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OF

NEW SOUTH WALES,

FOR

1893.

INCORPORATED 1881.

VOL. XXVII.

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THE HONORARY SECRETARIES.

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

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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.

NOTICE TO AUTHORS.

The Honorary Secretaries request that authors of papers (to be read before the Royal Society of New South Wales) requiring illustrations by photo-lithography, will, before preparing such drawings, make application to the Assistant Secretary for patterns of the standard sizes of diagrams &c. to suit the Society's Journal.

ERRATA.

Page 200, line 2, after "expression" insert "Neglecting H in comparison with B".

Page 205, Corollary (ii.), line 5,

$$\frac{B^2}{8\pi} - \tfrac{1}{4}\pi\,(B\,H - \tfrac{1}{2}\,H^2)$$

or

$$\frac{(B - H)^2}{8\,\pi}$$

should read

$$\frac{B^2 - H^2}{8\pi} - \frac{1}{4\pi}\,(B\,H - \tfrac{1}{2}\,H^2)$$

or

$$\frac{B^2 - 2\,B\,H}{8\pi}$$

Page 227, line 18 from top, for "points," read "joints."

PUBLICATIONS.

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

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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.

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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 Liége, 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.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.

1892 Professor William Turner Thiselton Dyer, C.M.G., 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.

ANNIVERSARY ADDRESS.

By Prof. W. H. WARREN, M. Inst. C.E., Wh. Sc., M. Am. Soc. C.E.

[*Delivered before the Royal Society of N. S. Wales, May 3, 1893.*]

In appearing before you as President of the Royal Society of New South Wales, on the Seventy-second Anniversary of its existence, it becomes my duty, following the custom established by my predecessors, to address you in the first place on the various matters more closely associated with the work of our Society; I propose afterwards to review briefly the progress of scientific research and discovery in New South Wales, and also the various engineering works which have been executed in connection with our Public Works during the period I have had the honour to occupy the President's Chair.

Notwithstanding the unparalleled depression which has affected more or less every interest in the Colony, it is gratifying to be able to state that the financial position of the Society is most satisfactory. The total receipts for the past year were £1256 9s. 4d.; and the expenditure £1150 11s. 11d.; the amount transferred to the building and investment fund was £84 16s., leaving a balance of £59 13s. up to the 31st of March. The Building and Investment Fund now amounts to £892 16s. 1d., and the Clarke Memorial Fund to £330 16s. 8d., which amounts are invested as fixed deposits in the Union Bank.

The number of members on the roll on the 30th of April, 1892 was four hundred and seventy-eight; thirty-three new members were elected during the past year. The Society has lost one honorary member, and six ordinary members through death; fourteen from resignation, nine from non-payment of subscription, five from failure to take up their membership as per Rule IXa., so that