solution, consequently more liquid has to be used than is necessary to bring about the desired change; this excess of solution in some cases may be objectionable. If the liquid be delivered from a wash-bottle the objections to a great extent are obviated, but the volume of liquid used cannot conveniently be arrived at, especially when the filtrate has to be quantitatively treated, because any extra operation tends to introduce errors into the analysis. The apparatus of which the following is a description was designed to overcome the above objections.

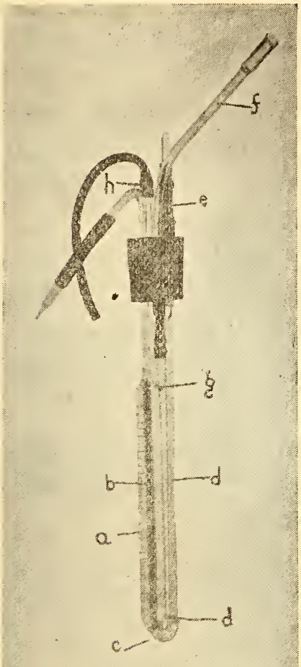


Fig. 1.

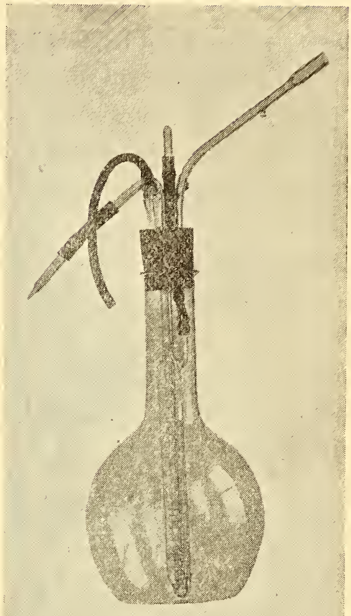


Fig. 2.

The measurements given are those of the actual apparatus made for use. Vessel *a* which is of thin glass 13·3 cm. long and 1·4 cm. wide, is graduated in cubic centimetres and fractions thereof, tube *b* is 5 mm. in diameter and 13·3 cm. long from junction at top of *a* to the bottom where it just enters *c*, (to bring *b* out more clearly for the purpose of photographing, it was partly filled with coloured liquid). Tube *g* is sealed on to *a*, and is connected to the lower extremity of *f* by a piece of stout rubber tubing. To use the vessel, rod *d* is slightly raised, the watertight joint at *d'* where rod *d* is ground into c, is thereby broken, air is blown from the mouth through the rubber connected to *h*, which is in direct communication with the air of flask only, until the level of liquid rises to the desired mark in *a*, rod *d* is then released, when it is automatically forced back into position by the rubber *e* which is stretched from the disc on *d* to the out-turned edge of a short glass tube through which *d* passes. This liquid is then delivered in the ordinary way by blowing into *f*, as soon as the liquid in *a* falls to the curved tube *c* liquid ceases to pass up *b*.

The vessel which was of 15 cc. capacity, delivered any desired volume within that limit to $\pm \frac{1}{5}$ cc. Fig. 2 shows the apparatus as it fits in an ordinary flask. As far as can be ascertained this apparatus has not elsewhere been described.

The author here takes the opportunity of tendering his thanks to Acting Professor Schofield for the interest shown and encouragement that he has often given him.

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 4, 1904.

The Annual General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 4th, 1904.

Act. Prof. F. B. GUTHRIE, F.I.C., F.C.S., President, in the Chair.

Fifty members were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ended 31st March, 1904, was presented by the Hon. Treasurer, and adopted :—

GENERAL ACCOUNT.

RECEIPTS.		£ s. d.	£ s. d.
Subscriptions	One Guinea	77 11 0	
	Two Guineas	350 14 0	
	Arrears	65 18 4	
	Advances	13 13 0	
			507 16 4
Parliamentary Grant on Subscriptions received—			
Vote for 1903-1904		500 0 0	
			500 0 0
Rent...			44 15 0
Sundries			20 14 9
Clarke Memorial Fund			300 0 0
Total Receipts			1373 6 1
Balance on 1st April, 1903			8 19 8
			£1382 5 9

Payments.	£	s.	d.	£	s.	d.
Advertisements	18	6	6			
Assistant Secretary	250	0	0			
Books and Periodicals	85	3	4			
Bookbinding	1	19	6			
Conversazione	73	1	3			
Expenses at Meetings	20	14	0			
Freight, Charges, Packing, &c....	6	13	3			
Furniture and Effects	27	17	6			
Gas	12	15	8			
Housekeeper	10	0	0			
Insurance	9	8	0			
Interest on Mortgage	56	0	0			
Office Boy	29	15	10			
Petty Cash Expenses	11	10	6			
Postage and Duty Stamps	29	0	0			
Printing	21	3	6			
Printing and Publishing Journal	283	12	10			
Printing Extra Copies of Papers	2	7	6			
Rates	47	1	0			
Repairs	11	11	0			
Stationery	7	11	7			
Sundries	27	3	0			
Total Payments				1042	15	9
Building and Investment Fund, Composition for Life Membership				21	0	0
Clarke Memorial Fund—Loan repaid	300	0	0			
Interest to date	5	2	8			
Printing and Advertising	1	14	0			
				306	16	8
Bank Charges				0	17	6
Balance on 31st March, 1904, viz.:—						
Cash in Union Bank...	0	15	10			
Cash in hand...	10	0	0			
				10	15	10
				£1382	5	9

BUILDING AND INVESTMENT FUND.

Receipts.	£	s.	d.
Loan on Mortgage at 4%	1400	0	0
Composition for Life Membership	21	0	0
	£1421	0	0

Payments.	£	s.	d.
Advance to General Account 31st March, 1897	8	0	6
Deposit in Government Savings Bank, March 31st, 1904 ...	21	0	0
Balance 31st March, 1904	1391	19	6
	£1421	0	0

CLARKE MEMORIAL FUND.

Receipts.	£	s.	d.
Amount of Fund, 31st March, 1903	454	5	3
Interest to 31st March, 1904	15	4	8
	£469	9	11

	£	s.	d.
Deposit in Savings Bank of New South Wales, March 31, 1904	236	9	5
Deposit in Government Savings Bank, March 31, 1904 ...	233	0	6
	£469	9	11

Audited and found correct, as contained in the Books of Accounts.

DAVID FELL, C.A.A. ....
T. TYNDALL PETERSON, A.S.I.A. } *Honorary Auditors.*

Sydney, 18th April, 1904.

D. CARMENT, F.I.A., F.F.A. *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

A vote of thanks was passed to the Hon. Auditors, viz., Mr. David Fell, c.a.a., and Mr. T. Tyndall Peterson, a.s.i.a., for their services.

Mr. W. A. Dixon, f.i.c., f.c.s., and Mr. W. J. MacDonnell, f.r.a.s., were appointed Scrutineers, and Mr. W. M. Hamlet, f.i.c., f.c.s., deputed to preside at the Ballot Box.

Before the ballot for the election of Officers and Council was proceeded with the question was raised as to whether members voting were compelled to vote for the whole number of members of Council required.

After considerable discussion it was resolved that any ballot paper bearing more or less than the required number (ten) for the Council be treated as informal.

A ballot having been taken, the following gentlemen were declared duly elected Officers and Members of Council for the current year:—

President:

C. O. BURGE, M. Inst. C.E.

Vice-Presidents:

W. M. HAMLET, F.I.C., F.C.S.	Prof. WARREN, M. Inst. C.E., Wh.Sc.
Prof. LIVERSIDGE, LL.D., F.R.S.	Act. Prof. F. B. GUTHRIE, F.I.C., F.C.S.

Hon. Treasurer:

D. CARMENT, F.I.A., F.F.A.

Hon. Secretaries:

J. H. MAIDEN, F.L.S.	Act. Prof. G. H. KNIBBS, F.R.A.S.

Members of Council:

S. H. BARRACLOUGH, B.E., M.M.E.	F. H. QUAIFE, M.A., M.D.
Prof. T. W. E. DAVID, B.A., F.R.S.	H. C. RUSSELL, B.A., C.M.G., F.R.S.
T. F. FURBER, F.R.A.S.	HENRY G. SMITH, F.C.S.
H. A. LENEHAN, F.R.A.S.	WALTER SPENCER, M.D.
CHARLES MOORE, F.R.B.S.	J. STUART THOM

The certificates of three candidates were read for the third time, and of seven for the first time.

The following gentlemen were duly elected ordinary members of the Society, viz:—

Adams, William John, M. I. Mech. E., 163 Clarence-street.

Jaquet, John Blockley, A.R.S.M., F.G.S., Acting Chief Inspector of Mines, Geological Surveyor, 'Cromer,' 91 Phillip-street.

Jenkins, R. J. H., Fisheries Commissioner, 'Pyalla,' 13A Selwyn Street, Moore Park.

The Chairman announced that the Officers and Committee of the Engineering Section had been elected for the ensuing Session:—

SECTIONAL COMMITTEES—SESSION 1904.

Section K.—Engineering.

Chairman—S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E.
Hon. Secretary—J. Haydon Cardew, Assoc. M. Inst. C.E.

Committee—C. O. Burge, M. Inst. C.E., G. R. Cowdery, Assoc. M. Inst. C.E., J. Davis, M. Inst. C.E., Henry Deane, M.A., M. Inst. C.E., T. H. Houghton, M. Inst. C.E., M. I. Mech. E., R. T. McKay, C.E., J. N. C. MacTaggart, B.E., Herbert E. Ross, P. W. Shaw, Assoc. M. Inst. C.E., J. Taylor, B. Sc., A.R.S.M.

Past Chairmen, *ex officio* Members of Committee for three years:—Norman Selfe, M. Inst. C.E., J. M. Smail, M. Inst. C.E., H. G. McKinney, M. Inst. C.E.

Section Meetings.

Engineering—In place of the customary monthly meeting, two or more *Sessions* extending over at least two nights each, will be held on dates to be announced later. It is hoped to devote each Session to the discussion of a single subject. The subject chosen for the first Session is:—"Technical and Industrial Education in Australia."

Ninety-two volumes, 644 parts, 44 reports and 69 pamphlets, total 849, received as donations since the last meeting were laid upon the table and acknowledged.

The following letter was received from Mr. A. W. Howitt, F.G.S., acknowledging the award of the Clarke Memorial Medal:—

Eastwood, Bairnsdale, 28th March, 1904.

The Hon. Secretaries, the Royal Society of N. S. Wales.

Dear Sirs,—I beg to acknowledge your letter of the 18th instant, conveying to me the information that the Council of the Royal Society had awarded me the Clarke Memorial Medal in recognition of the scientific work which I have done. Please to convey to your Council the deep sense which I have of the great honour which they have done me, and my profound gratification at the kindly feeling entertained for me by them. I greatly prize the medal which accompanied your letter and which will remain a valued heirloom in my family.

I remain, dear Sir, yours faithfully,

(Signed) A. W. HOWITT.

The Hon. Secretary (Prof. Knibbs) stated that he had been in communication with Monsieur Louis Nettement, late Acting Consul-General for France, who had very kindly promised to donate to the Royal Society's library a number of valuable reports in connection with the French Exhibition. It was unanimously agreed that the best thanks of the Society be conveyed to the Consulate for the generous gift.

The Chairman said he had the pleasure to announce that the Lecture Committee had made arrangements for the delivery of the following course of Science Lectures during the present Session, viz.:—

Popular Science Lectures.

A series of popular Science Lectures will be delivered at the Society's House, on the fourth Thursday in each month at 8 p.m., as follows:—(See exception *)

June 23rd—"*The Distribution of Life in Australasia,*" by Charles Hedley, F.L.S., Australian Museum, Sydney.

July 28th—"*The Fabric of the Universe,*" by G. H. Knibbs, F.R.A.S., etc., Acting Professor of Physics, University of Sydney.*

Aug. 25th—Conversazione (if practicable).

Sept. 22nd—"*The Solar System and Southern Sky,*" by H. A. Lenehan, F.R.A.S., etc., Acting Government Astronomer, Sydney Observatory.

Oct. 27th—"*The Nervous System in its Genesis and Development,*" by Dr. J. Froude Flashman, M.D., Honorary Lecturer in Psychological Medicine and Neurology, University of Sydney, Director of the Pathological Laboratory of the Lunacy Department.

Nov. 24—"*The Steam Engine and its Modern Rivals,*" by S. H. Barraclough, B.E. (Sydney) M. M. E. (Cornell); Assoc. M. Inst. C.E.; Lecturer in Mechanism and Applied Thermodynamics, University of Sydney.

* This lecture will be delivered in the Physics Lecture Theatre of the University.

Professor F. B. Guthrie, F.I.C., F.C.S., then delivered the Presidential Address, and afterwards vacated his seat.

The President, in the course of his address, said that the balance sheet showed that the Society was in a fairly flourishing condition; last year the Society exchanged its journal with 431 kindred societies, receiving in return 328 volumes, 1,729 parts, 207 reports, etc. The number of members on the roll on April 30th, 1903, was 344. During the year 22 new members had been elected; deaths numbered 6, and resignations 13, leaving a total of 347 to date.

A resumé was given of the condition of chemistry and chemists in the State. Of the teaching institutions, the University made ample provision for teaching chemistry; about 300 students were in attendance at lectures, and about 150 doing practical work in the laboratories. Within the last five years a well-equipped metallurgical and assaying laboratory had been erected where students received a complete course of instruction, including assaying and technical analysis and bulk treatment of ores. There were also the Technical College, the Mint, the Departments of Mines and Agriculture, Customs, and Explosives, and classes at the Hawkesbury College. Details were then supplied of the work done years ago, by the first Government Analyst, Mr. James Smith Norrie (1844 – 1871), then by his successor Mr. Charles Watt (1872 – 1886), and finally by the present occupant of the office, Mr. W. M. Hamlet. Finally there were manufacturing firms like Elliott Bros. and the Colonial Sugar Refining Company. In all, there were actually employed as chemists the following:—96 engaged in manufacture, 143 in analytical work, and 50 in metallurgical work, or 289 altogether. This was not a very large number, but it was likely to increase indefinitely. In proportion as existing industries became more robust, and new ones started, the need for scientifically-trained men would increase, and just in proportion as the importance of science was recognised in regard to these industries, so they would flourish. At the present time those who made their livelihood by chemical work laboured under serious disabilities, the principal of which was the absence of any recognised chemical qualification. It should be possible for those who employed chemists to be able to insist upon a certain qualification which would ensure competency, but at present there was no standard in existence here. In Victoria, they had put forward a scheme which contemplated the granting of certificates either by the Government or by a private examining body. In Continental countries every chemist was obliged to pass a stringent examination. In England the disadvantages accruing from the absence of qualification were so seriously felt that an Institute of Chemistry was started some years ago. This institute had its branches, and its branch examinations. The suggestion was put forward before the evil assumed greater dimensions here, that the largest employers of chemists, viz., the Government, should agree to regard the qualification of the London Institute as an essential to employment. The Institute would be only too glad to establish local branch examinations, and it would be far preferable to take advantage of the machinery of an existing institution than to create a new qualifying board, whose position would be more or less discounted by local jealousies and prejudices. In conclusion, stress was laid upon the necessity for centralising chemical research work. At present there existed the opposite tendency—to decentralise it as the departmental work grew. Thus they had their separate laboratories in the Mines and Agriculture, the Explosives, the Customs, etc., etc. This procedure was quite contrary to that in other countries, where the tendency had been to centralise. Our system did not necessarily mean greater efficiency, and it certainly was not nearly as economical as the maintenance of a single establishment. Personally he would like to see established a central scientific institute, where all the scientific work could be conducted. Failing this, a great deal could be done in consolidating scientific work and increasing its efficiency by the creation of a controlling Science Department, which would administer the different scientific establishments under departmental control. This would be of great advantage in research, especially where it required the co-operation of more than one branch of science. Investigation into subjects of national importance could then be carried out in continuity.

A vote of thanks was passed to the retiring President, and Mr. C. O. Burge, M. Inst. C.E., was installed as President for the ensuing year.

Mr. Burge thanked the members for the honour conferred upon him, and the meeting closed.

ABSTRACT OF PROCEEDINGS, JUNE 1, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 1st, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Thirty-seven members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of seven candidates were read for the second time, and of four for the first time.

The Chairman announced that Journal Vol. XXXVII., for 1903, was in the binder's hands and would shortly be ready for deliverly to members.

Also that a circular in regard to the first science lecture this Session (by Mr. C. HEDLEY) would be issued in about a fortnight, asking that applications for tickets might be made.

Ninety volumes, 172 parts, 5 reports, and 105 pamphlets, total 372, received as donations since the last meeting were laid upon the table and acknowledged. Included in these were 35 volumes of reports in connection with the Exposition Universelle Internationale de 1900 à Paris, received through the kind courtesy of Monsieur G. Biard d' Aunet the Consul-General and Monsieur L. Nettement, late Acting Consul-General for France.

The following letter was read :—

Commonwealth of Australia, Governor-General,
Government House, Sydney, May 18th, 1904.

Sir,—I am directed by His Excellency the Governor-General, to acknowledge the receipt of your letter of the 16th instant, and to say it will give him great pleasure to accept the position of Patron of the Royal Society of New South Wales, Sydney.

I have the honour to be, Sir, your obedient servant,
J. A. STEWART-BALMAIN, Captain,
Private Secretary,
To His Excellency the Governor-General.

The Hon. Secretary, the Royal Society of New South Wales, Sydney.

THE FOLLOWING PAPERS WERE READ:

1. "Possible Relation between Sunspots and Volcanic and Seismic Phenomena and Climate," by H. I. JENSEN, B.Sc., Junior Demonstrator in Chemistry and Geology, University of Sydney. (Communicated by Professor T. W. E. DAVID, B.A., F.G.S., F.R.S.)

This paper is a sequel to the author's note communicated to the Royal Society of New South Wales, on June 4th, 1902. The paper is divided into two parts. In the first part it is shown that while there has been a marked rise in solar activity since the middle of 1902, seismic and volcanic disturbances have fallen off on the earth, both in violence and frequency almost to a minimum. The causes to which Dr. J. Milne ascribes seismic disturbances in his "Earthquakes," are reviewed, and it is concluded that most earthquakes are primarily due to gain or loss of heat by a portion of the earth's crust, to *gain* in regions undergoing rise of isogeotherms after heavy sedimentation, to *loss* in regions of rapid secular contraction. In both cases it is shown that solar activity will exert a considerable influence if it be granted that more heat is received from the sun in years of sunspot maximum than in years of sunspot minimum. In areas undergoing heating and folding like Japan, Java, and Argentina, an increase in our annual supply of solar heat, such as is experienced at sunspot maxima, may exert a disturbing influence; but in areas undergoing cooling *comprising the greater part of the earth's land surface*, a falling off of solar heat leads to seismic disturbances, by hastening secular cooling, hence earthquakes are more numerous at sunspot minima than at maxima. It is freely admitted that various secondary causes or liberating forces, may have considerable influence in locating the time for earthquake outbreaks. Volcanoes are similarly shown to be in the main divisible into two classes (1) those which erupt at sunspot minima, and (2) those which tend to become violent at sunspot maxima. The latter are shown to consist mainly of volcanoes situated in an artesian or subartesian basin. The author discusses the problem of the influence of sedimentation on the stability of a region. Volcanic chains are situated chiefly near oceans which are or have up to Post-Tertiary time been suffering great sedimentation. Curves are given which show that both seismic and volcanic activity are at a maximum during a sunspot minimum, and that there is a very good agreement between the earthquake and eruption curve and the inverted sunspot curve. Of the lunar influences to which Elmer J. Still and others ascribe the main share of causing earthquakes, Perigee is shown to be the only one worthy of consideration. In the second part of the paper various sunspot and meteorological theories are considered. . . The author disagrees with the conclusions which Dr. Halm infers from his solar theory. The apparent inconsistency of the temperature curves of different latitudes, and their want of agreement with one another and with the sunspot curve, are only to be expected. Temperature at the earth's surface is to a greater extent a function of cloudiness, evaporation and general humidity of the atmosphere than of solar heat received by the earth. With proper allowance for latitude and general atmospheric movements it is not astonishing that in years of sunspot maximum the mean annual temperature is lower in tropical regions and higher in temperate regions. The observations and curves of Köppen, Nordmann, and Alex. McDowall are shown to be quite consistent with one another, if we admit that the earth receives its maximum annual allowance of heat at a sunspot maximum. The author considers the disagreement of rainfall curves for different regions *inter se*, to be likewise the result of latitude, the prevailing air currents, and geographical distribution. The climates of Australia and Mauritius are discussed, and the occurrence of heavy rains at sea during drought periods, the retreat of glaciers during cold winters, and the diminution in the number of cyclones during sunspot minima, are ascribed to the same cause, namely, the feebler circulation of the atmosphere due to the diminution in the amount of heat received from the sun during sunspot minima. An index to literature and tables of earthquake and eruption statistics follow.

Remarks were made by the Chairman, Prof. David, Dr. Walter Spencer, and Prof. Knibbs.

2. "On the absence of Gum, and the presence of a new Diglucoside in the Kinos of the Eucalypts," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum.

In this paper, which is the first of a series dealing with Eucalyptus kinos, the author shows that the supposed gum occurring in many Eucalyptus kinos is not gum but a peculiar tannin diglucoside. The insolubility in alcohol of this substance seems to have been the only reason for considering it to be gum. Professor Wiesner[1] stated that it was closely allied to Acacia gum, and J. H. Maiden[2] later formed one of his Eucalyptus kino groups (the Gummy Group) upon its presence. It does not appear possible to obtain it in a crystallised condition, nor could it be removed from aqueous solution by miscible solvents. It was obtained in as pure a condition as possible by repeated precipitation by alcohol from concentrated aqueous solutions. When dried and powdered, it was of a cinnamon colour, and this colour was not removed by boiling with animal charcoal. It is very soluble in water, and when boiled with acid for some time a "kino red" is formed in

[1] Abst. Pharm. Journ. [3] 2, 1871.
[2] Proc. Linn. Soc. N.S.W., 1899 and 1891.

quantity, a sugar being separated at the same time. The "kino red" dyes mordanted cloth a series of browns, alumina giving the best colour. When fused with potash it forms protocatechuic acid but not phloroglucinol. The sugar had no rotation, was reduced by Fehling's solution readily, was slowly but entirely fermented by yeast, and gave an osazone soluble in hot water, and which melted at 176–178° C. Were it not that it was inactive to light it might, from these reactions, be supposed to be melibiose, which is formed from melitose (Eucalyptus sugar) by hydrolysis, levulose being split off at the same time. This glucoside, for which the author proposes the name *Emphloin*, (as it principally occurs in the bark of certain species) is found in almost a pure condition in those Eucalypts known as "Ironbarks." The kinos of the "Stringybarks" and of the "Peppermints," although consisting of the same tannin, do not contain sugar and are not glucosides, but the author has already isolated glucoside, *Myrticolorin*, from the "Stringybarks," the sugar of which is glucose. This kino glucoside is practically a bark product, occurring in species which do not appear to give Eucalyptus Manna. Melitose however, is found in the bark of certain species in which the tannin is principally located in the wood, as in *E. pi tata*. For these reasons the author thinks that melitose itself should be considered a glucoside, the third glucose molecule taking the place of the tannin in the glucoside. The quantitative results, and the relative astringent values show the substance to contain an equivalent to two glucose molecules. Although entirely precipitated by gelatine, the glucoside has very slow action on hide, and thus the sluggishness of "Ironbark" liquors is accounted for. It now remains to devise a method whereby the glucoside may be cheaply hydrolysed, and thus the tannin in the bark of *E. sideroxylon*, for instance, be made available for tanning purposes.

Some remarks were made by Mr. Maiden, but on account of the lateness of the hour, the discussion was postponed to the next meeting.

3. "On some Natural Grafts between indigenous trees," by J. H. Maiden, Government Botanist and Director, Botanic Gardens.

The author obtained from George's River a composite log which in bark and timber showed the absolute fusion of White or Cabbage Gum (*Eucalyptus hæmastoma*, variety *micrantha*) and Stringybark (*Eucalyptus capitellata*). The red timber of the former contrasts well with the pale brown of the latter and the fusion of the two timbers is perfect. Such instances of the organic union of two species of the same genus have been rarely recorded. The author also exhibited a photograph by Mr. C. T. Musson, of the Hawkesbury Agricultural College, Richmond, where an Apple-tree (*Angophora subvelutina*) is growing out of a fissure in a Swamp Red Gum (*Eucalyptus tereticornis*, variety *latifolia*). Such instances are even more rare, but since the two trees are now growing, a log is not available to see if the organic union between the dissimilar timbers is as complete as in the first case. The author fully described the specimens and commented upon them.

EXHIBITS.

Exhibits in connection with their several papers were shown and explained by Mr. Smith and Mr. Maiden.

Mr. J. E. Carne, F.G.S., Department of Mines exhibited some polished specimens of nepheline-aegerine rocks from Barigan near Rylstone.

Some remarks were made by Prof. David.

ABSTRACT OF PROCEEDINGS, JULY 6, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 6th, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Eighteen members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of seven candidates were read for the third time, of four for the second time, and of three for the first time.

The Chairman announced that the Second Popular Science Lecture this session, on "The Fabric of the Universe," by Actg. Professor G. H. KNIBBS, F.R.A.S., would be delivered in the Physics Lecture Theatre of the University, on Thursday, July 28th, at 8 p.m.

Forty-eight volumes, 139 parts, 8 reports and 9 pamphlets, total 204, received as donations since the last meeting were laid upon the table and acknowledged. Included in these was a complete set of the Transactions of the American Society of Mechanical Engineers, Vols. I. – XXIV., 1880 – 1903.

The discussion upon paper by Mr. HENRY G. SMITH, F.C.S. (read June 1st) "On the absence of Gum, and the presence of a new Diglucoside in the Kinos of the Eucalypts," was continued by Mr. J. H. Maiden, the author replied and some remarks were made by the Chairman.

Actg. Professor F. B. GUTHRIE, F.I.C., F.C.S., recapitulated his suggestions as to "The desirableness of co-ordinating scientific work and research in New South Wales," as outlined in his Presidential Address on the 4th May; the following gentlemen took part in the discussion:—Mr.

Maiden, Dr. Walter Spencer, Mr. Carment, Mr. H. G. Smith, and the President. Prof. Guthrie replied.

Mr. H. A. Lenehan exhibited a crystalline formation in a rain-gauge from Bathurst, and Mr. H. G. Smith two photographs of gigantic trees in Victoria.

The following is an abstract of the first popular science lecture of the present session, delivered on the 23rd June, by Charles Hedley, F.L.S., Australian Museum, Sydney, on "The Distribution of Life in Australasia." The lecture described the Australian fauna, its isolation from the rest of the world, its rich development of marsupials and striking features. The general methods of zoogeographic study were outlined. Three divisions of Australian life comprise the Autochthonian, the Euronotian, and the Torresian. The first has a poor fauna but a rich flora, which is nearly allied to that of South Africa. The second is related to that of South America, and is believed to have reached this continent across Antarctica when the latter enjoyed a mild climate and extended long promontories to the northward. The third element is a recent migration from Papua and arrived by Cape York when Torres Straits was dry land.

ABSTRACT OF PROCEEDINGS, AUGUST 3, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 3rd, 1904.

C. O. Burge, M. Inst. C.E., President, in the Chair.

About twenty members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of four candidates were read for the third time, and of three for the second time.

The following gentlemen were duly elected ordinary members of the Society, viz:—

Bosch, Ernest, Consulting Optician, Mutual Life Building, Martin Place.

Cambage, Richard Hind, Chief Mining Surveyor, Park Road, Burwood.

Cooksey, Thomas, Ph.D., B.Sc. (Lond.), F.I.C., Second Government Analyst, "Clissold," Calypso Avenue, Mosman.

Evans, James W., Chief Inspector, Weights and Measures, "Glenthorne," Railway-street, Petersham.

Fraser, James, Engineer-in-Chief for Existing Lines, Bridge-street.

Holt, Rev. Wilfred John, Clergyman of the Presbyterian Church, "Kiora," Blackheath.

McKenzie, Robert, Sanitary Inspector, (Water and Sewerage Board), Bronte Road, Waverley.

Ramsay, David, Surveyor, Lyons Road, Five Dock.

Ross, William J. Clunies, B.Sc. (Lond. and Syd.), F.G.S., Lecturer on Chemistry, Technical College, Sydney.

Smail, Herbert Stuart Inglis, B.E. (Syd.), Assistant Engineer, Public Works Department, "Clytha," Neutral Bay.

Stanley, Henry Charles, M. Inst. C.E., Civil Engineer, Royal Chambers, Hunter and Castlereagh-streets.

The President made the following announcements, viz.:

(1) That consideration of the Conversazione intended, if practicable, to have been held on August 25th, had been postponed.

(2) That the Second Popular Science Lecture 1904, on "The Fabric of the Universe," by Prof. G. H. KNIBBS, F.R.A.S., would—by special request—be repeated in the Physics Lecture Theatre of the University on Friday, August 5th, at 8 p.m.

(3) That the Third Popular Science Lecture 1904, on "The Solar System and Southern Sky," by H. A. LENEHAN, F.R.A.S., etc.. Acting Government Astronomer, Sydney Observatory, would be delivered at the Society's House, on Thursday, September 22nd, at 8 p.m.

Thirty-four volumes, 185 parts, 13 reports, and 8 pamphlets, total 240, received as donations since the last meeting, were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ.

1. "On Eucalyptus Kinos, their value for Tinctures, and the Non-Gelatinization of the Product of Certain Species," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In this paper, which is the second of the series dealing with Eucalyptus kinos, the author shows that the tannins in the exudations from the various Eucalypts vary largely in character, and that while some kinos gelatinize in tinctures others do not. There is a remarkable regularity in the action of kinos from allied species, and the marked differences in the tannins themselves appear to be the reason why they act so differently as regards gelatinization. There are three tannins at least in Eucalyptus kinos and all are determinable by reagents. The one which gives the violet coloration and precipitate with ferric chloride gelatinizes the most rapidly, the one giving a green coloration with ferric chloride also gelatinizes but not so rapidly as the other. The tannin which gives a blue coloration with ferric chloride does not gelatinize in tinctures. The kinos which give this coloration, also a sparse precipitate slow to form, with iodine in potassium iodide, and a comparatively small amount of the copper salt insoluble in ammonia, all contain in excess this tannin, and the tinctures from these do not gelatinize. The astringency value of the several kinos also varies considerably, those giving the green coloration being the least astringent. The same species of Eucalyptus always gives a similar kino, and in this constancy follows the rule found to be characteristic of the essential oils of identical species. Those Eucalypts which give oils containing phellandrene, all appear to exude kinos which give the violet coloration with ferric chloride, and they, of course, gelatinize in tinctures most readily. All kinos contain mixed tannins, although as the species branch off through the various channels, certain of the tannins diminish in amounts either in one direction or another. The author shows that the addition of a small amount of formaldehyde to the tincture will determine in a few days whether a kino will gelatinize or not. Acetaldehyde also acts in the same way, but is slower in its action, and as a test not so satisfactory. So far, four Eucalyptus kinos have been found which do not gelatinize in tinctures, and they all have a high astringency value. They are obtained from *E. microcorys*, *E. calophylla*, *E. eximia* and *E. maculata*. The tinctures of the two last, however, give precipitates when diluted with water, that of *E. calophylla* gives a turbidity only, while that of *E. microcorys* does not give a turbidity even on the addition of a large amount of water. It thus appears that the difficulty of gelatinized tincture of kinos may be overcome by using these Eucalyptus kinos, and that without the addition of corrigents like glycerol. The paper includes tables illustrating the reactions of the several kinos, and also giving full data in reference to the gelatinization of the tinctures.

The author also announced the presence in most Eucalyptus kinos of a well defined organism which will grow in aqueous solutions of these kinos. To this organism may perhaps be traced the marked alteration in some kinos. It is being investigated by Mr. S. J. Johnston, B.A., B.Sc., of the Technological Museum.

Remarks were made by Dr. R. Greig Smith and Mr. Hamlet. Mr. H. G. Smith replied.

2. "On some Hydrographical data in relation to Ocean Currents," by H. A. LENEHAN, F.R.A.S.

A paper dealing with ocean drifts principally in the Southern Hemisphere. It contains a tabulated statement of 182 records, the most important of which travelled a distance of 11,350 miles between June 19, 1901 and March 5, 1904, at a daily rate of $11\frac{1}{2}$ miles. There are also eleven other drifts over 3,000 miles long. Two charts accompany the paper, showing the positions where the records were cast adrift and the places where found.

Remarks were made by Dr. Walter Spencer, Mr. G. H. Halligan, and the President. Mr. Lenehan replied.

Mr. HAMLET, F.I.C., F.C.S., exhibited a collection of metals in boiled and unboiled water placed therein for many years.

The following is an abstract of the Second Popular Science Lecture of the present Session, delivered on the 28th July and repeated, by special request, on the 5th August in the Physics Lecture Theatre of the University, by Prof. G. H. KNIBBS, F.R.A.S., on "The Fabric of the Universe." The lecturer, after pointing out the originating cause of mental and natural philosophy, traced the history of the theory of the atomic constitution of matter, from Mosphus of Phrygia, before the siege of Troy down to the present time, referring especially to the part played by Anaxagora, Leucippus, Democritus, Epicurus, Lucretius, Aristotle, Gassendi, Descartés, Boyle, Hooke, Newton, Helmholtz, and others in the evolution of the theory. The evidence of the existence of various orders of atoms was then indicated, viz., of the mechanical atom, the chemical molecule and atom, the aëtherergic molecule and atom, the atomic molecule and atom, electron, or corpuscle. The significance of constitutional formulæ in chemistry and of stereochemical knowledge, in relation to the progress of science and industry was briefly outlined, and the fact dwelt upon that the extension of human power is dependent upon abstract scientific knowledge. The aids to research, by means of which sense-limitations were transcended, were illustrated by a large number of experiments, and it was demonstrated in what way the structure of matter is being daily more and more completely and exactly determined by physical investigators. The lecture was given in the Physics Lecture Theatre in order that the experimental illustration of the lecture might be possible. The experimental demonstrations included the behaviour of electrons in the magnetic field, and illustrated the development of knowledge of matter through Sir Wm. Crookes' researches, and the modern developments of the electron theory. Various orders of luminescence, fluorescence, and the radiations of Lenard, Röntgen, Becquerel, etc., and of the radioactive substances were indicated and shewn.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 7, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 7th, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Sixty-two members and ten visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three candidates were read for the third time.

The following gentlemen were duly elected ordinary members of the Society, viz:—

Cameron, John Mindoro, Engineer, Public Works Department, 29 Bligh-street.

MacFarlane, Edward, Under-Secretary for Lands, 12 Fitzroy-street, Milson's Point.

Sellors, Richard Pickering, B.A. (Syd.), "Cairnleith," Springdale-road, Killara.

The following circular was read:—

"CONFERENCE ON 'TECHNICAL AND INDUSTRIAL EDUCATION IN AUSTRALIA.'

"The Engineering Section propose to hold, during the third week in October, (precise dates and hours to be announced later) a conference on the above subject. It is hoped that in addition to the members of the Section, many of those interested in this important subject will contribute to the discussion.

"The titles of papers to be read will be fully set out in a subsequent circular, but the following is a preliminary announcement of subjects that have been suggested as suitable topics for consideration:—

1. 'The present position of Technical and Industrial Education in Australia.'

2. 'The effect of systematic training in promoting the development of industries.'
3. 'Rational *versus* empirical training for industrial pursuits.'
4. 'The apprenticeship system.'
5. 'In what way the lower stages of education prepare for, and are essential to industrial training.'
6. 'The necessity for an adequate system of secondary education as a preparation for professional and scientific training.'
7. 'The appropriate scope and organisation of our Technical Colleges.'
8. 'The methods adopted for training the workers in specific local industries and possible improvements in same.'
9. 'To what extent is it economy for a nation to invest money in the scientific and industrial training of its people?'

"J. Haydon Cardew, Hon. Secretary."

Fourteen volumes, 152 parts, 8 reports, 5 pamphlets, 1 geological and 1 geographical map, total 181, received as donations since the last meeting, were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ:

1. "Notes on the Theory and Practice of Concrete-Iron Constructions," by F. M. Gummow, M.C.E., Assoc. M. Inst. C.E.

The author outlined the theory from the present standpoint of scientific research, and after reviewing the principal applications, concluded his paper by giving particulars of a test of concrete-iron plate beams, carried out on a large scale. The term "concrete-iron," the author explained, was applied to those constructions which consisted of Portland cement concrete and iron or steel insertions, both so intimately united that the construction would act as homogeneous bodies when taking up stresses, and at the same time allow of the utilization of each material to its utmost limit. The paper was illustrated with lantern slides of various concrete-iron constructions carried out in Australia and abroad, showing its varied and general use for numerous purposes.

2. "Further Experiments on the Strength and Elasticity of reinforced Concrete," by Professor W. H. WARREN, M. Inst. C.E., Wh. Sc.

The author stated that the paper consisted of an experimental investigation of the physical properties of Portland cement mortars and concrete when reinforced with steel, and the work described was a continuation of the work described in a paper read before the Royal Society in December, 1902. The real difficulty in obtaining correct calculations on steel-concrete work consists, mainly, in the want of knowledge existing of the physical properties of the materials used, and hence it becomes important to know the coefficient of elasticity of concrete in tension and compression under various stresses, also the manner in which it behaves when reinforced in various ways. The first part of the paper consists of a description of the methods employed in testing the specimens in tension, compression, and cross-breaking. The loads were applied by means of the University testing machines, and the effect produced was accurately determined whether it was an extension, a shortening, or a deflection of the piece, by means of Martens' mirror extensometers. The results obtained, the strength and coefficient of elasticities were recorded in numerous diagrams and tables. Experiments were made and discussed on the reinforcement of concrete columns in buildings with longitudinal steel rods, grills of steel, and hooped by means of soft iron or steel spirals, which has special reference to fireproof construction. The method of calculating the strength of steel-concrete structures was discussed in considerable detail, and numerous diagrams and equations were given illustrating the application of the results obtained in the experiments, and also giving simple rules for the guidance of architects and engineers in correctly designing such structures. In both the tension and compression tests the stress-strain curves show that the coefficient of elasticity diminishes as the intensity of stress increases. In the case of the beams, the deflections increased in a similar manner with increasing loads, and the extensions of the extreme fibre and the neutral axis, showed that the extensions increase in a reinforced beam from the point where the maximum tensile strength of the plain concrete has been attained to the point where fracture occurs, where it may be ten times as great as in a similar concrete beam not reinforced. The tensile co-efficient of elasticity in a reinforced beam becomes less in proportion to the greater extension, since the tensile strength of the concrete remains constant during the period included between the point where the fracture would have occurred in a plain beam to the actual fracture in the reinforced beam. The author's equations were compared with those obtained by M. Considere, Professor Hatt, and the recent regulations of the Prussian Government.

EXHIBITS.

The following celestial photographs were exhibited by Mr. C. J. Merfield, F.R.A.S. :—

Comet 1892-1, taken by Barnard of the Lick Observatory on the dates 1892 April 7 - 28.

Comet 1893 IV., by Barnard, taken on the dates 1893 October 20, 21, 22, and 1893 November 10.

Comet Holmes 1892 III., by Barnard.

Comet 1901 I., taken by Sir David Gill, at the Cape of Good Hope, on the dates 1901 May 4 – 6.

Great Nebula in Orion, by Sir Isaac Roberts.

Nebula about η Argus, by Sir David Gill.

Dumb-bell Nebula Vulpecula by Barnard.

The Moon (Age 7 d. 3 h.)	Lick Observatory	
The Moon (Age 12 d. 6 h.)		
The Moon (Age 16 d. 18 h.)		
The Moon (Age 23 d. 8 h.)		

Mr. MERFIELD also placed on view several photographs of the Yarrangobilly Caves near Kiandra, N. S. Wales.

With reference to his paper read at the June meeting, Mr. MAIDEN exhibited photographs from the Hon. J. B. Nash, M.D., M.L.C., showing (1) a White Gum whose branch had fused with the trunk of an adjacent Ironbark tree. From near Wallsend. Also on behalf of Mr. J. B. HENSON of East Maitland, he showed a photograph of a natural graft (2) where a Stringybark branch had rubbed against the trunk of a large White Gum, and the branch had fused with the trunk. Also photographs of a Smooth-barked Apple (*Angophora lanceolata*) showing instances where the branches had fused once, and even twice, with branches of the same tree. Mr. Maiden hopes to obtain botanical specimens to settle the identity of the trees referred to.

Mr. GUMMOW stated that on the 14th instant at 3 p.m. testing experiments of concrete-steel constructions would be carried out at his works at Alexandria, and he gave a cordial invitation to all present, who might be interested in the matter, to attend.

The President announced that the discussion upon the papers read that evening would probably take place at the meeting of the Engineering Section on the 21st instant.

ABSTRACT OF PROCEEDINGS, OCTOBER 5 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 5th, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Forty-four members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

Three new members enrolled their names and were introduced.

The certificates of two candidates were read for the first time.

The President announced that the Fourth Popular Science Lecture 1904 on "The Steam Engine and its Modern Rivals," by S. H. BARRACLOUGH, B.E., M.M.E., Assoc. M. Inst. C.E., would be delivered at the Royal Society's House, on Thursday, October 27th, at 8 p.m.

The following circular from the Engineering Section was read :—

"CONFERENCE ON TECHNICAL AND INDUSTRIAL EDUCATION.

"Owing to the report of the Commissioners of Education dealing with the above question not having been yet published, it has been decided to postpone the Conference which was proposed to be held in October (and of which preliminary notice has already been given) until next year, when it is expected the report will be to hand, as the Committee recognise that the subject will present greater interest to members when discussed in the light of the Commissioners' expressed views, and further, will be much easier handled by those who read papers. This action has been rendered necessary because it has been found that many of our members most qualified to express opinions on the subject would be precluded from taking part in the discussion prior to the publication of the said report.

A meeting will be held on Wednesday, 19th October, 1904, (in place of Wednesday, 21st September, as previously announced) to discuss the papers on "Water Filtration," and "Reinforcement of Concrete."

"J. HAYDON CARDEW, Hon. Secretary."

Twenty-five volumes, 97 parts, 14 reports and 3 pamphlets, total 139, received as donations since the last meeting were laid upon the table and acknowledged.

The following extract from a letter by the Government Statistician of Western Australia was read, and a copy of the vocabulary referred to laid upon the table :—

"Perth, 31 August, 1904.

"I am attempting at the present time to compile a short historical description of the Aborigines of this State with a brief vocabulary of the language of the various tribes, and am enclosing for your information a copy of a blank vocabulary which I am issuing to all persons who may be expected to assist by filling in such portions of it as they are able. It is difficult to say what the result will be, but possibly some useful and interesting information may be obtained to form the basis of a future thoroughly scientific and more ambitious investigation."

(Signed) MALCOLM A. C. FRASER, Govt. Statistician."

The Royal Society of N. S. Wales having been appointed Regional Bureau for this State for the International Catalogue of Scientific Literature, in accordance with the wish of the International Council publishes the following balance sheets :—

1. Balance Sheet 29th February, 1904.

LIABILITIES.

	£ s. d.	£ s. d.
To Loan from Royal Society—		
Amount free of interest	300 0 0	
Amount subject to interest at 4% per annum	3,500 0 0	—3,800 0 0
,, Subscriptions from Countries received in advance		649 6 0
,, Accounts in respect of the First Annual Issue unpaid—		
Printing and Binding	683 18 10	
Publishers' Commission	30 0 0	
Experts' Fees	109 0 0	
		822 18 10
		£5,272 4 10

Assets.	£ s. d.	£ s. d.
By Furniture	137 0 6	
,, Typewriting Machinery	69 11 7	
,, Office Fixtures	19 9 0	
,, Catalogue Apparatus	79 7 6	
,, Reference Books	45 4 7	
	350 13 2	
Less One-tenth thereof transferred to Income and Expenditure Account ...	35 1 4	
		315 11 10
,, Preliminary Expenses incurred before 31st December, 1901—		
Printing	763 10 6	
Director	500 0 0	
Honorarium to Dr. Morley as Secretary of Provisional International Committee	250 0 0	
Rent of Office	213 0 0	
Legal Charges	77 11 2	
Salaries	335 4 2	
Travelling Expenses	9 3 1	
Stationery	45 11 5	
Office Expenses	26 3 10	
Postage and Telegrams	61 1 8	
	2,281 5 10	
Less One-fifth thereof transferred to Income and Expenditure Account ...	456 5 2	
		1,825 0 8
,, Amount due from Countries, etc., for volumes sold		2,648 0 0
,, Suspense Account—		
Payments on account of Second Annual Issue	1,518 13 1	
Less received for volumes sold	1,342 7 3	
		176 5 10
,, Balance at Bank—		
Robarts, Lubbock & Co.	192 2 1	
Union of London and Smith's Bank ...	81 9 8	
,, Balance in hand	0 5 0	
		273 16 9
,, Excess of Expenditure over Income on the First Annual Issue		33 9 9
		£5,272 4 10

I have examined the above balance sheet and accompanying Income and Expenditure Account, with the books and vouchers, and have found them correct. I have also verified the balance at the Bankers, Administrative Expenditure has been apportioned by the Director between Preliminary Expenses and Expenses of the First and Second Annual Issues.

W. B. Keen,
Chartered Accountant.

3, Church Court, Old Jewry E.C.
27th April, 1904.

II. Income and Expenditure Account of the First Annual Issue.

	£ s. d.	£ s. d.
To Printing and Binding	3,444 11 0	
„ Publishers' Commission	330 4 8	
„ Experts' Fees...	614 3 4	
		4,388 19 0
„ Expenditure from 1st January, 1902, to 30th June, 1903 :—		
Director	750 0 0	
Salaries	817 5 2	
		1,567 5 2
Rent of Office		345 0 0
Stationery and Catalogue Cards	53 17 9	
Office Expenses	33 3 8	
Postages and Telegrams	45 12 9	
Insurance	8 4 0	
		140 18 2
Interest on Loan		183 11 2
„ One-tenth of cost of Furniture, etc., written off, as per Balance Sheet		35 1 4
„ One-fifth of Preliminary Expenses written off, as per Balance Sheet		456 5 2
		£7,117 0 0

	£ s. d.	£ s. d.
By Sales of Subscription Copies	6,913 18 6	
„ Sales of Trade Copies	169 11 9	
		7,083 10 3
„ Excess of Expenditure over Income carried to Balance Sheet		33 9 9
		£7,117 0 0

[No estimate has been made of the Income expected from the number of copies not yet sold, which at 29th February, 1904, were about 12,700.]

Resolution regarding retirement of Mr. John Tebbutt, F.R.A.S., etc., from systematic astronomical work.

The following resolution, moved by the Acting Government Astronomer (Mr. H. A. Lenehan), seconded by Mr. G. H. Knibbs, supported by the President (Mr. C. O. Burge) and others, was carried unanimously, and with acclamation:—

"In the opinion of this Society the occasion of Mr. John Tebbutt's retirement from systematic astronomical work, is a fitting opportunity for an expression of our appreciation of his arduous and able labours in the cause of astronomy, of the high standard of excellence which he has always maintained and which has been so widely recognised; also of the value of his written contributions made to the scientific journals not only of this State but also of Europe."

It was also moved that a copy of this resolution be forwarded to him.

THE FOLLOWING PAPERS WERE READ:

1. "Ethnological Notes on the Aboriginal Tribes of New South Wales and Victoria," by R. H. MATHEWS, L.S.

The paper treated of the grammars and vocabularies of some of the native languages, the complicated laws regulating marriage and descent, as well as several customs relating to the quest for food, punishment for breaches of the tribal laws, burial and mourning rites, initiation ceremonies, some peculiar superstitions, folk-lore, etc.

Some remarks were made by Dr. Walter Spencer and the President.

2. Preliminary Observations on Radio-activity and the Occurrence of Radium in Australian Minerals," by D. MAWSON, B.E., Junior Demonstrator, and T. H. LABY, Acting-Demonstrator of Chemistry in the University of Sydney. [Communicated by Prof. T. W. E. DAVID, B.A., F.R.S.]

A brief summary of observations on the radio-activity of minerals and occurrence of radium is given, showing that comparatively intense activity is only found associated in minerals with thorium and uranium. Bottwood and Strutt have independently shown that usually radium and uranium content are proportional. In these experiments the ionssation produced in an air gap was determined by measuring the saturation current across it, first with the mineral and then with black uranium oxide. Thus the activity compared to black uranium oxide was obtained. The presence of radium was looked for by Strutt's application of Rutherford and Soddy's discovery that radium gives off a radio-active gas, the emanation, which decays in activity to half its initial value in four days. A torbernite and euxenite were found highly active, but the specimens were too small to examine for radium. A Western Australian gadolinite, found by Professor Norman Collie to contain one bubble of helium in ten grams, was expected to contain radium, but none could be detected. Twelve monazites were found radio-active; one, with double the average activity of the others, from Pilbarra, Western Australia, gave on heating the radium emanation; five monazite and zircon sands were also active. No relation between thoria contents and activity was found, which points to the presence of uranium.

Remarks were made by Prof. David, Prof. Pollock, Mr. G. H. Knibbs, Mr. F. B. Guthrie, Mr. W. M. Hamlet, the authors, and the President.

3. "The Flood Silt of the Hunter and Hawkesbury Rivers," by Prof. T. W. EDGEWORTH DAVID, B.A., F.R.S., F.G.S., and Acting-Professor F. B. GUTHRIE, F.I.C., F.C.S.

During the floods last July in the Hunter and Hawkesbury rivers, samples of the flood water as well as of the flood silt were collected, at the instance of the authors, by Mr. A. J. Prentice, B.A., of West Maitland, and Mr. W. H. Potts, the Principal of the Hawkesbury Agricultural College. Determinations made at the laboratory of the Department of Agriculture show the following to be the chemical composition of the silts:—

Analysis of Silt from Hunter River Water.

	Per cent.
Insoluble in hydrochloric acid	=79·25
Soluble in hydrochloric acid—	
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3)	=10·02
Lime (CaO)	= 1·55
Potash (K_2O)	= 0·09
Phosphoric acid (P_2O_5)	= 0·18

		Per cent.
Volatile matter	=	9·61
Nitrogen	=	·084

Weight per acre, one foot in depth = 3,403,125 lbs.

Analysis of Silt from Hawkesbury River Water.

		Per cent.
Insoluble in hydrochloric acid	=	89·96
Soluble in hydrochloric acid—		
Oxide of iron and alumina (Fe_2O_3 and Al_2O_3)	=	4·77
Lime (CaO)	=	0·49
Potash (K_2O)	=	0·12
Phosphoric acid (P_2O_5)	=	0·08
Volatile matter	=	4·68
Nitrogen	=	0·105

Weight per acre, one foot in depth = 3,307,332 lbs.

Mr. Prentice estimates the average depth of the last flood deposit of the Hunter to be about two inches. This would supply the land with a top dressing of fertilising constituents to the following amount per acre:—

Lime	8,791 lbs.
Potash	510 ,,
Phosphoric acid	1,020 ,,
Nitrogen	476 ,,

The data for estimating the thickness of silt deposited by the Hawkesbury river are less complete than those for the Hunter. On the assumption that the thickness was only $\frac{1}{20}$ of that deposited by the Hunter River, the silt of the Hawkesbury flood would weigh 27,561 lbs. per acre, and would supply per acre:—

Lime	135 lbs.
Potash	33 ,,
Phosphoric acid	22 ,,
Nitrogen	29 ,,

A discussion was commenced by Mr. J. H. Maiden, Dr. R. Greig Smith, and Prof. F. B. Guthrie, but on the motion of Mr. C. A. Süssmilch it was postponed to the next meeting.

The reading of the following papers was postponed to the next meeting:—

1. "On the possible Identity of the Emanation of Radium and Dewar's Coronium (or Nebulium)," by T. H. LABY.
2. "Pot Experiments to determine the limits of endurance of different Farm Crops for certain injurious substances, Part III., Barley and Rye," by R. HELMS and Prof. F. B. GUTHRIE, F.I.C., F.C.S.

ABSTRACT OF PROCEEDINGS, NOVEMBER 2, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 2nd, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Thirty-four members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

One new member enrolled his name and was introduced.

The certificates of two candidates were read for the second time, and of one for the first time.

The President announced that the Fifth Popular Science Lecture 1904 on "The Nervous System in its Genesis and Development," by Dr. J. FROUDE FLASHMAN, M.D., Honorary Lecturer in Psychological Medicine and Neurology, University of Sydney, Director of the Pathological Laboratory of the Lunacy Department, would be delivered at the Royal Society's House, on Thursday, November 24th, at 8 p.m.

Fifty-four volumes, 305 parts, 18 reports, and 11 pamphlets, also 1 engraving, total 389, received as donations since the last meeting, were laid upon the table and acknowledged.

The discussion upon the paper on the "The Flood Silt of the Hunter and Hawkesbury Rivers," by Prof. T. W. E. David, B.A., F.G.S., F.R.S., and Acting Professor F. B. Guthrie, F.I.C., F.C.S., read at the previous meeting was continued, the following gentlemen taking part, viz.: Mr. Süssmilch, Mr. E. MacFarlane, Mr. Hall of the "Evening News" (by invitation of the President) Dr. Walter Spencer, and the President.

On the motion of Mr. MacFarlane, seconded by Dr. Spencer, it was resolved that the discussion be further adjourned, and that in the meantime the paper be set up in type, so that proofs would be available.

THE FOLLOWING PAPERS WERE READ.

1. "Pot Experiments to determine the limits of endurance of different Farm Crops for certain injurious substances, Part III. Barley and Rye," by R. Helms and Acting Professor F. B. Guthrie, F.I.C., F.C.S.

The authors describe experiments with barley and rye in continuation of those on wheat and maize (this Journal, xxxvi., p. 191 and xxxvii., p. 165) to determine the tolerance of these plants to certain ingredients commonly present in the soils and water used for irrigating in certain parts of the State, namely sodium chloride (common salt) and sodium carbonate (alkali); also the effect produced upon their growth by the presence of small quantities of plant poisons occasionally met with in fertilisers, such as ammonium sulphocyanide, sodium chlorate and arsenious acid. The general results are tabulated as follows :—

Barley.	Germination affected	Germination prevented	Growth affected	Growth prevented
NaCl	·10	·25	·10	·20
Na_2CO_3	·25	·60	·15	·40
NH_4CNS	inconclusive			
NaClO	·005	·007	·003	·006
As_2O_3	germination unaffected by ·62		·05	·10

Rye.	Germination affected	Germination prevented	Growth affected	Growth prevented
NaCl	·10	·40	·15	·20
Na_2CO_3	·25	·50	·25	·40
NH_4CNS	inconclusive			
$NaClO_3$	·001	·006	·002	·004
As_2O_3	·2	above ·4	·15	·30

Remarks were made by Mr. Maiden, Prof. Schofield and the President. Prof. Guthrie replied.

2. "The classification and systematic nomenclature of Igneous Rocks," by H. STANLEY JEVONS, M.A., B.Sc., F.G.S.; Lecturer in Mineralogy and Petrology in the University of Sydney.

The author first passes in review the general principles of classification, illustrating them by references to the properties of igneous rocks. The properties selected as bases of classification must depend upon the purpose for which the classification is required. Classification serves three main purposes:—(1) As an aid to the memory and a store of knowledge, and hence for teaching or didactic purposes; (2) to assist in research; (3) as a basis of a systematic nomenclature. The manner in which classification may assist in research is explained at length; and it is pointed out that a systematic nomenclature may be applied to almost any classification, so long as it does not consist of too many ranks, *i.e.* successive subdivisions on different properties. Whilst special classifications will always be required for special lines of research, it would be very useful to have a general classification adapted to serve all three purposes at once. There follows an explanation of how a general classification might render valuable assistance in research, by compelling petrologists to observe properties in the field and laboratory, with regard to which data are now very scarce. A general classification must of necessity be transient, as the progress of science will necessitate its being altered, at least in its lower ranks, every few years. The remainder of the paper deals specially with the problem of the classification and nomenclature of igneous rocks. The most important correlations for didactic purposes are found to be:—mineral composition with abundance, and mineral composition with chemical composition; those for research:—chemical composition with habit (*i.e.* shape, size, and depth below original surface) of mass, composition of the rock with the composition of neighbouring or connected igneous masses, and composition with origin (genetic). Each correlation consists of a pair of properties, and the property of each pair to be selected as a basis of subdivision in the general classification is decided on considerations which follow. For didactic purposes the more easily observed of the pair should be chosen; for research, the one which most requires to be observed. On these grounds the author selects for didactic purposes, mineral composition; for research, community of origin (so far as possible) and habit. It is noted that mineral composition and chemical composition are really groups of very numerous properties, for many minerals or oxides may be taken as bases of subdivision, either as ratios, percentages, or by the presence or absence method.

The author concludes that the most convenient general classification for the present time would be one constructed as follows:—

Rank I.—Based on alkali-lime-content of principal and minor mineral constituents. Produces 2 Series: alkaline and calcic.

Rank II. Based on similarity of principal mineral constituents. Produces 7 Sections, *e.g.* granitic, gabbroic, theralitic, etc.

Rank III. Based on community of origin from similar parent magmas. The latter are defined by the presence of certain index minerals in the consolidated rocks. (*e.g.* a granite, a granite-aplite, and a rhyolite, etc. may all be derived from one magma; other granites, rhyolites etc. will be derived from similar magmas). Produces 12 Orders, *e.g.* granates, essexates, etc.

Rank IV. Based on habit of mass. Produces 7 families in each order, *e.g.* granophites, dioromicrites, gabbrolavites (basalts), etc.

Rank V. Based on nature of minor mineral constituents. Produces a number of genera in each family, *e.g.* muscbi-granophite, anaugi-hyper-peridotite (harzburgite).

Rank VI. Based on texture, but to be applied only in families where there is much variety of texture. Produces Sub-genera, *e.g.* spheri-mono-rhyolite, graphi-bi-rhyolite, etc.

The system of nomenclature described is an elaboration of that already proposed by the author in a preliminary paper in the Geological Magazine (1901).

The desiderata of a systematic nomenclature are as follows:—(1) Each name should indicate the rank of the group to which it belongs. In the system proposed names of series end in -ane, of sections in -ote, of orders in -ate, and of families in -ite. Genera are shewn by the presence of a mineral prefix and sub-genera by a textural prefix. (2) Each name should indicate the feature which distinguishes the group from others of the same rank. This is not necessary in the higher ranks, but is accomplished for families, genera, and sub-genera. Thus a suffix, as

-aplite (for aplitic dyke), -micrite (meaning small mass), indicates the definition of the family. A contracted mineral prefix, as bi- (biotite) or hyper- (hypersthene) shows the predominating minor constituent of the genus; and another prefix the texture which defines the sub-genus. (3) Each name must be distinct and not easy to confuse with others. (4) The names must be as short as possible and easy to pronounce. Since the index minerals of orders cannot be easily stated in a name, root names are given to the orders, but this will involve no tax on the memory, as existing names of the corresponding well recognised groups are used; *e.g.* the order diorates includes all rocks derived from what is commonly known as the diorite magma. The definitions of accepted groups, granites, gabbros, etc., have not been altered, but only rendered slightly more precise. In conclusion, it is claimed that by use of the privative prefix a- or an-, and by means of other prefixes and suffixes, it is possible to name any igneous rock which may be conceived as likely to exist, and also to convey more information in the name than by any system yet proposed.

On the motion of Prof. David, seconded by Mr. Süssmilch, it was resolved that the discussion of this paper be postponed.

On account of the lateness of the hour the reading of the following paper was postponed :—

3. "On the occurrence of isolated crystals of augite in the tuffaceous mudstones near the top of the Upper Marine Series at Gerringong," by Mr. H. G. Foxall. Communicated by Prof. T. W. E. David, B.A., F.G.S., F.R.S.

The President announced that His Honor Judge Docker had kindly offered to deliver a lantern lecture to the members of the Royal Society on "What I saw in New Zealand;" further particulars as to date etc. would be announced.

The following is an abstract of the Third Popular Science Lecture 1904, on "The Solar System and Southern Sky," by H. A. Lenehan, F.R.A.S., Acting Government Astronomer, Sydney Observatory, delivered on the 22nd September, 1904. The lecturer introduced the subject by referring to the small part of the astronomical regions of the whole heavens that the solar system occupies, and of the immeasurable distance of the stars we see outside our system, also of the still more wonderful discoveries the telescope has revealed to us, and is still doing. He showed that hitherto supposed blank spaces in the crowded part of the Milky Way are studded with stars which were not discernible by telescope, but the long exposures of extra sensitive photographic plates had revealed what the eye failed to see with the same telescope. Going back to pagan times, the lecturer showed the solar system in vogue during the days of Ptolemy, and also the views of Aristarchus of Samos, and Cleanthus of Assos, who to a certain extent anticipated Copernicus; then the Egyptian theory of the planets, Mercury and Venus being satellites to the Sun, the Sun being a planet revolving around the Earth. Next the Copernican system introduced by a grave browed ecclesiastic, who on the foggy shores of the Baltic in the 16th Century of the Christian era, thought out this system which later by the combined mathematical work of Kepler and Newton was perfected, and is now the system proved beyond all doubt as the true one. Another astronomer of note, Tycho Brahe, was induced to offer a theory which had been thought out by him. Perhaps wrong deductions caused him to misread certain passages of the Holy Scriptures, or personal vanity may have induced his theories, but his system only had a brief existence. Sets of views were then thrown on the screen in which each system was indicated, and about 21 views of the different objects of interest in the sky—principally southern constellations, were described. Then the planets were described, their size, revolution and distances from the Sun; the features of the inner planets, the asteroids and their origin, and then the outer belt of the great planets and their probable present state. The probability of life in each was explained and reference made to the conditions of such life, if it existed, and the nature of it. The lecturer stated that it may be that beings specially created for such conditions are so placed, but certainly no beings constituted as we are, could exist in many of them.

Abstract of the Fourth Popular Science Lecture 1904, on "The Steam Engine and its Modern Rivals," by S. HENRY BARRACLOUGH, B.E., M.M.E., Assoc. M. Inst. C.E., Lecturer in Mechanism and Applied Thermodynamics, University of Sydney. The introductory portion of the lecture dealt with the question of mechanical energy or motive power as being always one of the great necessities of the human race, and its development therefore one of the chief functions of the engineer. An outline was given of the various available sources of power, and the methods adopted and the cost of exploiting them, the two most important being water-power and the potential energy in the immense natural supplies of fuel. The remainder of the lecture was devoted to a consideration of how the energy of the fuel is made available by means of heat engines, and a brief sketch was given of the thermodynamic principles underlying the operation of all such engines—of which in the past the ordinary reciprocating engine has been by far the most important, but whose supremacy is in these latter days seriously threatened by its modern rivals the gas engine and the steam turbine. The attempts made to apply steam to practical uses were described in outline from the time of Hero (B.C. 200 or later) to Newcomen, whose "atmospheric engine" (1705) was the first reciprocating engine operated by the agency of steam. A more detailed account was given of the life and work of James Watt and of his long connection with the historic firm of Boulton and Watt, in the course of which were described the various stages in the investigation of the defects of the Newcomen engine by which finally in 1769 the genius of Watt enabled him to produce what is essentually the modern reciprocating steam engine. In this connection illustrations were shown of the magnificent example of one of Watt's earliest engines, which after being erected for the Whitbread Brewery, London, in 1785, continued to work well for 102 years, and was then taken down and presented to the Sydney Technical College, in whose "James Watt Museum" it now stands. The modern applications of the steam engine for power-station purposes, for locomotion by road and rail, and for marine navigation were then described, concluding with an account of the huge engines of the latest Atlantic express steamer as representing the crowning effort of the art and science of steam engineering. The lecture concluded with an account of (1) the modern gas engine of large size using cheap "producer" gas or the waste gases from blast furnaces as fuel, and of (2) typical steam turbines. A comparison was made of the thermodynamic and mechanical characteristics of these two as compared with the reciprocating engine, and reasons were given why the former are in some cases replacing the latter. The lecture was illustrated throughout by limelight views and diagrams.

ABSTRACT OF PROCEEDINGS, NOVEMBER 16, 1904.

A Special General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 16th, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Eighteen members and one visitor were present.

The President announced (1) that the Fifth Popular Science Lecture 1904 on "The Nervous System in its Genesis and Development," by Dr. J. FROUDE FLASHMAN, M.D., Honorary Lecturer in Psychological Medicine and Neurology, University of Sydney, Director of the Pathological Laboratory of the Lunacy Department, would be delivered at the Royal Society's House, on Thursday, November 24th, at 8 p.m.

(2) That a Lantern Lecture on "What I saw in New Zealand," by His Honor JUDGE DOCKER, would be delivered at the Society's House, on Thursday, December 8th at 8 p.m.

THE FOLLOWING PAPER WAS READ:

"On the occurrence of isolated crystals of augite in the tuffaceous mudstones near the top of the Upper Marine Series at Gerringong," by Mr. H. G. FOXALL. (Communicated by Prof. T. W. E. DAVID, B.A., F.G.S., F.R.S.)

The paper gives the results of crystallographical and chemical examinations of a number of isolated crystals of augite, together with a short note on their occurrence. The crystallographical examination shows that the forms present on the crystals are [100], [010], [110] and either [011] or [$\bar{1}$11], with, in some cases other small faces which could not be accurately determined. The chemical composition is as follows:—

H_2O (100°)	0·41	MnO	0·29
H_2O (100° +) ...	1·25	CaO	19·73
SiO_2	47·21	MgO	8 97
Al_2O_3	11·12	Cr_2O_3	0·13
FeO	5·11		
Fe_2O_3	5·50		100·51
TiO_2	0·79		

One crystal drawing and two gnomonic projections accompany the paper. Some remarks were made by Prof. David.

THE FOLLOWING PAPERS WERE DISCUSSED:

1. "The Flood Silt of the Hunter and Hawkesbury Rivers," by Prof. T. W. EDGEWORTH DAVID, B.A., F.G.S., F.R.S., and Acting Prof. F. B. GUTHRIE, F.I.C. F.C.S.

Remarks were made by Mr. C. A. Süssmilch, Mr. T. F. Furber, on behalf of Mr. E. MacFarlane, Mr. R. T. McKay, Mr. J. H. Maiden and the President. The authors replied. Mr. MacFarlane emphasised the importance of the paper, not only in its scientific aspect but also from the fact that the periodical enrichment of the flooded lands formed a considerable factor in the general question of land settlement. He pointed out the relation which these lands bore to the large areas in climatically less favoured parts of the State, and entered into a comparison between the productiveness of the two classes of land, indicating how the richer lands must of necessity be regarded as the sources from which in times of drought food supplies must be drawn and on which the whole question of the habitableness of much of the interior must to some extent rest. He thought so highly of inquiries such as had been conducted by Professors David and Guthrie, that he would endeavour to cause such observations to be made as would perhaps form the basis of further investigation.

2. "The Classification and Systematic Nomenclature of Igneous Rocks," by H. STANLEY JEVONS, M.A., B.Sc., F.G.S.: Lecturer in Mineralogy and Petrology in the University of Sydney.

Remarks were made by Mr. W. J. Clunies Ross, Prof. David, Mr. C. A. Süssmilch, and Dr. Cooksey. Mr. Jevons replied.

The following is an abstract of the Fifth Popular Science Lecture 1904 on "The Nervous System in its Genesis and Development," by Dr. J. FROUDE FLASHMAN, M.D., Honorary Lecturer in Psychological Medicine and Neurology, University of Sydney, Director of the Pathological Laboratory of the Lunacy Department, delivered at the Royal Society's House, on Thursday, November 24th, at 8 p.m. The lecturer introduced his subject by indicating the enormous difference between the highest and lowest forms of nervous system. In dealing with the genesis of the system he pointed out that almost the whole body of an amœba possessed the general properties of undifferentiated protoplasm, viz., irritability, conductivity, and contractility, but that when we come to animals a little higher in the scale, we find a subdivision of labour—one part being detailed to receive impressions (the sense organs) another to conduct (the nerves), and another to contract (the muscles). It was further shown how other parts of the general protoplasm become differentiated into harder protecting structures to guard the more delicate sense organs, nerves, etc. The lecturer then traced the development of such a system, showing during the evening lantern slides of the nervous systems of ascidians, actinians, planarians, annelids, crayfish, scorpions, spiders, insects, oysters, snails, octopus, shark, frog, snake, turtle, birds, marsupials, squirrel, cat, dog, horse, dolphin, chimpanzee, gorilla, orang-utan, human idiot, and man. Reference was also made during the evening to the functions of the ganglion cell as well as to the phenomena of reflex action, instincts, and reason.

ABSTRACT OF PROCEEDINGS, DECEMBER 7, 1904.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 7th, 1904.

C. O. BURGE, M. Inst. C.E., President, in the Chair.

Thirty members and seven visitors were present.

The minutes of the preceding meeting and of the special meeting held on the 16th November, were read and confirmed.

One new member enrolled his name and was introduced.

Messrs. C. J. MERFIELD and C. HEDLEY were appointed scrutineers, and Mr. H. A. LENEHAN deputed to preside at the Ballot Box.

The certificates of two candidates were read for the third time, of one for the second time, and of one for the first time.

The following gentlemen were duly elected ordinary members of the Society, viz:—

Hill, John Whitmore, Architect, "Willamere," May's Hill, Parramatta.

Vogan, Harold Sebastian, Assoc. M. Inst. C.E., Authorised Surveyor, N.Z., Chief Draftsman, Existing Railways, N.S.W., Bridge-street, Sydney.

Mr. DAVID FELL, M.L.A., Member of the Corporation of Accountants of Australia and Mr. T. TYNDALL PETERSON, Associate Sydney Institute of Public Accountants, were re-appointed Auditors for the current year.

Eighteen volumes, 179 parts, 6 reports, and 12 pamphlets, total 215, received as donations since the last meeting, were laid upon the table and acknowledged.

In view of the fact that he would be leaving the State prior to the Annual Meeting in May, Mr. C. O. BURGE, M. Inst. C.E., had been asked, and had kindly consented, to deliver his Presidential Address that evening.

The following is an abstract:—The President, Mr. C. O. BURGE, said that the subject of his address would be the connexion between Engineering and Science, and showed that in the earlier ages that connexion was closer than in later times, for though the names of the designers of the great ancient works now extant in Egypt and throughout the Roman Empire were, to a large extent, lost, we might be fairly sure that, it being before the age of specialism, the science and engineering necessary for these monuments of human skill, were concentrated in the same individuals. Tracing down the names of the scientists who helped engineering from the earliest times, those of Thales, Anaxagoras, Ptolemy, Euclid, Hipparchus, Appolonius, Archimedes in the classic period, the Moors of Spain in the middle ages, and Leonardo da Vinci, who investigated the laws of motion at the dawn of the Renaissance period, were referred to. Astronomy, which helped geodesy, algebra, mechanics, hydraulics and hydrostatics, magnetism, logarithms, the invention of which was spoken of as one of the greatest efforts of the human intellect, and other subjects, were connected with the names of Cardan, Tartaglia, Stivinius, Record, Gilbert, Galileo, Copernicus, Kepler, Tycho Brahe, Napier, and others. But the constructing engineers or mechanics as they were then called, of those times, took no heed of these sciences, every one followed the great rule of thumb, and it was not till the time of James Watt, who was helped by the investigation of heat physics by Professor Black, that engineers took advantage, to any great degree, of mechanical science. Pambour, Clerk Maxwell, Faraday, Kelvin, and Lodge, with others, were mentioned as having more recently contributed to the achievements of the engineer, while the tendency in the latter half of the past century to educate the engineer in technical institutions rather than by pupilage helped further in bringing about the connexion which was the subject of the address.

The Odyssey of Homer was by some considered to be an allegory of man's life through this world, with its temptations and dangers, and of his protection therefrom by the heavenly powers. This wonderful story of old might be taken as an illustration of the subject of this address; the great hero Odysseus, working ever onward to his goal, but, even though he was called the man of many devices, the engineer of his age, blindly falling into difficulties often of his own making, nevertheless ever rescued and sustained by the fair goddess of all science, the grey eyed Athene.

Science had one great distinction over law, literature, and art, and that was originality. Law was a mass of precedents; literature was largely composed of echoes from the classics; while Greece and the middle ages had exhausted our ideas in art; not so in science, in which there were many brilliant originators. The absolute necessity of science to the conditions of modern life was then dwelt upon, illustrations being freely given, and the undue prominence given by Australians to physical culture rather as an end, than as a means to mental advancement, was also commented on, the latter principle being as old as Plato. There was an insufficient appreciation of scientific work, to which we might be awakened by some crushing loss in trading or in war. Foreign nations, and especially Germany, were in advance of us, evidence of which was given by the quotation of statistics. If we could induce some of these to dump down on our shores some of the common sense which guided them in such matters it would be well for the Empire. Technical education was not however, for all, and the solution of those fit for it was of great importance, Japanese example being quoted as to this.

It was pointed out that the Anglo Saxon race still led the way in original invention, while it was rather the German who perfected and made use of it. The Englishman Francis Bacon said, "knowledge is power;" it was the German of to-day who profits by that obvious aphorism. It was Shakespeare who wrote the mightiest plays ; it was in Germany that they were most acted.

As to engineering being helped by science, the greatest strides, in modern times, were in connexion with artificial light, mechanical energy by means of electricity, and in disposal of the refuse of cities, chemical welding, compounding of steam engines, improvements in the turbine, and the help of the analyst to the engineer, quite a modern combination, were also mentioned. The address then touched on the greater comparative intellect of the men of old, than that of modern men, considering the much slighter foundations on which they had to build, and that it almost seemed as if genius did not increase with population, leading to, in the far future, a hopeless and uninteresting mediocrity. In the future democracy of brains, where one man would be, intellectually, as good as another, the subtle fluid of original genius would become rarified into a sort of cerebral hydrogen. This tendency was shewn by the fact that in the later sciences, electricity for instance, there were no great outstanding figures—invention had been piecemeal.

Turning to the future, the field of discovery was great, the secrets of nature to be solved were inexhaustible. First in importance among the future triumphs of engineering helped by science, though many practical difficulties were in the way, was the application of electricity to our main line railways, the advantages of which were referred to. Then there were promises of the most wonderful character as regards conveyance of power by electricity without wires. The adoption of wide and straight streets in cities, even at the cost of much reconstruction, would be a work of the future, so as to enable the tram and motor car to expel the more costly horse, which was slow and insanitary, and in view of this, it was hoped that those who had the fixing of the Federal City would bear in mind the necessity of level ground for its site. Increased economy in the utilization of heat units in the ordinary steam engine, would be a work of the future, thus saving our rapidly diminishing fuel supply. The application of mechanical power, through electricity laid on to dwelling houses like gas or water to domestic service, was dwelt upon as more important than it would seem, at first sight, to be.

Other subjects were then touched upon as fit ones for the future, such as the direct utilization of the sun's rays for power, and of the rise and fall of the tide for the same purpose; the diminution of skin friction in ships; and of the resistance to air in ships and trains; the dispersion of fog by electricity; the further investigation of fatigue in metals used for construction; and the application of single phase electricity to traction. The address concluded by a reference to the necessity of reverent enquiry in the scientist, if he is to coax from nature her inmost secrets, so as to enable him, with the aid of his fellow worker the engineer, to promote the happiness, well being and comfort of his fellow men.

On the motion of Dr. WALTER SPENCER seconded by His Honor JUDGE DOCKER, a hearty vote of thanks for his services as President, and best wishes for his future welfare was carried with acclamation. Mr. Burge returned his thanks.

THE FOLLOWING PAPERS WERE READ:

1. "The Approximate Colorimetric Estimation of Nickel and Cobalt in presence of one another," by R. W. CHALLINOR. (Communicated by Acting-Professor J. A. SCHOFIELD, A.R.S.M., F.I.C.)

Use is made of the complementary colours of Ni and Co solutions apparently first observed by Maumené about 1851, and adapted to the mutual estimation of Ni and Co by Winkler in 1866. Winkler used solutions of varying strengths and in most cases much stronger than that used by the author. It is intended that the method should be applied to the solution of the weighed Ni and Co deposited by electrolysis. The mixed metals are dissolved in HNO_3, the solution evaporated to about 5 cc. to remove the greater part of the acid, diluted to a definite volume, and a fraction taken containing about ·05 grams of the mixed metals. Standard $Ni(NO_3)_2$ (·01 gram Ni per cc.) or $Co(NO_3)_2$ (·003 gram per cc.) solution is then added until the colour matches a neutral tinted solution containing ·012 grams Co and ·038 grams Ni as nitrates in 50 cc.; both solutions are contained in 50 cc. in Nessler tubes 10·9 cm. high from 0 cc. to 50 cc., and brought finally to the same dilution, the colours being compared by looking vertically down the tubes. A better method is to add a measured amount of the standard Ni solution till green and then to titrate back with the Co solution. The maximum error with the latter method is about ·0007 grams on ·05 grams of the mixed metals, *i.e.* about 1·5%.

2. "Note on a combined Wash-bottle and Pipette," by J. W. HOGARTH. (Communicated by Acting Professor J. A. SCHOFIELD, A.R.S.M., F.I.C.)

The apparatus described consists of a graduated pipette within an ordinary wash-bottle, and can be used for delivering definite volumes of a hot or cold liquid, either for dissolving or washing a precipitate upon a filter paper.

The following donations were laid upon the table and acknowledged :—

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(The Names of the Donors are in *Italics.)*

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PROCEEDINGS

OF THE

ENGINEERING SECTION.

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(IN ABSTRACT.)

First Session opened, 20th July, 1904.

Mr. S. H. BARRACLOUGH, in the Chair.

The Institution of Surveyors having been invited to hold a joint meeting, the President, Council and many members of that body were present.

The Chairman in welcoming the President and members of the Institution of Surveyors, pointed out the advantages of co-operation between kindred Societies when subjects of mutual interest had to to be discussed.

Mr. THOS. KENNEDY, Assoc. M. Inst. C.E., read a paper entitled "Tacheometer Surveying with an ordinary Theodolite," illustrated with diagrams.

Mr. C. SCRIVENER, L.S., Memb. Inst. Surveyors, contributed "Some notes on the Tacheometer and on Surveys conducted with that instrument on the Federal Capital site at Monaro," which in the absence of the author were read by Mr. T. F. FURBER.

Messrs. T. F. FURBER and LLOYD, Membs. Inst. Surveyors contributed papers, and the discussion was continued by Messrs. BURGE, NELSON, HAYCROFT, and CARDEW.

Mr. KENNEDY having replied, the Session stood adjourned until the following evening.

First Session continued, 21st July, 1904.

Mr. S. H. BARRACLOUGH in the Chair.

Present sixteen members.

Mr. J. M. Smail, M. Inst. C.E., read a paper entitled "**Filtration of Water.**"

The author described the filtration systems of some of the principal waterworks in Great Britain, Europe, and America recently visited by him, pointing out the characteristic features in each. He dealt with the subject under two heads: first, European method or "Slow Filtration," second American method, "Rapid or Mechanical Filtration." Tables were given shewing the constructive character of the filter beds employed by the London Water Companies and some of those in use on the Continent of Europe and in America, the capacity of the London subsiding and storage reservoirs and the average rate of filtration per square foot per hour. After explaining the processes of sand filtration the author quoted the regulations of the German Government drawn up under the direction of Dr. Koch for maintaining the efficiency of filtration beds.

He dealt with the rate of filtration, the amount of purification required, the cleansing and filling of the filters and other important details in the management of waterworks. The results of bacteriological examinations of water were given for the London and other waterworks in England. The question of preliminary roughing filters was alluded to with special reference to those in use in Paris. The depth of sand, the quality and size of the grains, and the various methods adopted for the selection and the measuring of the uniformity of the sand in Europe and America was described. He described the American practice of Slow Filtration giving a detailed account of the works at Lawrence, Mass. Under the heading of Rapid or Mechanical Filtration he treated of the aggregation and deposit of suspended matter by means of coagulants; he also gave a lucid description of a large installation at Little Falls for the supply of the City of New Jersey, detailing the works, the washing of the filters, the operation of the filters, the bacterial results, the removal of colour, the removal of turbidity, tastes and odours, the removal of coagulant, change in hardness, effect of rate of filtration, and other important matters.

He then dealt with the cost of mechanical filters and the cost of operation, and he summed up the advantages of the system as follows:—

(1) Capacity to treat very turbid waters.

(2) Capacity to remove a very large percentage of colour.

(3) Occupies a relatively insignificant area of ground.

(4) Protection from weather.

(5) Freedom from risks of objectionable growths and from tastes and odours they impart.

(6) Rapidly and easily cleaned, without risk of contamination by workmen.

(7) Sand bed can be easily and economically sterilized.

(8) Absolute control of each separate filter, together with complete knowledge of its condition.

(9) Allows water to be sent straight to the consumer with the least possible delay and expense.

In an appendix the author gave certain rules and regulations to be observed in judging the quality of a filtered surface water.

Mr. J. B. Henson, Assoc. M. Inst. C.E. read a paper on "Filtration as carried out on the Hunter River at West Maitland."

He first of all described the watershed of the supply and the nature of the water, giving comparative analyses of the solids in solution. The author said that the present arrangements for filtering the water are as follows:—A settling tank into which the water to be filtered is delivered from the pumps; four filter beds at a lower level, each 100 feet square, and a clear water tank.

The end of the pump delivery pipe in the settling tank is provided with an apparatus for spraying the water whereby its complete aeration is secured. Aeration is hardly required for the river water, but is necessary for the storage water which, being of a stagnant character, is deficient in air. Three systems of piping are provided for the filter beds—one to supply them with water, one to convey away the effluent to the clear water tank, and one to collect and convey away waste, scour, and overflow water. Each system of piping is provided with the necessary stop valves, but there are none of the automatic control arrangements which are usually found attached to modern types of filter plant. The main effluent pipe which receives the filtered water from each of the four beds has a stop valve on it at its outlet at the clear water tank. This valve did not exist in the original design, and was subsequently added to provide better control over filtering operations.

The sludge—largely composed of decayed vegetation—which lay in the bottom of the old lagoon, was not wholly removed when the reservoir was formed, and is added to by the death and decay of water weeds which grow luxuriantly in the reservoir. Endeavours have been made from time to time to get rid of the weeds, and large quantities have been removed, but fresh growths rapidly replace them. The sludge has a deleterious action on the quality of the water. During summer the water rises in temperature; when the cold of winter comes the surface layers are chilled and sink and displace the bottom water. A vertical circulation ensues which brings up the stagnant water which has been lying in contact with the sludge, and a general deterioration in the quality of the whole of the water consequently follows.

The filtering medium is clean river sand 2 feet 6 inches in depth, resting on 6 inches of fine gravel, under which are two layers of loose bricks arranged to form subdrainage ducts, the whole being contained in a water tight tank 7 feet in depth, the floor of which slopes to a central channel leading to the effluent outlet pipe.

The clear water tank was originally uncovered, and under the influence of sunlight vegetable growths developed rapidly and caused much trouble. The filaments were drawn into the pump suction, found their way into the water reticulation pipes, and choked the strainers of water meters. At certain seasons of the year, the growth was so abundant as to necessitate the cleaning out of the tank every three or four weeks. This, besides being expensive, caused inconvenient stoppages. A roof was constructed over the tank, and light being excluded the growth of aquatic plants ceased. No further trouble from this source has since been experienced.

The beneficial effect of filtration was shewn by tables of the analyses of storage water.

Mr. T. W. Keele, M. Inst. C.E., moved the adjournment of the discussion and the Session then terminated.

The Third Session opened 19th October, 1904.

Mr. S. H. Barraclough in the Chair.

Present twelve members and two visitors.

Mr. J. M. Smail, M. Inst. C.E., contributed a supplementary paper on "A method of Water Filtration adopted in Western Australia," communicated by Mr. Faulkner, illustrated by drawings of the works.

The system described in the paper had to be adopted on account of the water carrying so much clay in suspension, which was found to clog an ordinary sand filter in about 6 days; after some experiments a suitable medium was discovered in a sort of coarse cloth made up in the form of a tube 6 feet long and 20 inches diameter, the cost of which amounts to 3 shillings each. Firstly the water is passed through an aeration, then treated with lime and then passed into large settling tanks from whence it is conducted to the filter cloths through a system of pipes. The filter cloths are so arranged that every part is open to view, and are exposed on inside and outside to atmospheric influence in such a way that the thin film of water flowing down the cloths is thoroughly oxidised. The cloth filter has the advantage of requiring less space than the sand filter as from the way in which it is arranged it presents 27 feet of filter surface to each 6 feet of floor space, and owing to its ability to stand a greater pressure than the sand filters, twice the quantity of water may be put through, so that a cloth filter of a given floor area has nine times the capacity of a sand filter. Another advantage is that the cloths can be replaced after cleaning much quicker than a sand filter can be scraped and restored, and further, it regains its maximum efficiency of filtration much quicker than sand.

The cost of construction is low, and an expenditure of £6,200 will be sufficient to deal with 5 million gallons per day. The cloths last about 1 month when filtering water from the bores, but when filtering water from the ranges they last 6 months. 1,500 superficial yards of filter area are completely removed out of the tanks, washed and replaced by 4 men in 8 days; the cost of maintenance including wages, cloths, lime and repairs amounted to 0·6 of one penny per 1,000 gallons for the last two years. The experiments of Massachusetts Board of Health have demonstrated that the colon bacillus and the typhoid bacillus in polluted water were rapidly destroyed by sunlight on exposure of 30 to 60 minutes, and when the water was spread out into a thin film the time required for their destruction was only 15 minutes. The analyses of the water filtered by the cloth filters have never discovered the presence of pathogenic germs and all tests were highly satisfactory.

Mr. J. H. MAIDEN contributed a note on Aquatic Plants in Reservoirs. He described the microscopic plants known as fresh water algæ and the effect they had upon the water in reservoirs. He stated that American botanists gave a good deal of attention to the pollution of water supplies from this source, and while they found that each case requires individual treatment, they recommend the addition of copper sulphate to the reservoir, the salt being put in a sack at the stern of a row-boat which is rowed regularly over the surface of the reservoir. The amount used is small and they point out that the amount of copper which thus goes into the water supply is not injurious to the health of human beings. The author offers to collect specimens of these fresh-water algæ from the storage reservoirs of the State, in order to have them determined by specialists and to ascertain the dose of copper sulphate necessary to exterminate them.

A discussion on "Filtration of Water" was then opened by Mr. T. W. KEELE, M. Inst. C.E., who stated that the lessons to be learned may be briefly summed up as follows:—

(1) To give the maximum period of storage for the unfiltered water.

(2) To filter at a minimum rate.

(3) To filter through a maximum depth of fine sand.

(4) To frequently renew the filtering material.

He quoted Dr. Frankland's opinion on the storage of unfiltered water and the beneficial effect of sedimentation in the reduction of bacteria, and pointed out that Prospect Reservoir effected the sedimentation of Sydney Water Supply exactly on the lines of Dr. Frankland's recommendations. He dealt exhaustively with the rate of filtration for filter beds, the number of germs passing through the media, the aeration of water, and the necessity of keeping the upper layer of sand in a condition most favourable to filtration, quoting at length the opinions of many eminent authorities on all these questions. He concluded his remarks with an allusion to the Sydney Water Supply and the many difficulties the authorities had in preserving its purity without resorting to filtration.

Dr. TIDSWELL, M.B., M.Ch., discussed the question as a bacteriologist, and as a useful preliminary to further studies proposed to refer to the behaviour of bacteria in unfiltered water and subsequently to the changes they undergo during the process of filtration. He stated that they reach the water mainly with washings from the adjacent land, but in a less degree from the air with dust and rain, and even snow and hail. Bacteria are most numerous in river water during winter, interpreting this time as meaning the rainy season, when the land washings are most voluminous. The number of bacteria in a river will be materially affected by the character of the land through which it flows. The character of the contiguous land may be expected to influence not only the number but the kinds of bacteria washed in from it. The continuous existence of these bacteria in water has been mainly studied under laboratory conditions and their behaviour has been closely examined. It is commonly observed initially that a more or less marked and rapid increase in numbers is followed sooner or later by a gradual decline and not reaching the length of extinction for months at least. The rapidity of the increase is to some extent dependent upon the character of the water; where this is originally rich in bacteria the multiplication is less marked than where the initial number of the bacteria is low. Though possibly influenced by what may be called elbow room, the usual explanation of the fact just given is that it depends upon available food supply in relation to the number of feeders; where initially many species are present there often seems to occur a sort of selection which results in the survival of those best suited by the food material present.

Bacteria are by no means indifferent as to the quality of their nutriment, and from this point of view they may be divided into three groups. The first group comprises species such as the nitrifying bacteria, which feed almost entirely upon inorganic material. They are capable of surviving in water and play a certain part, but as they are non-parasitic and do not call for removal, we need not consider them further. The second group comprises the strict parasites which feed only on material within the living bodies of their hosts. They are incapable of prolonged existence in water, and may also be set aside for the present. The third group comprises species which can feed upon dead organic matter and which are in many instances indifferently parasites or not. This is the dangerous group from the point of view of the water hygienist. Yet they are not all capable of living in water because not only must they have organic matter to feed upon, but individual species must have it in a particular form. It is sufficient to appreciate the fact that certain bacteria will not grow unless the food material present is such as they are able to utilize. If proteid were not present in water, the proteid bacteria would not be able to live; if proteid were originally present but became by purification converted into other material the proteid bacteria would perish of starvation, and similarly as regards the other forms. It might happen that whilst proteid was being reduced through the stages of amido-compounds to ammonia, the water would successively be dominated by different species, first the proteid bacteria, then the amido-bacteria, then the ammonia bacteria would in turn flourish and succumb. Final extinction would be determined by exhaustion of all suitable pabulum, thus, in part at least, accounting for the gradual decrease to which reference has been made.

If these experimental results be applied to the consideration of natural waters it is evident that very much the same selective process must take place. At first the bacteria washed in may continue to live upon the particular organic matter washed in with them, but as this becomes diluted and destroyed by natural processes occurring in the river, species after species will be deprived of the necessary nourishment and so will speedily or slowly die of starvation. The ultimate bacterial flora of the water will obviously be composed of those species which regularly lead a free existence in nature, and whose nutritive requirements are satisfied by the simple materials permissible in food potable water. The importance of these considerations lies in the fact that given sufficient time even polluted streams would undergo self purification.

The author then proceeded to describe the manner in which these particular germs were bred, the mode of their occurrence, the way in which they are dispersed and eventually carried into the water courses. He instanced two typical cases, that of an outbreak of typhoid fever at Camborne in Cornwall and at Lansen in Switzerland. In neither of these cases was the polluting material originally great in amount: the extensive effects must be ascribed to multiplication of the bacilli after their entry into the water. How far typhoid bacilli can be carried by a river is apparently not determined by available data, but it is neither judicious nor practicable to set any limit of safety in this matter.

The author referred to the different modes adopted for the purification of water, making special reference to purification by subsidence and the effect of light upon bacteria in the water. He concluded that although the protection afforded by ordinary storage was inefficient, that could not be said of Prospect Reservoir, which is practically a lake, and would effect a more complete subsidence due to the greater distance to be traversed and the greater time available for that purpose. A lake such as this might be expected to offer a greater barrier than an ordinary storage reservoir. He described the characteristics of a sand filter, the relative efficiency of intermittent and continuous filtration, the effect of aeration and the action of the film. He found that as typhoid fever has resulted from the use of filtered water, a sand filter cannot be regarded as an entirely efficient safeguard. Nevertheless it has proved itself over and over again to have afforded protection when unfiltered water was causing disease, so that, though not flawless, the filtration of water through sand is extremely valuable.

Mr. McKinney, M. Inst. C.E., discussed the subject generally and drew attention to the difference between European and American practice as regards filtering area.

Dr. Quaife and Mr. Houghton having spoken, the latter moved the adjournment of the meeting.

Second Day of the Third Session, 31st October, 1904.

Mr. E. A. Whitehead, Engineer and Manager, Broken Hill Water Works, communicated a paper to the discussion. He alluded to the wide variation in the depth of filter beds and he thought that increasing the depth of sand to decrease the rate of filtration was an unnecessary expense. He agrees with the author that filtration through sand is straining water through insoluble media, but that the further action of oxidation has been overlooked. He objects to the mode of constructing filter beds as carried out at Lawrence, Mass., and considers that air and imprisoned gases will escape at the crowns of the corrugations and break the surface slime which is the true filtering medium. Dealing with rapid filtration as practiced in America, he says—that where attempts have been made to filter very turbid waters in ordinary sand filter beds even when preliminary coagulation and sedimentation have been used, the cost of scraping filters has been so high as to lead to the abandonment of the system. The successful working of rapid filtration depends upon the efficiency of the preliminary coagulation and sedimentation. It is necessary that the coagulant be added in exact proportion to the quantity of water to be treated, and that it be thoroughly mixed with the water. As regards sedimentation, some American engineers say that the time allowed should not be less than 12 hours; 48 hours is recommended when the cost of construction is low, but 24 hours is a fair allowance.

The results obtained by the mechanical filtration plant at Broken Hill shew that 62% of the bacteria present in the raw water as well as all the higher forms of plant and animal life are removed. After heavy rains the raw water is very turbid and carries in suspension a large amount of clayey matter, more in the form of a solution than a solid in suspension. At these times 10 grains of coagulant per gallon of water was hardly sufficient to obtain a clear effluent. Generally after subsidence the water was first treated with 2 grains of sulphate of alumina per gallon and then with a solution of lime equal to 1 in 400 of raw water. After describing the apparatus he gave tables illustrating the physical and chemical character of raw water, the effluent from the working filter and the effluent from the mechanical plant.

W. M. Hamlet, F.I.C., F.C.S., said that the trend of public opinion was all in the direction of obtaining pure water supplies and more particularly in the case of country towns;

it is a canon in the ethics of water engineering to jealously guard against any form of pollution, and where suspicion rests to purify the water supply. He pointed out that in the inauguration of our country water supplies purification was never contemplated or provided for, and when it is sought to be introduced as an afterthought, the works being completed it is generally either very expensive or impracticable to carry out. The absolutely pure standard of water is not to be found anywhere and not even in a chemical laboratory, but the sanitarian's standard may be defined as follows :—

1. A clean history
2. Freedom from pathogenic organisms
3. The minimum of organic and organised constituents
4. Reasonably soft, free from odour and colour.

Bearing this in mind, the impurities to be removed from water, however carefully gathered and stored may consist of living and non-living matter, both groups being subdivided into the visible and the microscopic. After describing the different modes of filtration he said that with regard to sand filtration a great change has come over the opinion of engineers and chemists as to what happens in a sand filter bed: it was thought at one time to be purely mechanical, but now it is considered to be biological as well, the mechanical action of the films of albuminous matter which entangles all the larger forms of life being only one aspect of the complex action of the filter.

In reporting on the efficiency of any process of filtration the biological purification is best expressed by giving the comparative number of bacteria per centimeter cube, recording the absence or the presence of pathogenic species, but the general results of the working of a filter is, and will be for some time to come, best expressed in terms of chemical analyses and when these are duly tabulated in curves and figures the engineer can see at a glance whether any given change in composition can be accounted for by rains, floods, drought or outside contamination. Chemical analysis allows of inquiry as to the origin of pollution to be made much quicker than would be the case if the biological methods were alone accessible.

Mr. HOUGHTON, M. Inst. C.E., exhibited a diagram shewing the storage capacity of unfiltered water, the area of storage reservoirs, and the area filtered per million gallons of daily supply for the month of June last, for five of the London water companies, to shew that some companies favour large storage and a quick rate of filtration, and others smaller storage and a slower rate. The average rate varied from 0·98 to 2·22 gallons per square foot per hour. He quoted Dr. Frankland's figures to shew the great value of sedimentation in storage water, which in the case of the companies just quoted, shewed a reduction of bacteria from about 76·7 per cent. in 13 days to 92·9 per cent. in 6·3 days. He thought that the author's description of the action of a sand filter-bed was not quite correct, but that it is rather a breaking up of the water into small particles so that it comes more into contact with the bacteria in the pores of the sand, in support of which he quoted Gill on the filtration of the Muggel Lake Water Supply. He disagreed with the statement that water containing more than 100 germs per ccm. is not sufficiently cleansed, and that water should not be condemned because of the number of bacteria it contains, instancing the fact that water drawn from the taps in Melbourne contained on a average of 199 examinations, 154 bacteria per ccm. He thought he was the only engineer that had any experience of mechanical filters in Australia, and when he was asked to advise the Broken Hill Water Supply Co. on the best means of purifying the water the analysis of the water supplied to him shewed solids varying from 260 to 760 parts per million, and the albuminoid from ·16 to ·30 parts per million, although since then the proportion had been greatly increased.

To deal with the question by means of subsiding reservoirs would have been too costly, and ordinary sand filters would have been of very little use on account of the large amount of fine clay in suspension. Rapid mechanical filters having been adopted, the process was to bring the water from the pumping station into a subsiding reservoir which held one hour's supply. In the tank are copper plates. In the filters of which there are four, the medium is quartz, nothing larger than would pass a 144 mesh sieve and nothing smaller than would remain on 1,600 mesh. The filters work very well so long as the solids are not excessive, but when they amounted to 1,000 per million they gave trouble; when they filter at the rate of about 50 cubic feet per hour a good effluent is obtained. Working at this rate the filters had to be cleansed about once every 2 or 6 days, which operation takes about 15 minutes, with an expenditure of about 20,000 gallons of water. Using about ½ to 2 grains of coagulant we get a reduction in the albuminoid ammonia of about 55 per cent. and in bacteria of about 62 per cent. He exhibited a diagram shewing the curves of purification for quartz and sand respectively, which are practically identical. The deposit of clay on the quartz in the filters is very considerable, and sometimes the machinery employed for raking the filters is unable to break it up, and the question of cleansing by the aid of forced air is now being considered. He thought that mechanical filters for Sydney Water Supply would be a mistake, the sand filters have been proved to be efficient in operation and cheap in maintenance.

Mr. CHAS. W. SMITH, M. Inst. C.E., said that the subject of water filtration has been so thoroughly threshed out by hydraulic engineers and biologists of all nations and the data obtainable are so complete, down to the minutest detail that there should be apparently no difficulty in selecting a method applicable to each individual water works. He did not think that in Australia mechanical filtration need be employed, save in such locations as are liable to excessive animal pollution and where the sources of supply are under official control. The watersheds of the cities and larger towns should be under such strict supervision that serious contamination would be impossible, and the simple and more economic method of rational sand filtration should meet all requirements. In New South Wales there is an instance of sand filtration at West Maitland, as most fully described by Mr. Henson; at Broken Hill is established the only mechanical filtration plant in Australia as applied to water works. In Victoria the process of precipitation by means of lime was in operation at Bendigo and Geelong at the time of the speaker's connection with those works some years ago, and where satisfactory results were obtained by the use of about 1℔. of lime to 1,000 gallons of water treated.

In South Australia while no system of artificial filtration has been established, certain of the townships adjacent to Adelaide got their water from wells sunk in the sand detritus adjacent to the creek; the wells were lined with brickwork, laid dry in the lower part and with mortar joints in the upper part, thus securing filtered water which was conveyed from the gathering wells by cast iron mains to covered service reservoirs. In Brisbane where vegetable organisms in the water gave considerable trouble, the speaker had recommended sand filtration; the media to consist of top layer of sand 3 feet 6 inches thick including a 3 inch layer of powdered cinders in the middle, the whole resting on a series of layers aggregating 2 feet thick of coarse sand, fine gravel and broken rock, preferably limestone. In the water supply of Buenos Ayres it had been found that the introduction of a layer of cinders in the filter produced a brilliantly pellucid water, and the albuminoid ammonia was reduced from 0·24 part per million in the raw water to 0·01 part per million in the filtrate. He alluded to experiments now being carried out in Brisbane for the destruction of algæ by the use of copper sulphate, where it is found that the result is not so satisfactory with the soft water which obtains there as with the harder waters in America.

Mr. J. Haydon Cardew, Assoc. M. Inst. C.E. in moving a vote of thanks to the author of the paper, said that although filtration of water was fully understood and successfully practised in Europe and America it had been almost entirely neglected in Australia. The Sydney water supply although it is gathered on an area which, geologically considered, is extremely favourable to purity, is exposed to many dangers from the character of the settlement on its surface, and it was a question worthy of the consideration of the authorities whether filtration should not be adopted if only as a precautionary measure. In country towns water supplies in this State the question was one of even greater urgency, because it was well known that there were only a very few that supplied water fit for human consumption, and that if the quality of the water was tested by the rules and conditions laid down in the paper, the majority of the country water supplies of the State would be absolutely condemned. In this country, probably due to climatic conditions, there is generally an abnormal development in all storage reservoirs of animal and plant life; in one reservoir myriads of small green frogs swarmed to such an extent as to block the pipes, and although the gathering ground was of granitic formation, only devoted to grazing cattle and remarkably clear of fallen timber and vegetation, the odour of the water was extremely obnoxious. In other reservoirs and in settling ponds numbers of rats and mice were observed. These references, together with the remarks made by other speakers on the presence of algæ would point out the necessity for filtration, but there are other very grave dangers of pollution arising from the presence of the dead bodies of cattle and sheep which invariably find their way into the watercourses at times of drought, and are washed down to the reservoir at the first flood; in districts affected by pleuro or tuberculosis the water which flows off the pastures must be more or less contaminated, and it is conceivable that hydatids would be found in any reservoir; even the Sydney Water Supply canals are extremely liable to this form of pollution. The presence of rabbits in large numbers is a danger prevalent everywhere in the State to the purity of the water supply, and the discovery of dead rabbits in the canals above Prospect sufficiently emphasises the necessity for the filtration of all water destined for human consumption.

The question of the great variation in depth of media adopted in the various waterworks in England is deserving of some comment, as it seems to indicate some want of knowledge in guiding principles. It is generally understood that the top film of sedimentary and organic mud on the surface of the sand performs the principal duty of straining and interception of bacteria, while the sand beneath the film performs in a lesser degree the same duty, its principal function being the support of the film, the aeration of the passing water and the generation of water bacteria, which Piefke has demonstrated to be of great importance in the satisfactory working of the filter. The relative proportion of the duty performed by the several parts of the media has been experimentally determined by Dr.

Frankland, and is clearly illustrated by the diagram plotted from his figures, a study of the diagram shews that although the top film intercepts the majority of the passing organisms a great number manage to pass through, and are intercepted by the underlying sand. The curves appear to demonstrate that results are not improved beyond a depth of 600 mm. or about 2 feet, and that the existence of a more open stratum below the sand in the shape of gravel is deleterious to the effluent. It is reasonable to suppose that the nature of the water and of the sand would be important factors in determining the depth of media, but experiments seem to shew that given a sufficient depth to ensure the stability of the film, the depth of the sand need not vary so greatly as appears to be the practise in English waterworks.

The cost of filtration of water is of such importance from an economic standpoint that some trouble has been taken to gather evidence concerning it. Mr. Price Williams, M. Inst. C.E., in a paper read before the Institution of Civil Engineers two years ago, gives the cost of filtration on sand beds for the past 30 years to 8 of the London water companies, and from those figures a diagram has been prepared; it embraces the period 1871 to 1901; the average cost during the period referred to is 6/6 per million gallons or 5·51 per cent. of all charges of maintenance. Now if the experience of London is applied to the Sydney Water Supply and the amount of water consumed in 1901-2 is dealt with, the cost of filtration calculated by the percentage of all charges as given above would be 8/3¾ per million gallons.

Mr. Loxley Meggitt, F.I.C., in seconding the vote of thanks to the author, said that although not an expert on water filtration he had carried out experiments in connection with the purification of sewage from factories, and he thought it strange that work on similar lines had not been done in regard to the purification of water.

One of the speakers referred to the case of waters that developed a bad odour and emitted gases in the pipes, he considered the trouble could be cured and the water purified by bacterial treatment in a form of septic tank, and after that by intermittent filtration.

The Chairman in putting the vote of thanks to the meeting expressed the great pleasure he had experienced in presiding at such an excellent discussion, and hoped it would be the precursor of others.

The Session then terminated.

Unfortunately the diagrams which were very interesting cannot be printed.

TACHEOMETER SURVEYING WITH AN ORDINARY THEODOLITE.

By Thomas Kennedy, Assoc. M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, and the Institution of Surveyors N. S. Wales, July 20, 1904.*]

Tacheometer surveying consists in getting heights and distances without chaining and levelling in the ordinary manner. It is proposed to describe a simple system of tacheometry that can be taken with an ordinary theodolite and so avoid the use of special instruments or fixed stadia wires in the theodolite.

This system of tacheometry has recently been used on an extremely rough railway trial survey on part of the North Coast, being the ascent to the Dorrigo Tableland from the Orara River. The country is mostly covered with a dense undergrowth, the clearing of which added to the difficulty of the survey, as every line had to be cleared for observations. It was found possible, however, by this method of tacheometry to stake level and cross level from 60 to 80 chains in a day besides reducing all field notes. The ascent from the valley of the river to the tableland was almost abrupt, the total rise being 1,700 feet, and the direct distance from the river to the top being about six miles. A distance of 18 miles had to be developed to get the ruling grade. The first mile was level, so practically the whole ascent had to be made on the ruling grade rising approximately 100 feet to the mile. The field work of the survey was commenced on the 1st May and completed on the 1st August (three months). The plans were plotted in Head Office.

The method is known as the "Tangential" and consists in setting on the vertical arc of the theodolite consecutively a pair of angles whose natural tangents differ from each other by ·01 when the base is ·66 or 1. By using the ·66 base the resultant heights are in feet and the distances in links (should the heights and distances be required both in feet, then the angles from the natural tangents corresponding to ·01, ·02 and ·03, etc., can be taken direct from a table of natural tangents). The two tables of tangents have been calculated to give distances in chains and links or feet, from a level surface to a slope of sixty feet in one chain.

If any two angles be taken from the table and set alternatively on the vertical arc of a theodolite, and a levelling staff divided to hundredths of a foot be read at each setting, then the difference of the staff readings will give the horizontal distance in chains and links or feet according to the table used, and this distance multiplied by the natural tangent of either angle will give the height in feet from the instrumental axis to the intersection of the cross hairs on the staff when that angle is set on the vertical arc corresponding to the tangent used for multiplication.

The natural tangents are given on the table opposite to their respective angles. As a practical example

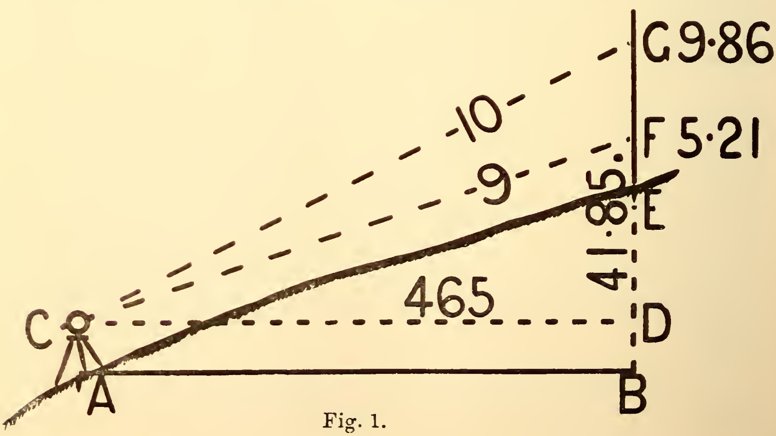


Fig. 1.

The operation in the field is as follows:—In figure 1 let AE represent any section of sloping ground. It is required to find the horizontal distance AB, and the vertical height BE. Set a theodolite over a peg A and measure the height of the instrument AC. Then from the table of tangents giving distances in feet, set the angle on the vertical arc that most nearly corresponds with the slope of the ground AE. Let this angle be 5° 08′ 34″; it will be found from the table of tangents that this angle will give a rise of 9 feet in 100 feet. An ordinary levelling staff divided to $\frac{1}{100}$ of a foot is held on E, and a reading of the staff taken, this will be the height EF, let it equal 5·21 feet. From the tables the next higher angle is 5° 42′ 38″, which is set on the vertical arc of the theodolite this angle will give a rise of 10 feet in 100 feet. The staff is again read giving the height EG, which equals 9·86 feet. Then the difference of the staff readings $9·86 - 5·21 = 4·65$ which, multiplied by 100, is the horizontal distance AB. Then $465 \times 9 = 41·85$ feet, this being the vertical height, DF and BE can easily be found by adding BD and subtracting EF. For obtaining the height of the instrument a small length of an old metallic tape was used, and so graduated that the height from the ground to the top of the tripod recorded the actual height of the instrumental axis. This was found more convenient than holding the staff beside the instrument. The shortening of the tape enabled the observer to reach from the ground to the top of the tripod.

The reduction of field notes taken by the tangential method can be carried on in the field, as very little more calculation is required than to reduce notes taken by ordinary levelling. A sample page of field notes is shewn and the notation is so arranged that the notes can be entered in an ordinary level book.

On a recent survey for extended contours at Barren Jack, the proposed dam site on the Murrumbidgee River, the site was contoured for 1,100 feet along the river to a height of 500 feet on one side and 410 feet on the other, the time occupied on the survey being four days. The country has an average slope of between 30° and 40°. On the last day the tacheometer notes were reduced in the field and survey was found to close before leaving for head quarters where the plans were plotted.

The advantage of knowing the reduced level and distance is of great assistance in locating railways or contours. In fact it is almost impossible to locate a long ruling grade for a proposed railway without chaining and levelling the traverse in the ordinary way. This especially applies to rough and heavily timbered country. With an assistant to book and check the reduction of notes there was found to be no delay in the field work, and with sufficient field hands it would be possible in one day to traverse level and cross level about two miles of preliminary railway survey in ordinary open rolling country—as much as one and a quarter miles was so surveyed in one day, but the country was rough and heavily timbered, the time was mostly taken up in clearing the traverse lines. When the work has to be done without an assistant, it is better to have the table of tangents on a separate sheet, preferably mounted on a stiff card about the size of a page of the level book, so that the angles can be read off without having to refer to another book.

The accuracy of the work is quite close enough for preliminary surveys for railways or contouring areas of land. As an example of the comparative results, a table is shewn with the different results between the level staff and chain and the tacheometer over about one mile of rough country. The difference in distance is only five links, and of level one-hundredth of a foot at the end; but in places the difference in level amounts to 1·65 feet, and the distance differs by 26 links. As the errors give and take the results are quite near enough for preliminary surveys.

On five miles forty-six chains of trial survey that was staked out with tacheometer and afterwards chained and levelled in the ordinary way, the final result gave the difference in distance of 84 links, and the difference in the reduced level of 7·30 feet. The number of traverse lines was 171 and their average length 2·6 chains. The short lines were unavoidable on account of the rough nature of the country, as the line staked ran under a steep mountainous slope covered with a dense undergrowth. Upon re-levelling, it was found that the errors were mostly in the steep slopes, and it was afterwards found advisable to repeat the angles and to exercise great care in setting them on the vertical arc of the instrument. The table was originally calculated to the nearest minute only, but this was not accurate enough, so a table of angles to the nearest second was substituted. On the cross sections the same accuracy is not necessary.

The theodolite should have the bubble attached to the vertical arc and not on the telescope. The theodolite used had the bubble removed from the telescope and fixed on the arc, and being much longer and more sensitive than the bubble usually attached to the arc, the result was very satisfactory, and the cost of removing the bubble was 25s. So as to enable the staff holder to hold the staff truly vertical, a longitudinal bubble was attached, this being frequently adjusted with a plumb bob. For ordinary levelling it has been found that the bubble on the staff gives greater accuracy and more expeditious levelling than waving the staff. Some difficulty was experienced in reading the staff at a greater distance than four chains, and it would be advantageous to have the staff divided to read every two-hundredths of a foot instead of one.

The plotting of plans.—Where the country is steep it is better to adopt a large scale for the plan, and nothing less than two chains to one inch should be adopted where the contours are to be marked at every ten feet apart. The section can be plotted to the ordinary scale used in New South Wales on preliminary railway surveys—that is four chains to one inch.

For marking off the contours on the plan, the heights are scaled from the plotted section and the points marked on plan of the traverse line. The cross level is written on the plan where the ground changes, and to divide the cross section into even spaces a device is shown on the diagram. A similar one suitable for the work required should be drawn on clear tracing linen. The use of this diagram was found to greatly facilitate the division of the contours.

Suppose contour lines are to be marked every 5 feet between the points *x* and *y* whose heights are 81 and 107 feet above datum. It will be observed that every fifth radial line is alternately marked different. Assuming as in example, that the bottom outside line represents 80, the next dotted line represents 85 and so on. Now make the station (*x*) coincide with any part of the line (81) that is the one next that standing for 80, then run that line over the point until the line corresponding to 107 coincides with the point (*y*), always taking care that the line between the points themselves is parallel to the lines *a*, *a*, *a*. Prick through on the thick dotted lines which occur between the stations *x* and *y*, and in this case these will give the contours for 85, 90, 95, 100, and 105. The diagram should be traced and the dotted lines marked alternately red and blue.

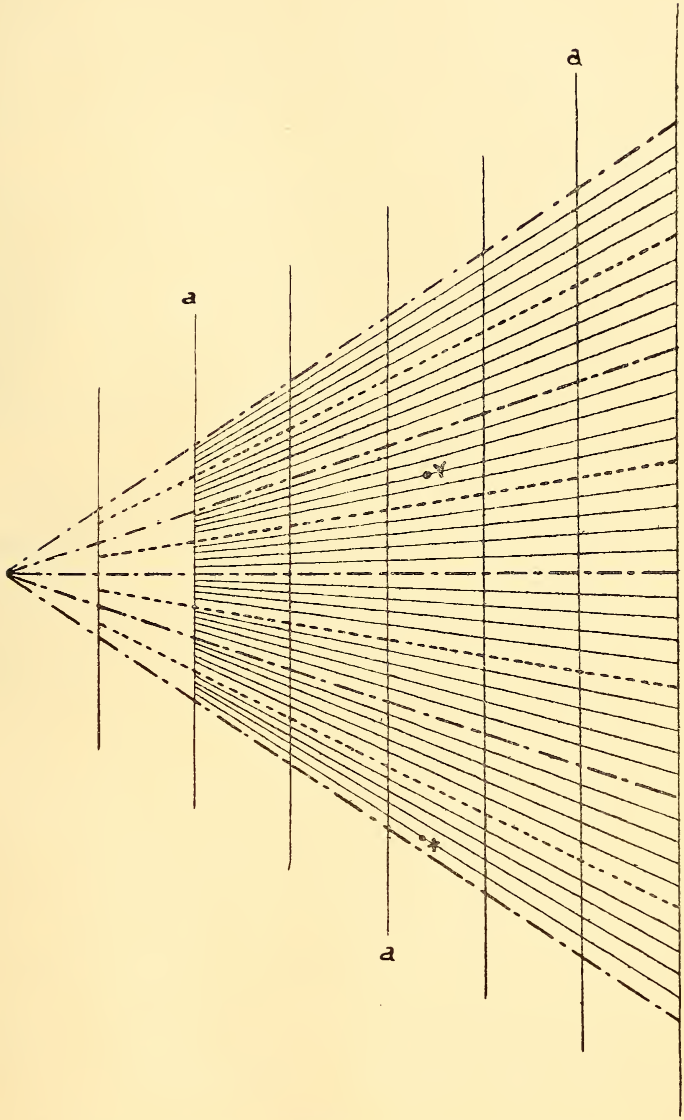


DIAGRAM FOR MAKING CONTOUR LINES.

In railway location where curves not sharper than 10 chains radius are to be used no great advantage is gained by making contour maps of the route, as the usual practice in New South Wales of writing the reduced levels on the plan gives quite as accurate results whilst the office work is considerably reduced.

In rough country better results are obtained by the use of contours as it is then necessary to use sharp curves. If curves of five chains radius are to be used, then to get the best results from cross sections they should be taken almost at every chain and the heights written on the plan. These figures do not convey to the eye any impression of the nature of the country, whilst by the use of contours a good idea may be taken in at a glance.

In surveying preliminary lines for a proposed railway, long lengths have frequently to be staked on the ruling grade; then the tacheometer system is a great assistance in locating the line. The main traverse should, however, be always levelled and chained as a complete check on the work. This can be carried out by an assistant whilst the plans and sections are being plotted. On some portion of the Dorrigo survey alternate lines had to be staked. They were run out by the tacheometrical method and checked on to the main traverse at about half-mile intervals. These lines served to extend the contours and a wide belt of country differing in level by 500 feet was in some instances shown. The advantage of having extended contours was of great assistance in the location on the plan of the proposed railway to the Dorrigo for over the whole ascent of 1,700 feet—three separate schemes have been formulated giving ruling grades on each route of 1 in 30, 1 in 40, and 1 in 60 respectively. On the 1 in 30 and 1 in 60 it is proposed to use five chain curves, whilst on the 1 in 40, the 10 chain curve is adhered to, as on the latter the ordinary engines and rolling stock can be used, whilst the lines with sharp curves would require special engines.

TABLE OF TANGENTS, DISTANCES, LINKS.

+	Tan	−	+	Tan	−
° ′ ″		° ′ ″	° ′ ″		° ′ ″
0 52 05	1	89 07 55	25 09 33	31	64 50 27
1 44 09	2	88 15 51	25 51 59	32	64 08 01
2 36 09	3	87 23 51	26 33 54	33	63 26 06
3 28 06	4	86 31 54	27 15 19	34	62 44 41
4 19 56	5	85 40 04	27 56 14	35	62 03 46
5 11 40	6	84 48 20	28 36 38	36	61 23 22
6 03 15	7	83 56 45	29 16 31	37	60 43 29
6 54 40	8	83 05 20	29 55 54	38	60 04 06
7 45 54	9	82 14 06	30 34 45	39	59 25 15
8 36 56	10	81 23 04	31 13 06	40	58 46 54
9 27 44	11	80 32 16	31 50 57	41	58 09 03
10 18 17	12	79 41 43	32 28 16	42	57 31 44
11 08 34	13	78 51 26	33 05 06	43	56 54 54
11 58 34	14	78 01 26	33 41 24	44	56 18 36
12 48 15	15	77 11 45	34 17 13	45	55 42 47
13 37 37	16	76 22 23	34 52 31	46	55 07 29
14 26 39	17	75 33 21	35 27 20	47	54 32 40
15 15 18	18	74 44 42	36 01 39	48	53 58 21
16 03 36	19	73 56 24	36 35 28	49	53 24 32
16 51 30	20	73 08 30	37 08 48	50	52 51 12
17 39 00	21	72 21 00	37 41 39	51	52 18 21
18 26 06	22	71 33 54	38 14 02	52	51 45 58
19 12 46	23	70 47 14	38 45 56	53	51 14 04
19 58 59	24	70 01 01	39 17 22	54	50 42 38
20 44 46	25	69 15 14	39 48 20	55	50 11 40
21 30 05	26	68 29 55	40 18 51	56	49 41 09
22 14 57	27	67 45 03	40 48 55	57	49 11 05
22 59 20	28	67 00 40	41 18 31	58	48 41 29
23 43 13	29	66 16 47	41 47 41	59	48 12 19
24 26 38	30	65 33 22	42 16 25	60	47 43 35

D − Horizontal Distance
T = Tangent
S = Staff Reading

Rise = $DT - S$
Fall = $DT + S$

TABLE OF TANGENTS DISTANCES, FEET.

+	Tan	−	+	Tan	−
° ′ ″		° ′ ″	° ′ ″		° ′ ″
0 34 22	1	89 25 38	17 13 24	31	72 46 36
1 08 45	2	88 51 15	17 44 41	32	72 15 19
1 43 06	3	88 16 54	18 15 47	33	71 44 13
2 17 26	4	87 42 34	18 46 41	34	71 13 19
2 51 45	5	87 08 15	19 17 24	35	70 42 36
3 26 01	6	86 33 59	19 47 56	36	70 12 04
4 00 15	7	85 59 45	20 18 16	37	69 41 44
4 34 26	8	85 25 34	20 48 25	38	69 11 35
5 08 34	9	84 51 26	21 18 21	39	68 41 39
5 42 38	10	84 17 22	21 48 05	40	68 11 55
6 16 39	11	83 43 21	22 17 37	41	67 42 23
6 50 34	12	83 09 26	22 46 57	42	67 13 03
7 24 25	13	82 35 35	23 16 04	43	66 43 56
7 58 11	14	82 01 49	23 44 58	44	66 15 02
8 31 51	15	81 28 09	24 13 40	45	65 46 20
9 05 25	16	80 54 35	24 42 09	46	65 17 51
9 38 53	17	80 21 07	25 10 25	47	64 49 35
10 12 14	18	79 47 46	25 38 28	48	64 21 32
10 45 29	19	79 14 31	26 06 18	49	63 53 42
11 18 36	20	78 41 24	26 33 54	50	63 26 06
11 51 35	21	78 08 25	27 01 18	51	62 58 42
12 24 27	22	77 35 33	27 28 28	52	62 31 32
12 57 10	23	77 02 50	27 55 24	53	62 04 36
13 29 45	24	76 30 16	28 22 09	54	61 37 51
14 02 11	25	75 57 49	28 48 39	55	61 11 21
14 26 33	26	75 33 27	29 14 56	56	60 45 04
15 06 35	27	74 53 25	29 41 00	57	60 19 00
15 38 32	28	74 21 28	30 06 50	58	59 53 10
16 10 20	29	73 49 40	30 32 26	59	59 27 34
16 41 57	30	73 18 03	30 57 50	60	59 02 10

D = Horizontal Distance
T = Tangent
S = Staff Reading

RISE = $DT - S$
FALL = $DT + S$

COMPARATIVE RESULTS.

By Level and Staff.			Number of Station.	By Theodolite used as a Tacheometer.		
Reduced Level.	Mils.	Chs.		Mls.	Chs.	Reduced Level.
1743·85		57·27	117		57·27	1743·85
1710·03		60·14	118		60·04	1711·24
1696·98		61·65	119		61·60	1697·77
1690·44		64·78	120		64·74	1691·30
1707·63		67·74	121		67·68	1708·35
1697·77		68·70	122		68·64	1698·49
1689·91		71·52	123		71·41	1690·04
1694·73		72·72	124		72·64	1695·81
1683·20		74·79	125		74·79	1684·06
1663·03		77·70	126		77·68	1663·98
1682·37		78·86	127		78·84	1683 37
1674·65		79·85	128		79·84	1675·62
1634·44	1	2·06	129	1	2·01	1636·08
1632·70	1	4·08	130	1	4·04	1634·35
1674·90	1	6·02	131	1	5·91	1675·11
1718·01	1	9·02	132	1	8·85	1717·49
1717·06	1	10·00	133	1	9·83	1716·56
1650·29	1	12·93	134	1	12·71	1650·59
1687·73	1	15·37	135	1	15·09	1687·13
1679·81	1	16·74	136	1	16·50	1679·14
1662·00	1	18·27	137	1	18·01	1661·67
1654·98	1	19·83	138	1	19·55	1654·67
1595·75	1	24·54	139	1	24·28	1595·12
1616·09	1	26·93	140	1	26·74	1615·96
1632·97	1	29·65	141	1	29·48	1632·98
1633·43	1	31·62	142	1	31·50	1633·43
1636·06	1	34·97	143	1	34·90	1636·04
1638·00	1	36·14	144	1	36·05	1637·99
1624·35	1	40·74	145	1	40·69	1624·36

FIELD NOTES TAKEN IN FIELD AND RECORDED IN ORDINARY LEVEL BOOK.

Height of Theodolite.	Staff Readings.	D × T	DT − S Rise	DT + S Fall	Reduced Level	Distance Chains	Through Mileage M. C.	Station	Remarks
					1896·40		1 42·49	Δ 34	
1901·32 4·92	7·85 4·95	75·40		83·25	1818·07	2·90	45·39		$\frac{26}{27}$ D gully
	6·40 2·70	40·70		47·10	1854·22	3·70	46·19	Δ 35	$\frac{11}{12}$ D
1859·04 4·82	4·70 2·20	72·50	70·30		1929·34	2·50	48·69	Δ 36	$\frac{30}{29}$ E
1934·15 4·81	5·73 5·08	10·40	5·32		1939·47	·65	49·34	Δ 37	$\frac{17}{16}$ E
1944·61 5·14	6·72 5·29	11·44		18·16	1926·45	1·43	50·77	Δ 38	$\frac{06}{09}$ D
1931·73 5·28	11·55 10·90	0·00		10·90	1877·67	·65	53·47		$\frac{01}{00}$ E back from Δ 39
	4·41 1·06	43·55		47·96	1883·77	3·35	54·12	Δ 39	$\frac{13}{14}$ D
1888·57 4·80	13·43 12·38	0·00		13·43	1875·14	1·05	55·17	Δ 40	$\frac{00}{01}$ D

29 77 = Sum of Instrument Heights 75 62   126 65   21 65
75 62 = Rises   105 39

105 39   21 26

D stands for the horizontal distance; T the tangent of the smaller angle; S the height read on the staff when the telescope points at the smaller angle; R the rise or fall.

Rise = R = DT − S; Fall = R = DT + S. But should the result give a minus sign it is an indication that there is a fall. The letters D and E in the remarks column refer to D for Depression and E for Elevation.

WATER FILTRATION.

By J. M. SMAIL, M. Inst. C.E.

[Read before the Engineering Section of the Royal Society of N. S. Wales, July 21, 1904.]

FILTRATION of water supply is a subject which the members of the Engineering Section of the Royal Society have not up to the present discussed, perhaps for the reason that it is one which has not become prominent as a necessary factor in the preservation of the health of the community of this State. I have therefore, prepared a few notes on the subject, which I trust will be freely aud fully discussed. It is proposed to deal with the question under two heads, first European method or "Slow Filtration." Second, American method, "Rapid or Mechanical Filtration." On the former perhaps, it may be found that nothing new has been advanced, yet on the other hand something of interest may be found. The author has had an opportunity of seeing both methods under working conditions.

EUROPEAN METHOD OR SLOW FILTRATION.

When filtration of water is brought up, the mind invariably turns to what is being carried out in connection with the water supply of London, which may well be termed the Metropolis of the World. Without wearying you with the history of the development of filtration of water supplies it will be sufficient to state that the question did not take a concrete form until the year 1828, when the late Mr. James Simpson installed the system in connection with the Chelsea Waterworks, which was followed by all the companies drawing water from the Thames, and by all the large cities and towns in Great Britain and Ireland with two notable exceptions, Glasgow and Manchester. The watersheds which form the source of supply to these cities being practically waste and under the absolute control of the City Councils, pollution of supply is reduced to nil and sedimentation and screening being considered sufficient protection to Public Health.

The following table shews the character of the filter beds employed by the water companies for filtering the water taken from the rivers Thames and Lea :—

Chelsea.

	Ft.	In.
Thames sand ...	4	6
Shells etc.	0	3
Gravel	3	3
Total	8	0

East London.

	Ft.	In.
Sand	2	0
Hoggin	0	6
Coarse gravel ...	1	0
Total	3	6

Grand Junction—1st.

Harwich Sand ...	2	6
Hoggin	0	6
Free gravel... ...	0	9
Coarse gravel ...	0	9
Boulders	1	0
Total	5	6

2nd—New Pattern.

Sand	2	0
Gravel	0	6
Drains	0	3
Total	2	9

Lambeth.

Thames sand ...	3	0
Shells etc.	1	0
Coarse gravel ...	3	0
Total	7	0

New River.

Sand	2	3
Gravel increasing in coarseness towards bottom	3	4
	5	7

Southwark and Vauxhall.

Harwich sand ...	3	0
Hoggin	1	0
Fine gravel... ...	0	9
Coarse gravel ...	0	9
Total	5	6

West Middlesex.

Harwich sand ...	1	9
Barnes sand ...	1	0
Gravel screened to different sizes and arranged in layers	1	0
Total	3	9

Subsiding and storage reservoirs for unfiltered water. Available capacity in gallons per million gallons supplied:

	Gallons		Gallons
Chelsea ...	12,200,000	New River ...	5,120,000
East London ...	21,600,000	Southwark and Vauxhall ...	4,300,000
Grand Junction	3,500,000	West Middlesex	5,960,000
Lambeth ...	6,180,000		

Filtering area in acres per million gallons of the average daily supply:—

	Acres.		Acres.
Chelsea	0·58	New River	0·43
East London ...	0·64	Southwark and Vauxhall	0·61
Grand Junction ...	1·13	West Middlesex ...	0·72
Lambeth	0·50		

Average rate of filtration per square foot per hour:—

	Gallons.		Gallons.
Chelsea	1·75	New River	2·25
East London ...	1·33	Southwark and Vauxhall	1·50
Grand Junction ...	1·63	West Middlesex ...	1·25
Lambeth	1·80		

From a description of the water supply to Edinburgh, published by the Edinburgh Council, filtering material is,

Broken stone, granite whinstone	3 feet 3 inches
Gravel size of walnuts	0 ,, 6 ,,
Gravel size of beans	0 ,, 6 ,,
Coarse sand	0 ,, 6 ,,
Fine sand	1 ,, 6 ,,
Total	6 ,, 3 ,,

Average rate of filtration 3·08 gallons per square foot per hour. This is excessive.

Liverpool—Vyrnwy Water.

		Second Installation.	
Gravel ...	1 foot 0 inch	Gravel ...	1 foot 0 inch
Sand ...	2 ,, 0 ,,	Sand ...	2 ,, 6 ,,
Total ...	3 ,, 0 ,,	Total ...	3 ,, 6 ,,

Average rate of filtration per square foot per hour, 2·2 gallons.

York.

Cobbles and gravel graded	...	2 feet 6 inches
Fine river sand	...	4 ,, 0 ,,
Total	...	6 ,, 6 ,,

Average rate of filtration 1 gallon per square foot per hour.

The low rate of filtration is explained by the engineer as being considered advisable by the company in order to secure water of undoubted purity. Considering the source of supply, river Ouse, I can quite understand the feelings of the company and their engineer. A recent bacteriological examination which will be referred to further on, is quite in accord with the rate of filtration carried out.

In connection with the composition of slow filter beds on the Continent and America, Professor Mason gives the following information :—

	Berlin.		Warsaw.	
	Ft.	In.	Ft.	In.
Fine sand	1	10	2	0
Coarse sand	0	2		
Fine gravel	0	6	0	2
Medium gravel ...	0	5		
Coarse gravel... ...	0	3	0	3
Small stones	0	4	1	0
Large stones	1	0	0	11
Total	4	6	4	4

	Zurich.		Hague.	
Fine sand	2	8	1	0
Coarse sand	0	6	0	10
Fine gravel	0	4		
Coarse gravel ...	0	6	0	10 (sea shells)
Large stones	...		0	6
Total	4	0	3	2

America.

	Hudson, N.Y. Ft.	In.	Ploughkeepsie. Ft.	In.
Fine sand ...	0	6	2	0
Coarse sand	1	6		
Fine gravel...	0	6		
Medium gravel	0	6	1	6
Coarse gravel	0	6		
Small stones	0	6	0	6
Large stones	2	0	2	0
Total ...	6	0	6	0

Australia.—Hunter River Water Supply.

Sand...	3 feet 0 inches
Gravel	0 ,, 6 ,,
Total ...	3 ,, 6 ,,

With the exception of Liverpool and Edinburgh, which are supplied with water from moorlands, the foregoing may be taken as typical cases dealing with water obtained from rivers.

In dealing with river waters it has been found conducive to efficient filtration to adopt sedimentation in storage reservoirs, or the use of coagulents, sulphate of alumina or lime. The advantages of sedimentation cannot be overlooked. A few days rest will effect the clarification of river waters containing all but the finest particles, and the deposition of mineral matter in suspension results in a considerable reduction of bacteria present. In connection with the matter, Dr. Frankland has published the following figures in relation to some of his investigations of the London Water Supply. Samples taken from the West Middlesex Works at Barnes, gave the following results :—

	Bacteria per cc.
Unfiltered Thames water from Hampton ...	1,437
Unfiltered water after passing through one subsiding reservoir	318

Unfiltered water after passing through two subsiding reservoirs	177

A reduction of 88%.

New River Waterworks, Stoke Newington.

	Bacteria per cc.
New River Cut above reservoir	667
Outlet of first reservoir	560
Outlet of second reservoir	183

Reduction of 72%

Apart from the reduction of bacteria by mechanical sedimentation of mineral matter, it is possible that the bacterial action of the harmless species under the influence of sunlight and air may cause a great reduction in the number and vitality of the harmful bacteria. The percentage of reduction would fix the amount of storage necessary, it is obvious that as the matter in suspension varies in different rivers the storage necessary can only be determined by actual experiment with the water to be treated.

The author had an opportunity of inspecting the large storage reservoirs in course of construction at Staines, England, for the West Middlesex, Grand Junction and New River Waterworks Companies conjointly. The water is taken from the Thames at about 300 yards above the Bell Weir, and conducted to the reservoirs by conduits open and covered, and steel mains to the pumping station, from which it is pumped by five triple expansion Worthington engines to the reservoirs. The reservoirs are about 1¼ miles long by ⅝ mile wide at northern end, and nearly a mile wide at southern end. The average depth of water in reservoirs is 30 feet, and the capacity is equal to 3,300 million gallons. These immense reservoirs as well as storing water will act as sedimentation reservoirs before passing into the companies' filters. The longer the period allowed for sedimentation the better for subsequent filtration and lessening the cost of cleaning the filters, but it is obvious that the first cost of the work would be increased proportionately.

Sand Filtration.

Filtration through sand is straining water through fine insoluble media. The flow being continuous, the interstices in the sand become clogged with the coarser particles in the water, the interstitial space being reduced, the finer particles are in turn intercepted, until in rotation the bacteria are intercepted by the slimy coating thus formed. The bacteria increase in number until the filter becomes blocked and scraping of the top layer has to be carried out.

In order to maintain a high degree of efficiency several important points have to be observed, and the regulations issued by the German Government, drawn up under the supervision of Dr. Koch, are as interesting as they are valuable:—

1. In judging the quality of a filtered surface water the following points should be specially observed: (*a*) The operation of a filter is to be regarded as satisfactory when the filtrate contains the smallest number of bacteria, not exceeding the number which practical experience has shewn to be obtainable with good filtration at the works in question. In those cases where there are no previous records shewing the possibilities of the works and the influence of the local conditions, especially the character of the raw water, and until such information is obtained it is to be taken as a rule that a satisfactory filtration shall never yield an effluent with more than about 100 bacteria per cc. (*b*) The filtrate must be as clear as possible, and in regard to colour, taste, temperature and chemical composition must be no worse than raw water.

2. To allow of a complete and constant control of the bacterial efficiency of filtration, the filtrate from each single filter must be examined daily. Any sudden increase in the number of bacteria should cause a suspicion of some unusual disturbance in the filter, and should make the superintendent more attentive to the possible causes of it.

3. Filters must be so constructed that samples of the effluent of any one of them can be taken at any desired time for bacteriological examination.

5. The person entrusted with the carrying out of the bacterial examinations, must present a certificate that he possesses the necessary qualifications, and wherever possible he shall be a regular employee of the waterworks

7. Every single filter must be so built that when an inferior effluent results which does not conform to the standard, it can be disconnected from the pure water pipes and the filtrate allowed to run to waste; this wasting should take place, so far as the arrangement of the works will permit (1) immediately after scraping a filter, and (2) after replacing the sand to its original depth.

8. The best sand filtration requires a liberal area of filter surface, allowing plenty of reserve, to secure under all local conditions a moderate rate of filtration adapted to the character of the raw water

15. The thickness of the sand layer shall be so great that under no circumstances shall it be reduced by scraping to less than 30 centimetres (12 inches), and it is desirable so far as local conditions allow to increase this minimum limit Special attention must be given to the upper layer of sand, which must be arranged and continually kept in the condition most favourable for filtration. For this reason it is desirable that, after a filter has been reduced in thickness by scraping and is about to be re-filled, the sand below the surface as far as it is discoloured should be removed before bringing in new sand.

16. Every city in the German Empire, using sand-filtered water, is required to make a quarterly report of its working results, especially of the bacterial character of the water before and after filtration to the Imperial Board of Health.

I have only quoted some of the rules, the full text can obtained from "Purification of Sewage and Water," by Mr. Dibdin, F.I.C., etc.

To shew the importance of regulations in connection with this question, and in view of the prevalence of cholera on the Continent and possible introduction into Great Britain, and importance of efficient filtration of the metropolitan water supply, he requested the particular attention of the directors of water companies to the following points, viz.:—

"1. That every effort should be made to maintain the layer of sand in each filter at the greatest practicable thickness.

"2. That the rate of filtration should be as slow as possible consistently with the supply of the required quantity of water.

"3. That the sand removed from the surface of the filters with the deposit should, if it was to be replaced in the filter, be completely freed from all taint of organic matter."

In a paper read before the Institute of Civil Engineers, November 24th, 1896, Dr. Percy Frankland observed, in reference to a former paper read by him in 1886, as follows:—

"The principles then enumerated were as follows:—(1) To give the maximum period of storage for unfiltered water. (2) To filter at a minimum rate. (3) To filter through a maximum depth of fine sand. (4) To frequently renew the filtering materials. In reviewing the numerous investigations which have since been carried out on this subject, it will be shewn that the only one of these principles which require any modification in the light of more recent researches is the last. Further researches appear to shew that the power of arresting bacteria possessed by a filter bed suffers no diminution with age, so that frequent scraping is not necessary for the maintenance of the efficiency of the individual bed. It is, however, quite possible that it may be of advantage for the efficiency of the filtration plant taken as a whole. Thus, by running a filter bed over a long period of time without cleansing, its yield becomes diminished, and as a certain volume of water must be supplied daily this may necessitate filtering through other beds at a disadvantageous high rate, and so obtaining a filtrate from the entire works inferior in bacterial quality to that which would result if scraping were practised more frequently and a more uniform rate of filtration employed with all the beds ”

Dr. Koch, in dealing with water filtration in relation to cholera, says "The question now is what lessons we have to learn from them for the future?" The numerous and thorough investigations which have been made for some years past at Berlin and Altona Water Works with regard to the process of filtration and the bacterial condition of the water before and after filtration, has led to the conviction that filtration rate of 100 millimetres, or 3·97 inches an hour, affords a sufficient guarantee for the satisfactory working of a filter bed. Further experience of those water works, however, has shewn that we do not gain very much by simply making this demand. For, with the now existing arrangements, most water works will not be able to fulfil it, and in point of fact they do not fulfil it. The principle must be adhered to, nevertheless, that in future a filtration rate of 100 millimetres must be the first condition; but we must formulate our demand in more precise terms, and so far supplement that the purpose aimed at may be attained with certainity. This is effected by the somewhat extended demands.

1. The filtration rate of 100 millimetres, or 3·937 inches, must not be exceeded. In order to render this possible, each filter must be provided with a contrivance by means of which also it may be ascertained at any moment whether this rate is observed or not.

2. Each filter basin, so long as it is at work, must be bacteriologically examined once a day. It must therefore

have an apparatus enabling one to take specimens of the water immediately after its leaving the filter.

3. Filtered water containing more than 100 germs capable of development per cubic centimetre, must not be allowed to enter the pure water reservoir. The filter must therefore be so constructed that insufficiently cleansed water may be removed without mixing with the well filtered water.

Dr. Koch further states:—"To these sentences I have some further remarks to add. Strictly speaking the last two demands would alone suffice to avert the danger of the infecting of filtered water so far as is possible with sand filtration at all. But it seems to me questionable whether the demand of the daily bacteriological control could be limited to times of danger, that is to times of maximum consumption of water, periods of frost, and when epidemics seem imminent; in the intervals a less elaborate control, say the examination of collected waters every three days would suffice. The weekly bacteriological investigations of the collected filtered water, now usual where the water is bacteriologically examined at all, is to be regarded as insufficient under all circumstances. For the times of less bacteriological control, however, guarantee for the regular working of the filters must be given by strict limitation and control of the rate of filtration. The rate of filtration is generally calculated by ascertaining the proportion of the water filtered in 24 hours to the filter. But everybody who knows the ordinary working of water works knows also the demands made upon them in the course of 24 hours vary very considerably. At certain hours of the day very much water is consumed; at night, on the other hand, the consumption is small. If the reservoir is not large enough to balance these inequalities, this is effected by changes in the rate of filtration. The statement then that a water works filters at the rate of 100 millimetres, if based on the calculation above, has but a conditional value.

The opinion that filtered water containing more than 100 germs is not sufficiently cleansed, has been completely justified by the experience of the Altona Water Works, which is confirmed by that of other works. Of course this statement is not to be understood to mean that water containing 101 or 105 germs per cubic centimetre is to be rejected without more ado. Each case must be intelligently judged by itself, and the number 100 is merely intended to afford to those called upon to form such judgments a basis founded on experience.

Special prescriptions as to the cleansing and filling of the filters, the limit to which the sand layer may be allowed to waste, the removal of the first water after the putting in of new sand and after each cleansing, are not necessary if the working of the filters is subjected to regular bacteriological control and the water which must according to the result of bacteriological examination be regarded as inadequately filtered removed. It is the manager's affair to take care that the filtered water always fulfils the bacteriological demands. The construction and that treatment of the filters which yield the water freest of germs will always be the best.

Each water works will have to construct its own rules with the help of bacteriology; especially it will have to find out how long its unfiltered water requires to form a good filtering mud layer, how much water must remain unused after the cleaning owing to its containing too many germs, how far the sand layer may be allowed to waste, etc. It is also the manager's business to ascertain the best remedy, if, as so often happens, too great demands are made on the water works, and regular filtration is thus rendered impracticable. In one case the only remedy will be the enlargement of the water works; in another, in the prevention of waste. All this, as I have said, may be left to the water works management, if only it binds itself always to provide a bacteriologically sufficient water. In all cases, however, in which bacteriological control is declined, it will be absolutely necessary, in order to prevent mischief, to subject the work to the most vigilant supervision with regard to all the defects alluded to above.

The opinion of Dr. Koch has been quoted so far, as it contains, in my opinion, the rationale of the question of filtration of water for human consumption. It clearly shews that the work of the biologist and engineer must be in conjunction to obtain satisfactory results in the interests of public health. The lines laid down are those practically followed in the water supply of cities of Great Britain and the Continent, where sand filtration is necessary.

It is interesting to note the results of bacteriological examinations of water supplied to the metropolis of London. The bulk of the water supplied to London is drawn from the upper reaches of the Thames and river Lea, together with the New River and wells belonging to the Kent Company.

In report of March 1901—after a continuance of floods in the Thames and its tributaries, Sir Wm. Crookes, F.R.S., and Professor Dewar, F.R.S., report viz.:—Our bacteriological examination of 401 samples taken during the month has given the results recorded in the following table; besides these samples we have examined 387 others from special wells, standpipes, etc., making 788 samples in all:

	Microbes per cc.
New River unfiltered (mean of 27 samples) ...	210
New River filtered (mean of 80 samples) ...	11
Thames unfiltered (mean of 27 samples) ...	7410
Thames derived water from clear water wells of eight Thames derived supplies—	

	Microbes per cc.
(Mean of 213 samples)	17
Ditto ditto (highest)	310
Ditto ditto (lowest)	0
River Lea unfiltered	187
River Lea from the East London Water Company's Clear Water Wells (mean of 27 samples) ...	9

After the 320 daily samples taken from the general filter wells of the Metropolitan Water Company's, 19 samples or 5·9% were sterile, 10 samples or 3·1% contained more than 100 microbes, and of these only three samples contained more than 150 microbes. The ten excess samples contained an average of 118 microbes per cc.

Another example of the reduction of bacteria by sand filtration of water drawn from rivers is at York, England. The water is drawn from the river Ouse, the intake being some distance above the town, but is not free from pollution at this point. The examination in 1903 by Mr. Thomas Fairley, Bacteriologist is viz.:—

	Unfiltered Water.	Filtered Water.
January	698	5
February	245	4
March	560	3
April (heavy floods) ...	2270	15
May	295	1
June	203	4

It should be remarked that the water supplied by the York Water Company passes first into subsiding reservoirs and then through American rapid filters from which it passes to the slow sand filters for final treatment. The result being satisfactory, both chemically and bacteriologically.

As a contrast to the foregoing river services, the bacteriological examination of water supplied to the City of Liverpool from the different sources is quoted from the report of Professor Boyce, F.R.S. of Thompson-Yates Laboratories of University College. The water is obtained from Lake Vyrnwy in Wales, and Rivington District near Liverpool, and several wells, all being filtered. The average number of bacteria per cc. for the 365 daily samples is 30 per cc. The samples were taken from the fountain in Monument Place, London Road and from a tap in Ashton Hall :—

Vyrnwy water ...	26	average number per cc.
Rivington water ...	20	,, ,,
Mixed well water ...	33	,, ,,

The first two are surface waters, the last being a mixture of three large wells.

It is unnecessary to go into details of construction as these will vary according to circumstances. It may be necessary to provide subsiding reservoirs, and it would appear that in dealing with river waters this provision is absolutely necessary. Further it may be necessary to interpose preliminary filtration through roughing filters before final treatment, such provisions have had to be made in countries where the slow system is in vogue. The Puech system of filtration combines the above. The idea is to introduce a preliminary roughing filter by means of which the coarser particles in suspension are intercepted, with the result that the slow sand filters do not require scraping so frequently, thereby saving a great amount of labour and the time otherwise lost in the deposit of the film of mud before filtration can commence. This system is in use in Paris, and it is stated that the slow filters will run three or four times longer without scraping.

The depth of sand necessary for filtration appears to be adopted as 3 feet, although there are cases where a lesser depth is used, but the universal practice is not to remove more than 12 inches by scraping, thus leaving 2 feet as the minimum depth for working conditions; if the source is a polluted one, a greater depth should be retained, because at times the surface of the sand gets broken, and polluted water passes down to the underdrains. The greater the depth of sand, the more support there is for the surface layer of slime, which, as is generally known, is the most useful part of the filter. The quality and size of grains of sand is of importance. There is considerable diversity of opinion on this subject. Some engineers favour the use of sand so fine that 60% of the particles would pass through a sieve of 4,900 meshes to the square inch; it is stated that excellent results have been obtained from same. On the other hand it is contended that such fine sand is neither necessary or desirable. The method adopted in one case in selecting sand for filters appears to have some merit. The plan adopted is to have sieves of different mesh, and to select by trial the sieve which will remove 10% of the finest sand from a sample known weight. A sieve of 900 meshes to the square inch is then used, and all particles which will not pass the mesh are removed; the balance of sand left after removing the fine and the coarse is approximately of uniform size, and may be looked upon as the most important of the bulk. The fraction represented by the weight of the residue, divided by the total weight of the original sample, gives the measure of the uniformity of size of the sand, and the nearer this fraction is to unity the more suitable the sand is for filtration purposes. This method is adopted by Mr. Silcock, M. Inst. C.E. The uniformity co-efficient of sand used in 27 cities in Great Britain and on the Continent ranges from 4·7 to 1·5, the latter being that recommended in American practice.

The rate of filtration on the Continent and in Great Britain averages about 1·5 gallons per square foot per hour. As a result of careful observation, it has been found that to maintain a high bacterial standard the rate of filtration must not exceed 4 lineal inches per hour, or practically 2 gallons per square foot per hour—or rather more than one million gallons per acre. It is essential that this should not be exceeded, and that the controlling appliances should be such as to ensure uniformity of work of filtration.

American Practice.

The European system of slow filtration does not appear to be much in evidence in connection with the water supply to the cities in the United States, where water has to be drawn from rivers. Many of the earlier installations were constructed on the European method, but where the water to be treated is very turbid the results have not been satisfactory.

Mr. John W. Hill, Chief Engineer Bureau of Filtration, is carrying out extensive works in connection with the water supply of Philadelphia on the European system. The total land appropriated for filters and other works totals 462·5 acres. The system comprises subsiding reservoirs, preliminary filters, plain sand filters, and clear water basins. The water is drawn from the Schuylkill and Delaware rivers. One section of the system includes a sedimentation reservoir with a capacity of 72 million U.S. gallons, and a system of preliminary filters of daily capacity of 40 million U.S. gallons to be extended to 97 million gallons for future consumption. It will be seen that this system comprises sedimentation and double filtration, and, considering the source from which the water is drawn, this system is obviously necessary. The works are in progress, and can only be incidentally referred to as a type of slow filtration.

The author had an opportunity of examining another type of slow filtration at Lawrence, Mass. It is of unique construction, influenced by the state of the town funds when economy of construction had to be an essential factor. The filter was designed by Mr. Hiram F. Mills, Chairman of Committee of Water Supply and Sewerage of the State Board of Health of Massachusetts. It is located on the northern bank of the Merrimack River, immediately east of the pumping station. It is somewhat irregular in outline, having a total length of 750 feet and average width of 140 feet and a surface area, including the main carrier of 2·44 acres. The filter surface, by transverse carriers, into 25 portions or beds, each having an average width of 30 feet, gives an available filtering surface, including lateral carriers, of 2·36 acres, or without the carriers of about 2·3 acres. In constructing the filter, the bed and bank of the river were excavated generally to 7 feet below usual low water, for a distance of about 150 feet southerly from the old filter gallery, and in the river bank east or down stream a sufficient distance for the total length of the filter.

Main conduit and underdrains.—The underdrain pipes which extend across the filter from north to south are arranged with centres about 30 feet apart. For a width of 5 feet along the line of drain pipe the excavation was continued to elevation 29 and midway between the lines of underdrains for a width of 5 feet, the depth of the excavation was only to elevation 31. The bottom between these two levels for a width of 20 feet was excavated with a slope of 1 : 10. Thus it will be seen that the bottom of the filter when excavated ready to receive the filtering material, was waved, with alternate level ridges, between the lines of underdrains, and flat valleys in which the underdrains themselves are placed.

The conduit which receives the filtered water is circular in shape, of brickwork 4 inches thick, the bricks are laid without mortar in the end joints, thus allowing spaces a little more than $\frac{1}{3}$ inch wide for the entrance of the filtered water. The conduit is 2 feet in diameter for 105 feet from end of filter gallery; thence 20 inches for 120 feet, 16 inches for 65 feet, 12 inches for 30 feet, continuing with successive lengths of 30 feet each of vitrified pipes having diameters of 10, 8, and 6 inches respectively. The entire conduit was surrounded with 8 inches of gravel, the inner 4 inches being of stones about 2 inches in diameter, and this was covered with layers of stones of decreased sizes. From the conduit and old filter gallery, which was pierced at suitable places for the purpose, lateral underdrains of vitrified pipe were laid upon the excavated bottom with a slope of 1 : 100. The pipes were laid in the following order: beginning at the main conduit, one length of 10 inches, two lengths of 8 inches, from 35 to 65 feet of 6 inches, ending with three lengths of 4 inches. The pipes were placed so that the spigot end of one approached, but did not enter, the socket of the next, and the drains throughout were covered with a 4 inch layer of 2 inch gravel. Upon this layer, which averaged about 6 inches in actual depth, there were placed successive courses of gravel of the following sizes and of the approximate thickness (giving an average section) to make a total of 12 inches of underdrain material; 2 inches of $1\frac{1}{2}$ inch, 1 inch of $\frac{3}{4}$ inches, 1 inch of $\frac{3}{8}$ inch, and 1 inch of $\frac{3}{16}$ inch gravel, with 1 inch of coarse mortar sand. The $\frac{3}{16}$ material was spread out to a width of 17 feet, and the last course was spread out to a width of 20 feet. Beyond the pipes, the largest stones forming the lowest course were laid upon the surface of the excavation and were spread out to a general width of 5 feet, with the next courses each spread out a little beyond the course below. The largest stones used in the underdrains were selected by hand, and if covered with dust or dirt were washed. The stones of the two larger sizes, viz., 2 inch and $1\frac{1}{2}$ inch, were placed by hand at the open joints of the pipes, but the layers of smaller sizes were shovelled into place.

Filter Sand.—Immediately over the centre lines of the underdrains, that is over those portions excavated to the greatest depth and extending 5 feet on either side, there was placed a body of sand with a maximum depth of 5 feet in the centre. Over the ridges of the excavations for the filter, midway between the lines of underdrains and for a distance of 10 feet on either side, a body of sand was placed, having a minimum depth over the flat portion of the ridge of 3 feet; the effective size of the sand over the underdrains was approximately 0·25 millimetres, and of the remainder about ·30 millimetres.

It will be seen from this species of construction, that the lowest portions of the filter surface are those directly over the ridges of the excavation and half-way between the underdrains; the general elevation of the surface of these parts being 3 feet below the usual low water elevation of the river, and 1 foot below the sand surface over the underdrains. For a width of 5 feet over the centre line of both ridges and underdrains the surface of the sand is flat, and between these level areas the sand has a slope of 1 in 10. This form of surface is such that water can be readily introduced upon the filter to refil without producing currents sufficiently rapid to cause appreciable disturbance. The sand was deposited in two layers, the first being well compacted before the second was put in place. The filter is filled by gravitation from the river, but pumps are provided in case the water in river falls below gravitation level. The working level is generally kept at 2 feet over the lateral distributing carriers and 1 foot over the crown of the head when at grade.

The system is an economical one for a comparatively small community. The principal advantage appeared to be that vent pipes for exit of air, as is usual in European filter beds, were not necessary, the wavy formation of beds admitting of the air finding vent at the crown of the ridges as the water level rose. The filter bed, not being subdivided, does not admit of one section being thrown out of work for cleaning while the other keeps up supply. Since my visit, the Water Board has divided the area into three sections by dividing walls, thus admitting of filters being worked as in Great Britain and Europe. There was nothing novel in either the removal or the washing of the sand. The cost of maintenance of the filter was given in 1900 as 7·02 dollars per million U.S. gallons; in 1904 the cost was 7·07 dollars per million U.S. gallons.

The author had an opportunity of contrasting the raw water of the Merrimac with the resultant filtered water, and when it is taken into consideration that there was no subsiding or sedimentation reservoirs, or roughing filters, the quality of the filtered water was remarkable. The percentage of bacteria removed was as high as 99%. This work has been referred to on account of the novelty of construction—the engineer having struck out on bold lines with satisfactory results—also to shew how a community can cope with an alarming epidemic of typhoid through drinking the polluted waters of the canal and river by factory hands and others. It is stated that the actual benefit derived from the use of the filtered water as against the former use of that from the river, may be fairly represented by the prevention of deaths of 40 persons out of every 100 dying from typhoid fever in Lawrence during the six years prior to the construction of the filter.

Rapid or Mechanical Filtration.

This method has been well denominated "the American system." Mechanical filtration has gradually developed from the filtration of polluted water from paper factories for re-use, to its present position of filtering river water of doubtful quality for human consumption. One company alone—the Jewell Filter Company—has constructed plants in various towns in North America, the aggregate capacity of which is equal to 400 million Imperial gallons daily, about equal to the quantity filtered under the slow filtration method in England and Wales. The necessity for a different method of treatment is no doubt owing to the turbidity of the rivers and the enormous consumption per capita as compared with European cities; the consumption in some cities is enormous.

The American engineer takes the water as it comes from the river, treats it with a coagulant—sulphate of alumina—which brings about the aggregation and deposit of the greater part of the suspended matter. By this means from 40 to 75 of both suspended matter and bacteria is removed before it reaches the filter bed, and this is performed in as many hours as it would take days in ordinary subsiding reservoirs.

The relative advantages claimed in comparison with slow sand filters are :—

1. Capacity to treat very turbid waters.
2. Capacity to remove a large percentage of colour.
3. Occupy a relatively insignificant area of ground.
4. Protection from weather.
5. Freedom from risks of objectionable growths, and from tastes and odours they impart.
6. Rapidly and easily cleansed, without risk of contamination by workmen.
7. Sand bed can be easily and economically sterilized.
8. Absolute control of each separate filter, together with complete knowledge of its condition.
9. Allow water to be sent straight to the consumer with the least possible delay and expense.

Having stated the advantages claimed for this system, it will be necessary to see how these claims are supported by actual practice. The author had an opportunity of inspecting a large installation at Little Falls for the supply of the City of New Jersey. These works were designed by J. Waldo Smith, M. Am. Soc. C.E., and carried out under the direction of George W. Fuller, M. Am. Soc. C.E.

The water is drawn from the Passaic River, the sanitary character of which is considered satisfactory. The water in the river, when it reaches the filtration station, is not muddy under ordinary conditions, although after heavy freshets it carries from 25 to 100 parts per million of suspended matter. At times the water is noticeably coloured due to dissolved vegetable matter coming from several large swamps on the upper portion of the drainage area. Frequently the water contains quite large amounts of amorphous matter, consisting principally of finely divided organic material. Much of this seems to come from the bottom of the stream, as the water flows for a few miles through the Great Piece Meadows just above the intake, where the river has very little slope, and where deposited sediment is stirred up by carp and other fish. This finely divided amorphous matter, together with the colour which appears in the water, gives it at times what might be called a "dirty appearance, and causes it to be less desirable for domestic use than the analyses indicate." At the time of my visit the water in the river was decidedly dirty, and the above description aptly describes it. The Chief Engineer of East Jersey Water Company, J. Waldo Smith, M. Am. Soc. C.E., recommended that filtration works of the American or mechanical type be adopted on the grounds of economy, as conditions of level suited this system; whereas, if slow filtration had to be adopted, a more extensive area of land would have to be acquired, and additional pumping plant to raise the river water to the available site.

General description of works.—"The works have a nominal capacity of 32 million U.S. gallons daily, and are capable for short periods of yielding 48 million U.S. gallons daily. The area occupied is 170 feet by 219 feet, outside measurement. The structures are built in concrete on rock foundations. At the west end is the coagulating and subsiding basin, 130 feet long, 42 feet wide, and 43 feet deep on inside lines, the capacity being $1\frac{3}{4}$ million gallons. At the east end the lower portion of the building contains a clear water basin in two compartments; each, on an average, is 121 feet long, 58 feet wide, and 29 feet deep to the maximum flow line for the filtered water. The total capacity of the clear water basin is about $3\frac{1}{2}$ million gallons. Above the clear water basin there are 32 rectangular concrete filter tanks, 24 feet by 15 feet and 8 feet deep, arranged in four rows of 8 filters each. The total area of filter surface is 11,520 square feet. Between each pair of rows of filters there is a pipe gallery, in which the main pipes, with branches to the adjoining filters, are placed. This gallery is 12 feet wide and 13·5 feet high. Over each pipe gallery there is a platform at a level slightly above that of the water in the filter tanks, on which the attendant stands when operating the filters. There are two wings to the main building, with which they connect. The filters are covered with a flat concrete roof, with a manhole over each filter for access.

"The coagulating basin is covered with a flat concrete roof, which forms the floor of the main building. This building is 132 feet by 46 feet, and contains the machinery for the rotary blowers and pumps, and devices for applying coagulant, storage for the same, also the laboratories, offices, etc. All machinery is driven by electric motors, the current being generated at the pumping station."

The method of filtration is conducted as follows:—"River water is taken from the head-race canal and delivered to the filtration works through a 66 inch steel main, discharging into a concrete standpipe, 10 feet in diameter, located at the north end of the coagulating basin. In this stand pipe the water is treated with a solution of coagulant and after thorough mixing by the natural agitation in the stand pipe, it passes from the bottom of same into the coagulating basin, and thence to the south end, where near the surface, it is collected in a perforated pipe through which it passes to the filters. After passing through the filters the water enters the clear-water basin, from which it flows through a 66 inch steel suction main, encased in concrete, leading to the main pumps."

Washing of filters.—" Wash water is applied to the filters by centrifugal pumps, having a capacity of 3,000 gallons per minute. When the wash water is applied to the filters, it enters the filtered water outlet pipe, passes through the the manifold pipe of the strainer system, and thence through the strainers themselves into and through the sand layer. The dirty wash water is removed in part through lateral gutters about 60 inches in cross-section, placed along the sides of each filter tank. The dirty wash water leaves the filter through the inlet pipe, to which there is a branch leading to the sewer. The wash water is applied with a vertical velocity of about 1 foot per minute, equal to about 7½ gallons per square foot per minute.

" Compressed air under a low pressure is used in agitating the sand layer and facilitating the removal of the accumulated materials during the washing, in place of mechanical stirring devices with rake arms. Air is supplied by two No. 3 Root's rotary blowers, driven direct by electric motors. Each has a guaranteed capacity of 1,500 cubic feet of free air per minute under pressure of 5 lbs. The ordinary working rate is 1,000 cubic feet per minute under a pressure of 3 lbs."

The filters are operated as follows:—Along the front of each operating table is a series of 6 levers, each of which controls one of the valves in the filter. Each lever is suitably marked by a brass plate giving the name of the valve it controls. Directly behind each lever is an indicator which shows the position of the valve. On the right end of the table are two sets of push-buttons, which govern the electric current to the automatic starting-gear, by means of which the motors operating the wash water pumps and blowing engines are started and stopped by the operations of the filter. At the left end of the table are sample tubes, through which raw and filtered water are pumped by small centrifugal pumps located in the gallery. The pumps are driven by water motors, and the valves are operated on from the table. Taps are provided for drawing test samples. Loss of head gauges are fixed on the table also.

The plant has been in continuous service since September 4th, 1902. The staff employed when operating to full capacity, 32 million gallons per 24 hours, will be 2 trained men, both of whom will be familiar with analytical matters, 2 filter attendants, and 1 attendant in the machinery room on each watch. The total force with two twelve-hour watches would be 10, including the man in charge and his principal assistant. The average quantity of wash water used for the entire plant is 4·2% of the water filtered. The period of service between washings is 9·68 hours.

Bacterial Results and Principal Information Relating Thereto.
Averages by Months.

Month	Sulphate of Alumina, Grains per Gallon	Turbidity			Colour			Amorphous Matter, Standard Units per cubic Centimetre		Bacteria, Per Cubic Centimetre			Bacteria, Percentage Removal
		River Water	Coagulating Basin Effluent	Filtered Water	River Water	Coagulating Basin Effluent	Filtered Water	River Water	Coagulating Basin Effluent	River Water	Coagulating Basin Effluent	Filtered Water	
1902													
September ...	0·74	10	6	3	31	20	11			5400	3900	190	96·5
October ...	1·59	6	5	1	52	31	7	1100	380	3800	650	90	97·6
November ...	1·63	5	4	2	45	28	7	280	80	3500	1100	60	98·3
December ...	1·70	7	4	1	44	24	5	450	210	5800	1800	50	99·1
1903													
January ...	0·84	6	5	0	31	21	5	200	115	4000	1700	110	97·2

" During the month of January lower quantities of coagulant were used intentionally with the view of seeing the efficiency of different ratios, and, with the uniform rate of application of coagulant, the bacteria results obtained during that month are of most value for this particular purpose.

Removal of colour.—" It has been found as a result of repeated examinations, especially in noting the appearance of the filtered water in a large porcelain-lined bath-tub, that it is not possible for a consumer to recognise any colour when the filtered water contains 10 parts per million or less. A colour of 20 parts is also practically unnoticeable to the consumer. These works have been operated with the view of keeping the colour below 10 parts. It has been found, however, that the quantity of coagulant necessary to reduce it to that point is practically as great as that required to reduce it to 5 parts."

The following table shows the monthly average results of the applied coagulant, and the colour in the raw and filtered water:—

Month	Sulphate of Alumina Grains per Gallon	Colour	
		River Water	Filtered Water
1902			
September...	0·74	31	11
October ...	1·59	52	7
November ...	1·63	45	7
December ...	1·70	44	5
1903			
January ...	0·84	31	5

Removal of turbidity.—"The turbidity of the filtered water usually ranges from nothing to 2 parts. Now and then it becomes as high as 3 parts. All these amounts may be properly regarded as traces, and it may be said that for all practical purposes the filtered water has no turbidity.

Removal of organic matter.—"The following table shows the average removal of organic matter:—

Parts per Million				Percentage of Organic Matter Removed	
Nitrogen as Albuminoid Ammonia		Oxygen Consumed			
River Water	Filtered Water	River Water	Filtered Water	Albuminoid Ammonia	Oxygen Consumed
0·121	0·075	6·3	1·6	38	75

Removal of tastes and odours.—"The Passaic river water ordinarily has a slight musty or vegetable odour, and at times during the autumn it has a swampy odour which is noticeable to persons unfamiliar with the water, but which is not disagreeable, and in fact is hardly recognised by those familiar with surface waters from swampy areas. The removal of tastes and odours by filtration is appreciable, but when the swampy odour is present in the river, it is still clearly recognisable in the filtered water on careful examination. Studies of the practicability of removing it by aëration have been made, but it is found that this is unsuccessful, as the odour and tastes still persist after vigorous aëration for some 10 to 12 hours. The taste and odours are evidently produced by oily substances liberated from the vegetable growths in the swampy areas, and apparently could be removed only by filtration through sand at exceeding low rates.

Removal of coagulant.—"In no case has the filtered water contained any undecomposed sulphate of alumina. Regarding the removal of the aluminum hydrate, ordinarily this is complete, although now and then the numerous analyses made, indicate that faint traces of the hydrate in a very fine colloidal form have appeared in the filtered water. These traces are too small to be measured, although, in a general way, it may be said that there are times when it would probably amount to about 0·06 parts per million, equal to 0·0035 grain per gallon. The average would be less than 0·01 part per million, corresponding to a removal of more than 99 per cent. of the hydrate contained in the raw water. These traces are gradually diminishing as the sand layers are becoming 'ripened.'

Change in hardness.—"The following table gives a comparison of the average hardness of the river and the filtered waters:—

River Water			Filtered Water		
Temporary Alkalinity	Permanent Incrusting Constituents	Total Hardness	Temporary	Permanent	Total Hardness
23	12	35	15	19	34

Effect of rate of filtration.—"The rate of filtration, as far as the quality of the filtered water is concerned, does not seem to be a factor of significance. If the applied water is well coagulated, satisfactory results will follow with a rate of filtration at least as high as 185,000,000 gallons per acre per 24 hours; and, with an inadequately coagulated water, good results cannot be obtained at rates of 80,000,000 gallons per acre per 24 hours, or much less. That the number of bacteria in the filtered water is not materially affected by the rate of filtration, is shown by the following tables:—

AVERAGE RESULTS SHOWING REMOVAL OF BACTERIA BY FILTERS OPERATING AT DIFFERENT RATES.

Average for 20 weeks.

Rate of Filtration	Rate of Filtration		Bacteria per Cubic Centimetre		Percetages of Removal of Bacteria
	Gallons per Acre Daily	Gallons per sq. ft. per Minute	River Water	Filtered Water	
High ...	185,000,000	3·0	3,500	100	97·1
Normal ..	125,000,000	2·0	3,500	90	97·4
Low	80,000,000	1·2	3.500	80	97·7

AVERAGE RESULTS, SHOWING THE EFFECT OF THE RATE OF FILTRATION ON PERIOD OF SERVICE AND PERCENTAGE OF WASH WATER.

Average for 20 weeks.

Rate of Filtration	Period of Service Hours	Volume of Water Filtered per Run	Percentage of Wash Water
High ..	7·52	470,000	3·8
Normal ..	10·18	425,000	4·1
Low	12·93	258,000	4·4

"The larger yield of filtered water between washings by the high-rate filters, apparently is explained by the deeper penetration into the sand layers of matters removed from the water. Regarding the percentage of wash-water, the actual volume of water required per filter for cleaning does not seem to be exactly proportionate to the amount of accumulated matters in the sand layer."

I am indebted to G. W. Fuller, M. Am. Soc. C E., for the foregoing description of this plant.

From personal observation of the system under working conditions, I was impressed with the ease by which the attendant controlled the rate of filtration and washing of the filters. One attendant is all that is required on watch in the filter room, and two others in the machinery and coagulating rooms. After examination of the raw water, and the same after passing through the coagulating process and filters, the change in the appearance of the water was marked. The results of the chemical analyses and bacteriological examination show that the water would be considered a good potable water. The concentration of a plant capable of dealing with so large a quantity as 32,000,000 U.S. gallons per diem, within the area occupied, leads to the consideration as to whether this system (judging by the results shown) does not bear favourable comparison with the English method of slow filtration, which requires areas ranging from 0·42 acres to 1·33 acres per million gallons (Imperial), exclusive of subsiding reservoirs. I venture to think that it does. The initial cost of a slow filtration plant to deal with the quantity dealt with at these works would be higher than the American system. If coagulation could be obtained at a comparatively low rate, I think the working expenses would be lower per million gallons treated.

Cost of Filters.

The cost of construction depends upon local conditions of site, cost of land, etc., together with the character of the water to be dealt with. The following information is obtained from the work on "Public Water Supplies," by Turneaure and Russell, 1901, from which it will be seen that the cost of construction of filter, covered and uncovered, exclusive of subsiding reserves, is somewhat high. Large beds and extensive works will cost less per unit area than smaller ones, other things being equal. At Berlin, covered filters of about 0·6 acre each have cost about £14,600 per acre. At Zurich, filters of one-sixth acre each, cost for the masonry and filtering materials only, about £10,000 per acre for open and £15,000 for closed beds. Engineer Lindley estimates as a reasonable cost in Europe for carefully designed filters, about £14,200 for covered and £9,400 for open filters.

Taking the average quantity filtered by the London companies at $1\frac{1}{2}$ million gallons per acre per day as a basis, the cost of construction of filters works out at an average of £6,700 per million for uncovered and £10,000 per million gallons for covered filters, exclusive of subsiding and clear water reservoirs.

At Ashland, Wis., U.S.A., three covered filters of one-sixth acre each, cost £8,370, but the engineer estimated that under normal conditions the cost there would be about £7,300 for beds of $\frac{1}{2}$-acre each, which is equal to about £14,600 per acre. At Ploughkeepsie, a single open bed of 29,640 square feet cost £6,021, equal to £8,750 per acre. At Berwyn, Pa., three open beds of 7,500 square feet, each cost £3,862, equal to £7,500 per acre. The best figures at hand for the cost of filters on a large scale are those for the Albany plant. The cost for eight covered filters of an area of 0·7 acre each, was £9,500 per acre, not including land and engineering; the latter item, figured *pro rata* from the total cost, would add about £520 per acre. The covers were estimated to have added about £2,700 per acre to the cost. The cost of covers is thus seen to be much less than indicated by European experience, due chiefly to the use of concrete and to a more economical design. To the cost of filters will have to be added the cost of clear-water reservoir, and usually sedimentation basins, amounting to from £625 to £2,080 per million gallons capacity, according to the circumstances. The total cost of the Albany plant, including the low-service pumping station, but not including the conduit, was about £81,250, or £5,420 per million gallons capacity.

The cost of filtering plant, buildings, etc., in the American or rapid sand filtration, taking the cost of works completed and in operation, averages £4,600 per million gallons (Imp.) In this case the cost depends on local conditions of site. The cost of filtering plant, inclusive of machinery, buildings, etc., is given by the manufacturers at £2,600 per million gallons (Imp.)

Operation of Filters.

The average cost of working the filters of seven London Water Companies for fifteen years, has been stated by Mr. W. B. Bryan, Engineer of East London Water Company, to be slightly over 4/- per million gallons, the minimum being 3/- for the Chelsea Company, and the maximum 4/9 for the Grand Junction and West Middlesex Companies. In Germany the cost is higher on account of the turbid water to be dealt with. At Liverpool the cost has been given at 4/9; at Hudson, N.Y., 3/8; and Ploughkeepsie as high as 11/7, due to ice. In the city of Laurence, Mass., U.S.A., the cost of operation, exclusive of ice cutting, was 4·95 dollars per million gallons (Imp.) The work comprised in cost is scraping, conveying sand, sand washing, sanding, filter maintenance, extra filter maintenance, and coal for pumps. Turneaure and Russell give the cost of operations at Albany, N.Y., in 1900 at 8/4 per million gallons. In some cases the cost of maintenance ranges from 10/6 to 14/6 per million gallons.

The cost of operating an American or rapid filtering plant will vary according to whether coagulant is used or not; if used, the quantity per gallon of water will influence the cost. The Jewell Company state that the average cost of operating a plant of this description when one grain of sulphate of alumina per gallon of water is used, exclusive of labour, is about 3·5 dollars per million gallons. The reports of engineers in charge of plants at different places as to cost of operating varies considerably. At Lexington, N.Y., where alum is used, the cost per million gallons is 4 dollars. At Wilkesbarre, Pa., the cost of filtering 9 million gallons per day did not exceed one dollar per million gallons —the maximum cost works out at 2·30 dollars per million gallons. In Sydney the cost of operating, for labour alone, would be about 3/4 per million gallons where a coagulant is not required. The cost of installation, as given by Mr. Fuller for a complete going plant, is 15,300 dollars per U.S. million gallons (about £3,060), or about £3,672 per million Imp. gallons.

It would be difficult to compare prices in America with this country, as the conditions under which the filtration plant would have to be constructed and worked may considerably vary. It is, however, beyond question that the American rapid filtration is much cheaper in first cost for dealing with turbid waters than the European method, whether the cost of working the former will be more than counterbalanced by the greater yearly charge for interest of the latter, can only be demonstrated by two installations working under the same conditions. The experience gained by the author leads him to the conclusion that the American system is eminently suited for dealing with the turbid waters of our inland rivers, more especially where land resumption is an item.

Fortunately, so far, Providence is bountiful in giving the citizens of Sydney one of the best natural water supplies in the world, which only needs the treatment of Nature's laboratory on its course to the metropolis, added to mechanical straining prior to distribution. How long this state of things will last depends in a great measure on the citizens themselves in preserving the natural purity and prevention of pollution. The amount of money spent in Europe and America in artificial purification is enormous; this, however, is the result of centuries. In this State the source of supply is practically in its virgin state—that it should be so kept is a duty which devolves upon every citizen.

It is a very difficult matter to obtain reliable data as to the cost of maintaining slow sand filters, the yearly charges being, as a rule, mixed up with other maintenance charges. I hope to be able to shortly obtain other information on this head which will be of use in question with relative merits of the two systems.

Appendix.

1. In judging the quality of a filtered surface water, the following points should be specially observed :—(*a*) The operation of a filter is to be regarded as satisfactory when the filtrate contains the smallest possible number of bacteria, not exceeding the number which practical experience has shown to be attainable with good filtration at the work in question. In those cases where there are no previous records showing the possibilities of the works and the influence of the local conditions, especially the character of the raw water, and until such information is obtained it is to be taken as the rule that a satisfactory filtration shall never yield an effluent with more than about 100 bacteria per cubic centimetre. (*b*) The filtrate must be as clear as possible, and in regard to colour, taste, temperature, and chemical composition, must be no worse than the raw water.

2. To allow of a complete and constant control of the bacterial efficiency of filtration, the filtrate from each single filter must be examined daily. Any sudden increase in the number of bacteria should cause a suspicion of some unusual disturbance in the filter, and should make the superintendent more attentive to the possible causes of it.

3. Filters must be so constructed that samples of the effluent from any one of them can be taken at any desired time for bacteriological examination.

4. In order to secure uniformity of method, the following is recommended as the standard method for bacterial examination:—The nutrient medium consists of 10% meat extract gelatine with peptone, 10 cubic centimetres of which is used for each experiment. Two samples of the water under examination are to be taken, one of 1 cubic centimetre and one of ½ cubic centimetre. The gelatine is melted at a temperature of 30° to 35° C., and mixed with the water as thoroughly as possible in the test-tube by tipping backwards and forwards, and is then poured upon a sterile glass plate. The plates are put under a bell-jar which stands upon a piece of blotting paper saturated with water, and in a room in which the temperature is about 20° C. The resulting colonies are counted after forty-eight hours with the aid of a lens. If the temperature of the room in which the plates are kept is lower than the above, the development of the colonies is slower, and the counting must be correspondingly postponed. If the number of colonies in 1 cubic centimetre of the water is greater than about 100, the counting must be done with the help of the Wolffhügel's apparatus.

5. The person entrusted with the carrying out of the bacterial examinations must present a certificate that he possesses the necessary qualifications, and wherever possible, he shall be a regular employee of the waterworks.

6. When the effluent from a filter does not correspond with the hygienic requirements it must not be used, unless the cause of the unsatisfactory working has already been removed during the period covered by the bacterial examinations. In case a filter, for more than a very short time, yields a poor effluent, it is not to be used until the cause of the trouble is found and corrected. It is, however, recognised from past experience that sometimes unavoidable conditions (high water, etc.) render it impossible, from an engineering standpoint, to secure an effluent of the standard quality. In such cases it will be necessary to use a poorer quality of water; but, at the same time, if such conditions arise as outbreaks of epidemics, suitable notice should be given of the condition of the water.

7. Every single filter must be so built that, when an inferior effluent results which does not conform to the standard, it can be disconnected from the pure water pipes, and the filtrate allowed to run to waste. This wasting should, as a rule, take place, so far as the arrangement of the works will permit, (1) immediately after scraping filter; and (2) after replacing the sand to the original depth. The superintendent must himself judge, from previous experience acquired by the continual bacteriological examinations, whether it is necessary to waste the water after these operations, and if so, how long a time will probably elapse before the water reaches the standard purity.

8. The best sand filtration requires a liberal area of filter surface, allowing plenty of reserve, to secure under all local conditions, a moderate rate of filtration adapted to the character of the raw water.

9. Every single filter shall be independently regulated, and the rate of filtration, loss of head, and character of the effluent shall be known. Also each filter shall, by itself, be capable of being completely emptied, and, after

scraping, of having filtered water introduced from below until the sand is filled to the surface.

10. The velocity of filtration in each single filter shall be capable of being arranged to give the most favourable results, and shall be as regular as possible, quite free from sudden changes or interruptions. On this account reservoirs must be provided large enough to balance the hourly fluctuation in the consumption of water.

11. The filters shall be so arranged that their working shall not be influenced by the fluctuating level of the water in the filtered reservoir or pump-well.

12. The loss of head shall not be allowed to become so great as to cause a breaking through of the upper layer on the surface of the filter. The limit to which the loss of head can be allowed to go without damage, is to be determined for each works by bacterial examination.

13. Filters shall be constructed throughout in such a way as to insure the equal action of every part of their area.

14. The sides and bottoms of filters must be made watertight, and special pains must be taken to avoid the danger of passages or loose places, through which the unfiltered water on the filter might find its way to the filtered water channels. To this end special pains should be taken to make and keep the ventilators for the filtered water channels absolutely tight.

15. The thickness of the sand-layer shall be so great that under no circumstances shall it be reduced by scraping to less than than 30 centimetres (12 inches), and it is desirable, so far as local conditions allow, to increase this minimum limit. Special attention must be given to the upper layer of sand, which must be arranged and continually kept in the condition most favourable for filtration. For this reason it is desirable that, after a filter has been reduced

by scraping, and is about to be refilled, the sand below the surface, as far as it is discoloured, should be removed before bringing on the new sand.

16. Every city in the German Empire using sand-filtered water, is required to make a quarterly report of its working results, especially of the bacterial character of the water before and after filtration, to the Imperial Board of Health.

17. The question as to the establishment of a permanent inspection of public waterworks, and if so, under what conditions, will be best decided after such quarterly reports have been furnished over some period of time.

* * *

Filtration of Water at the Hunter District Water Works, West Maitland.

By J. B. Henson, Assoc. M. Inst. C.E.

The water for the supply of the inhabitants of the district controlled by the Hunter District Water Supply and Sewerage Board, is taken from the Hunter river at a point about $1\frac{1}{2}$ miles up stream from the town of West Maitland. The area of the watershed of the Hunter river, above the water works intake, is about 7,090 square miles, the population settled thereon numbers approximately 30,000, and large numbers of cattle, sheep, horses, etc., are depastured on the catchment area. The Board have control of the river, for the prevention of pollution, for a distance of 20 miles up stream from the intake. Within this limit the country abutting on the river is occupied for agricultural and pastoral purposes, and there is no concentration of population in villages or towns. Higher up stream, however, there are some populous towns—Singleton, Muswellbrook, Aberdeen, and others—situated on the banks of the river.

The river water varies very much in quality, between the extremes of a perfectly clear hard water in dry seasons and a turbid comparatively soft water in wet seasons. The following are comparative analyses of the solids in solution in the water at such times:—

	Sodium Chloride	Magnesium Chloride	Magnesium Carbonate	Calcium Carbonate	Calcium Sulphate	Organic Matter	Total Hardness
After a flood ...	77·45	10·70	33·42	47·98	21·25	34·40	200
During drought	292·5	43·4	84·0	99·0	35·4	23·3	330

The above quantities are parts per million. The chlorides, carbonates, and sulphates dissolved in the water vary considerably from time to time, both in relation to each other and to the volume of water.

Flood waters descend the valley of the Hunter rapidly after rainfall on the catchment area, and within the space of a few hours the river water will change from one extreme to the other. When the river is in flood the water is too turbid for use. To provide against such contingency a storage reservoir has been formed in the vicinity of the water works by constructing an earthen embankment across the outlet of an old lagoon. This reservoir contains, when full, a reserve supply of 170 million gallons of clear water which is resorted to when the river water is turbid, and it is replenished mainly by water pumped from the river at suitable times and by rainfall on its catchment area of 200 acres.

The sludge—largely composed of decayed vegetation—which lay in the bottom of the old lagoon, was not wholly removed when the reservoir was formed, and is added to by the death and decay of water weeds which grow luxuriantly in the reservoir. Endeavours have been made from time to time to get rid of the weeds, and large quantities have been removed, but fresh growths rapidly replace them. The sludge has a deleterious action on the quality of the water. During summer the water rises in temperature; when the cold of winter comes the surface layers are chilled and sink and displace the bottom water. A vertical circulation ensues which brings up the stagnant water which has been lying in contact with the sludge, and a general deterioration in the quality of the whole of the water consequently follows.

A few years ago the author designed a small syphon suction dredge to be operated by the difference in head between the water in the reservoir and that in the old lagoon at about 20 feet lower level. The dredge was constructed and acted most efficiently; a large quantity of sludge was removed without any appreciable disturbance to the water in the reservoir; the results were beneficial. The foregoing brief description of the waters which have to be used, show the importance of subjecting them to careful filtration and management.

The present arrangements for filtering the water are as follows:—A settling tank into which the water to be filtered is delivered from the pumps; four filter beds at a lower level, each 100 feet square, on to which the water from the settling tank is delivered by gravitation—the filter beds have no roof over them; a clear water tank at a lower level into which the clear effluent from the filter beds flows.

The end of the pump delivery pipe in the settling tank is provided with an apparatus for spraying the water whereby its complete aeration is secured. Aeration is hardly required for the river water, but is necessary for the storage water which, being of a stagnant character, is deficient in air. Three systems of piping are provided for the filter beds—one to supply them with water, one to convey away the effluent to the clear water tank, and one to collect and convey away waste, scour, and overflow water. Each system of piping is provided with the necessary stop valves, but there are none of the automatic control arrangements which are usually found attached to modern types of filter plant. The main effluent pipe which receives the filtered water from each of the four beds has a stop valve on it at its outlet at the clear water tank. This valve did not exist in the original design, and was subsequently added to provide better control over filtering operations. Its use will be described later on.

The filtering medium is clean river sand 2 feet 6 inches in depth, resting on 6 inches of fine gravel, under which are two layers of loose bricks arranged to form subdrainage ducts, the whole being contained in a water tight tank 7 feet in depth, the floor of which slopes to a central channel leading to the effluent outlet pipe.

Each bed has two water level gauges, side by side—one is in communication with the water above the sand, and the other with the water in the channel under the sand. When a bed is working, the difference of level of the water in the two gauges is the filtering head, and indicates the condition of the sand. The least difference is seen when the bed is clean, and the greatest after it has been in prolonged use and the interstices in the surface layer of sand have been choked with deposits of vegetable matter and fine clay. When this stage is reached the bed is put out of action, dried and the surface pared off, after which it is ready to start again. At each paring a portion of sand is unavoidably removed and the thickness of the sand bed is gradually diminished. When the reduction amounts to 9 inches, the bed is made up again to its original thickness by the addition of new sand.

When it is required to recharge a bed which has been dried off, the main effluent valve at the clear water tank is shut and the effluent outlet valve of the dry bed is opened. This allows the filtered water from the active beds to flow into the bottom of the dry bed, and gradually rise up to the surface; as soon as this stage is reached, the valve which controls the supply of unfiltered or raw water is opened, and the filling of the bed above the sand is completed from this source; the main effluent valve is then reopened and adjusted, and filtration is resumed.

In practice, however, the beds are not always allowed to run continuously. At certain times of the year each bed is shut off in rotation at short intervals. The water is lowered to a point a few inches below the surface of the sand, which is thus exposed to the direct action of the air and sunlight for a day or two, if practicable. The bed is then recharged and filtering resumed. This practice was adopted to check the growth of vegetable and animal life in the water on the beds, but it requires careful control.

The clear water tank was originally uncovered, and under the influence of sunlight vegetable growths developed rapidly and caused much trouble. The filaments were drawn into the pump suction, found their way into the water reticulation pipes, and choked the strainers of water meters. At certain seasons of the year, the growth was so abundant as to necessitate the cleaning out of the tank every three or four weeks. This, besides being expensive, caused inconvenient stoppages. A roof was constructed over the tank, and light being excluded the growth of aquatic plants ceased. No further trouble from this source has since been experienced.

Occasionally the finer growths of weeds on the filter beds collect the minute bubbles of gas which are evolved at the surface of the sand. The bubbles become entangled and accumulate until a buoyancy is gained sufficient to lift the weed from its anchorage, and in doing so a patch of the skin of the bed is torn off, leaving the bare sand exposed. Through this bare sand, no doubt, the water percolates faster than through the protected areas round it until a fresh skin is formed.

No bacteriological examinations of the water are made. Samples of the water before and after filtration are taken once a month and forwarded to the Board of Health, Sydney, for chemical examination. These examinations show that a very great improvement in the water is effected by the filters. The storage water, which before filtration is unsuitable for domestic purposes, is after aeration and filtration converted into a water of satisfactory purity. The beneficial effect of filtration is shown by the following results of analysis of storage water:—

	Parts per million— Before filtration.	After filtration
Oxygen absorbed in 4 hours ...	2·10 ...	·92
,, ,, 15 minutes ...	1·05 ...	·46
Combined ammonia	·54 ...	·14
Free ammonia	·09 ...	·00

It is only under exceptional circumstances that storage water is alone supplied to the filters. Usually equal volumes of storage and river water are taken. Better results are obtained in this way, as the following analyses of mixed water will show:—

	Parts per million— Before filtration.	After filtration
Oxygen absorbed in 4 hours ...	1·00 ...	·47
,, ,, 15 minutes ...	·50 ...	·24
Combined ammonia	·20 ...	·07
Free ammonia	·01 ...	·00

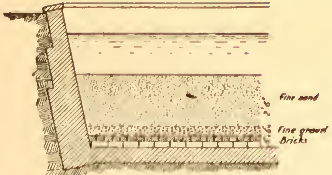
The average results throughout the year are as follows for filtered water:—

Oxygen absorbed in 4 hours	·64
,, ,, 15 minutes	·31
Combined ammonia	·10
Free ammonia	·00

The rate of filtration is not allowed to exceed 4½ inches per hour; this corresponds to the passage of a volume of 21·05 gallons per superficial yard of surface per hour.

In the practical working of the filter beds they are as far as circumstances will admit, supplied with equal volumes of storage and river water mixed together in the supply pipe to the aerating fountain. This ensures a more uniform quality of water and mitigates the severity of the change which would otherwise occur in passing direct from river water to storage or vice versa.

FILTRATION OF WATER
AT THE HUNTER DISTRICT WATERWORKS



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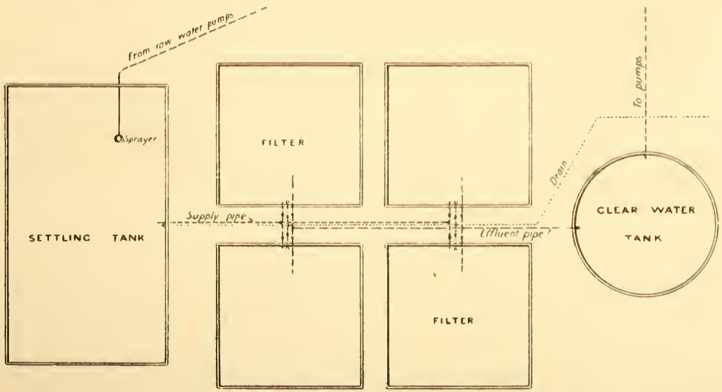
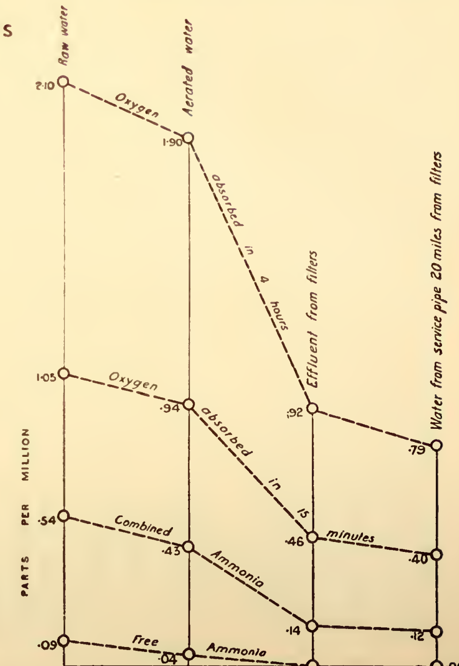


J. B. H. 1904

PLAN AND SECTION OF TANKS AND FILTERS

RESULTS OF FILTRATION OF WATER FROM THE STORAGE RESERVOIR



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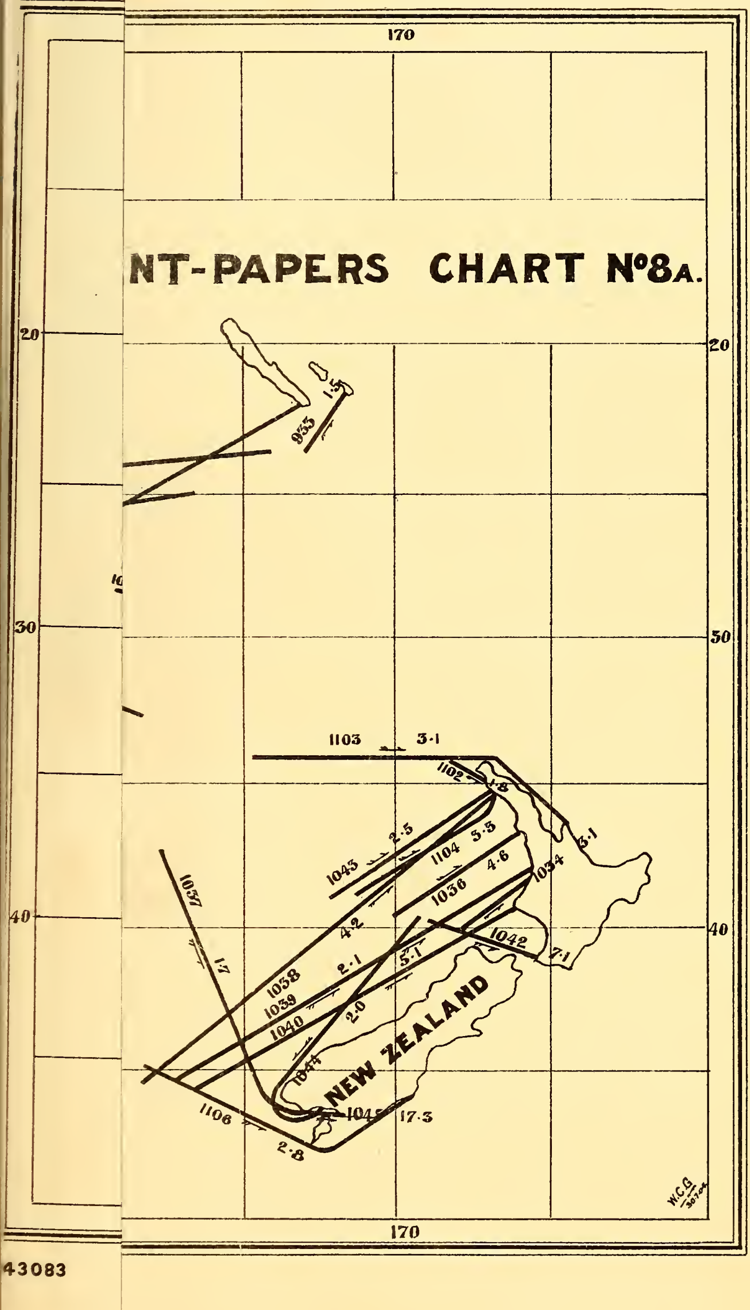
Natural Graft (White Gum and Stringybark); section through bark and wood.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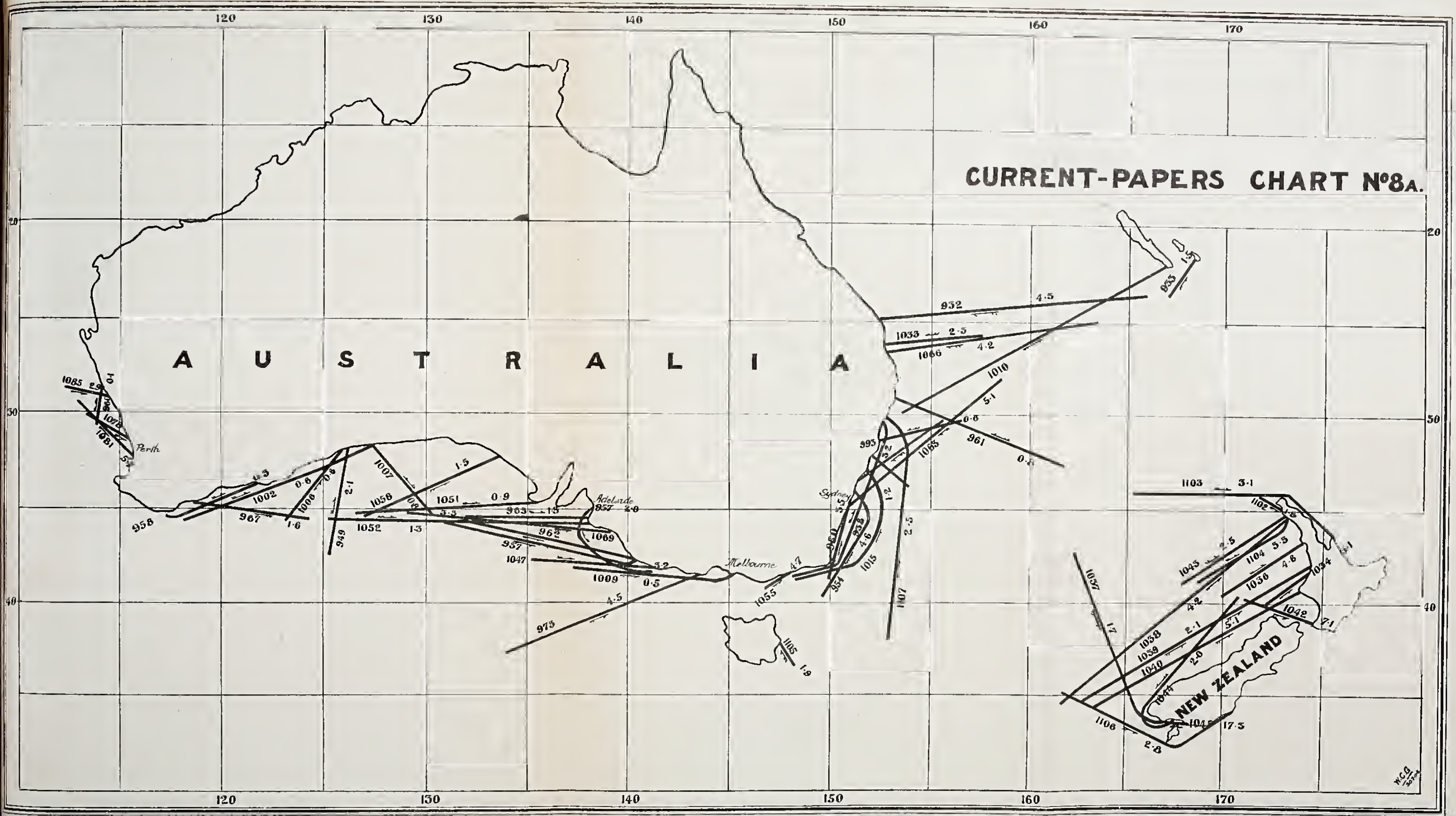

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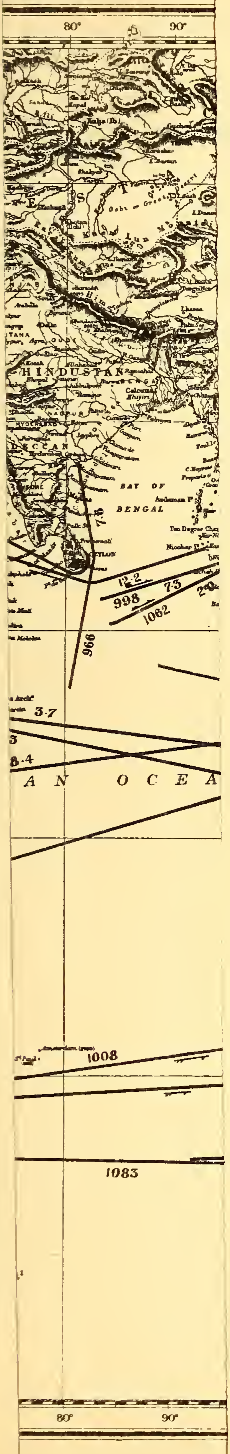
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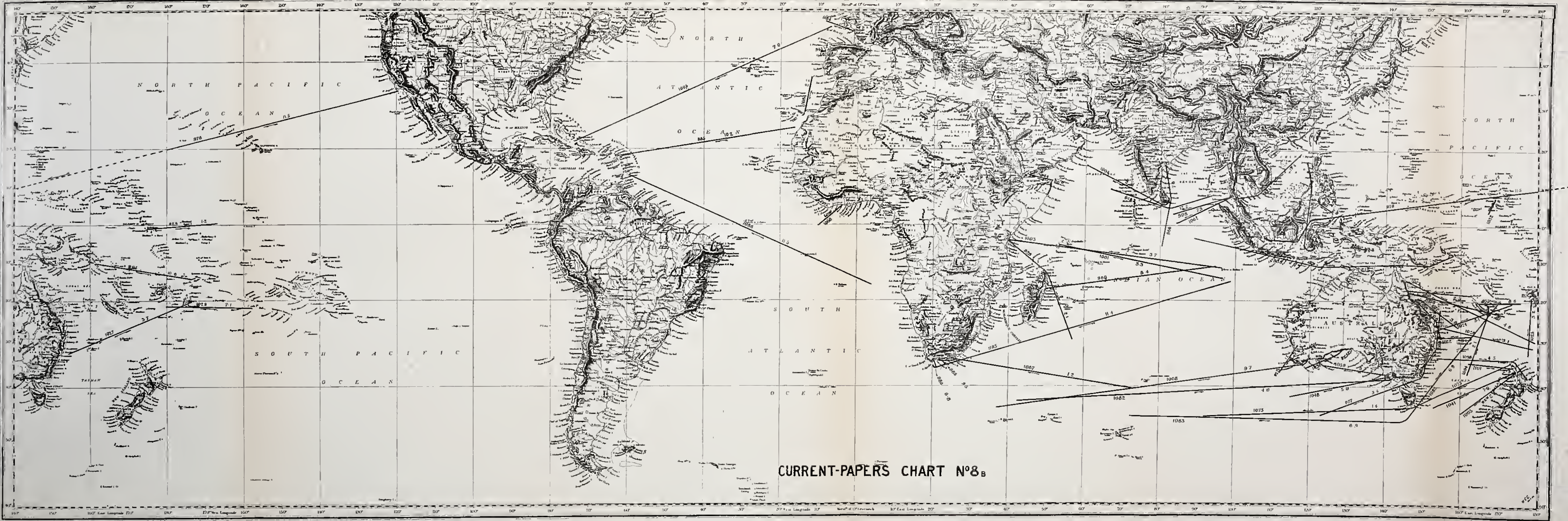

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London Published at the Admiralty 21st January 1874 under the Superintendence of Rear Admiral G. H. Richards C.B. F.R.S. Hydrographer

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Natural Graft, Apple (*Angophora*) growing in fissure of Swamp Gum.

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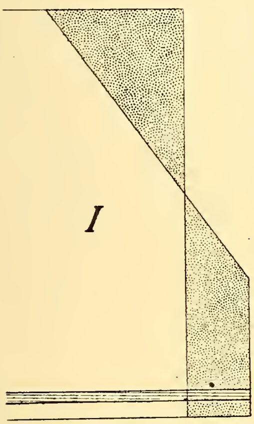

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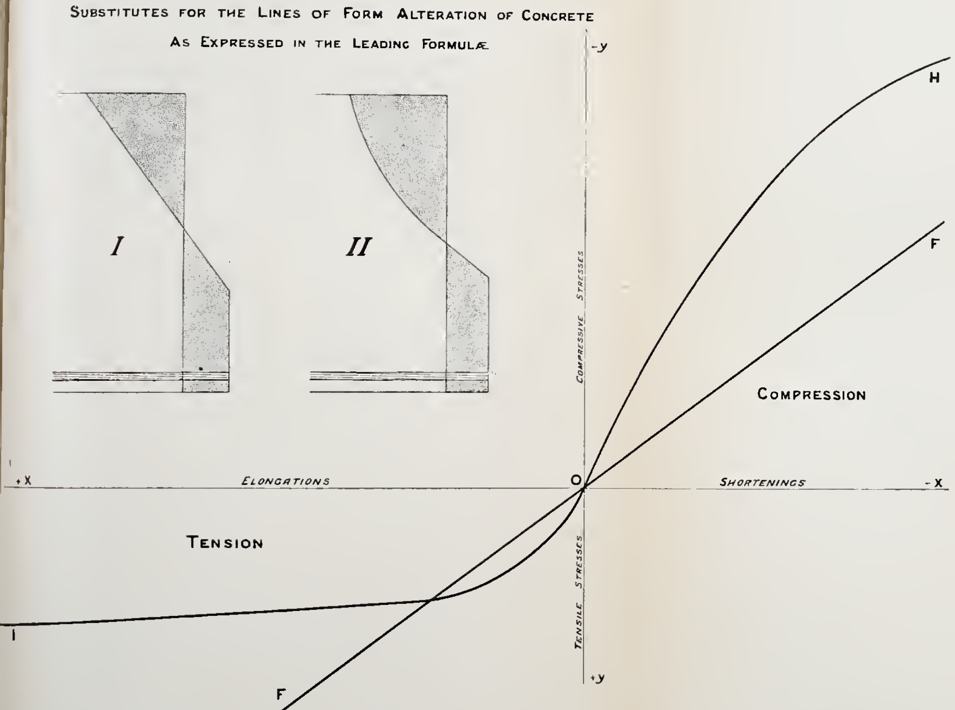

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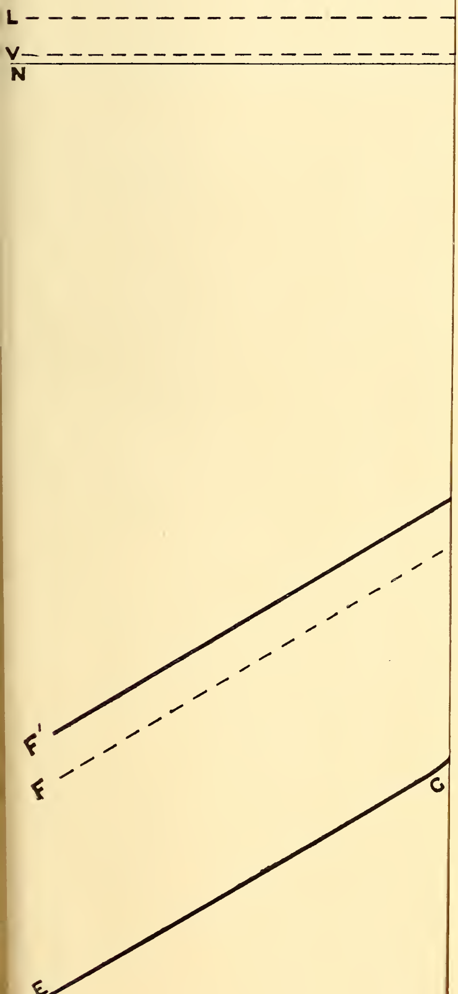

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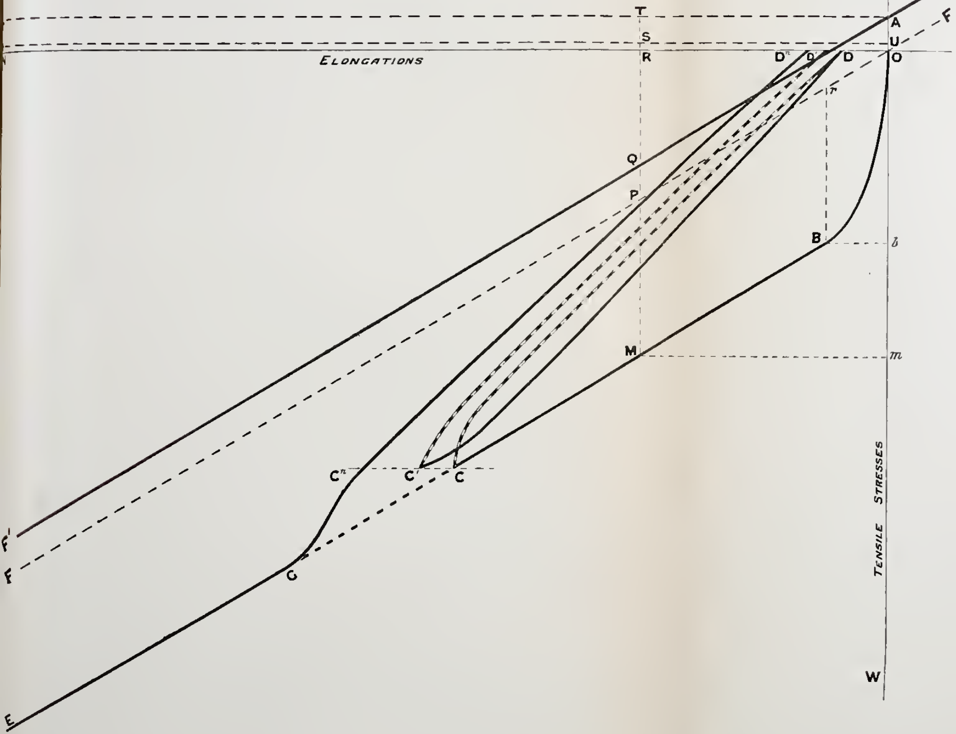

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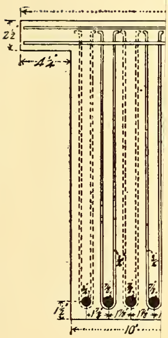

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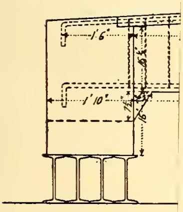
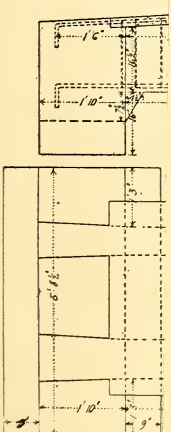
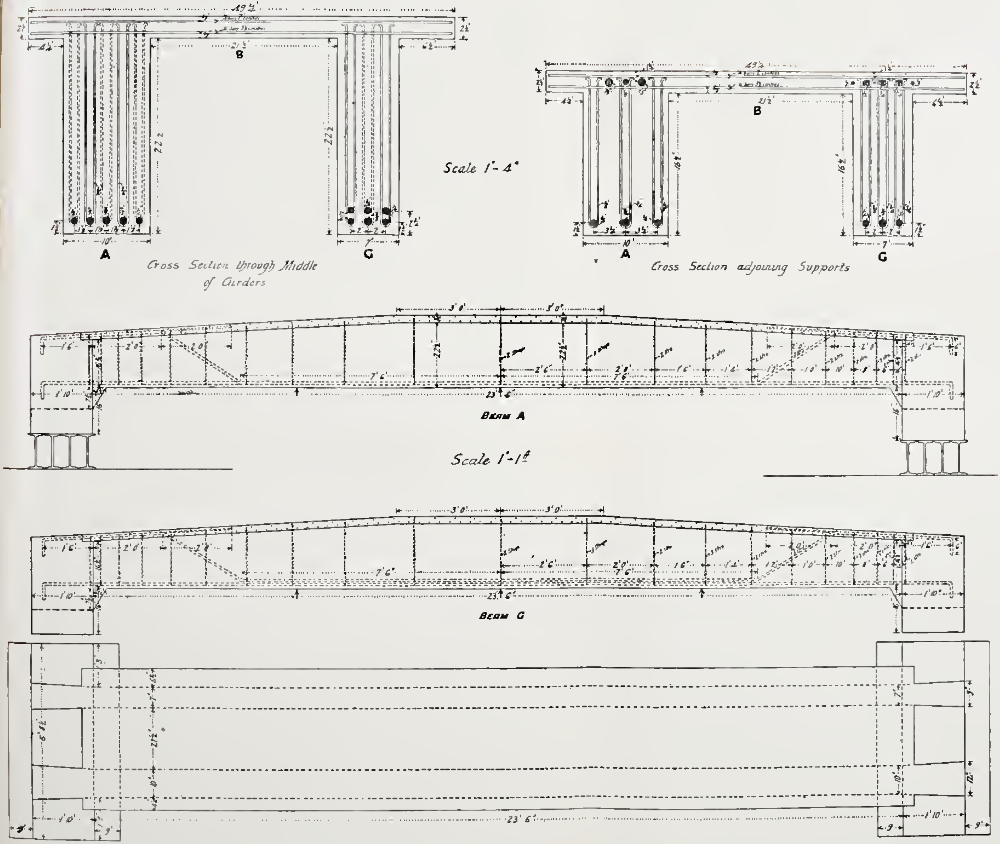


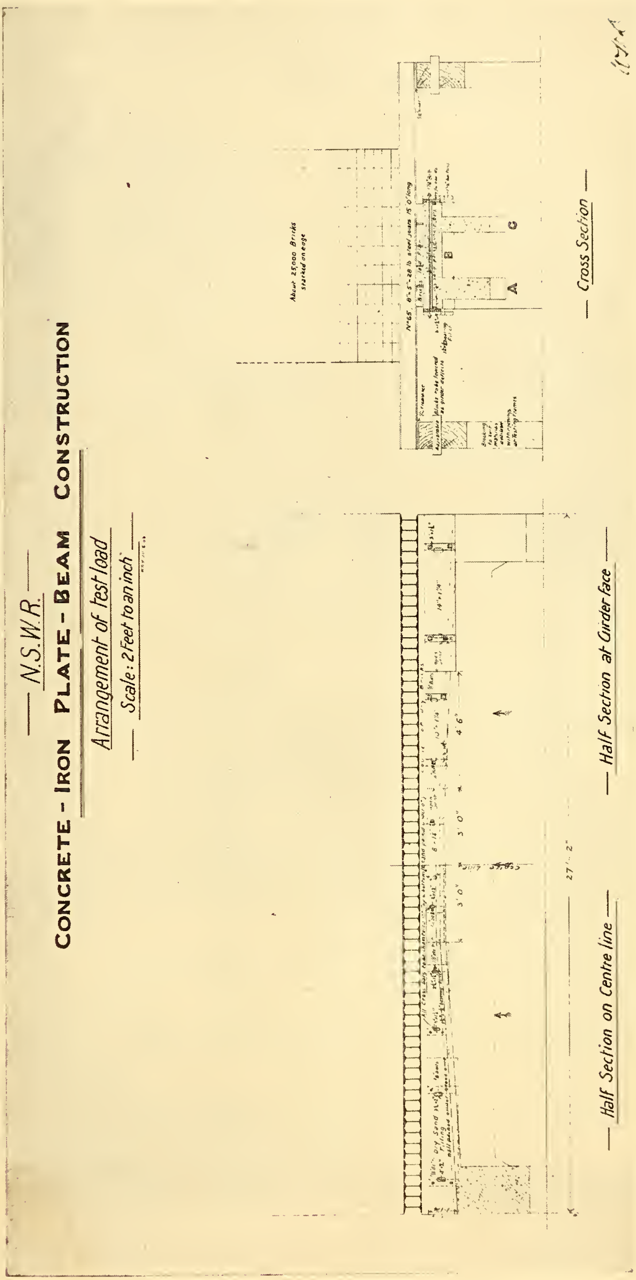


Concrete-Iron Plate-Beam Construction

Built at Newcastle N.S.W. May 1903.

Tested July 1903.

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CONCRETE - IRON PLATE - BEAM CONSTRUCTION
Arrangement of test load
Scale: 2 Feet to an inch
Cross Section
Half Section at Girder face
Half Section on Centre line

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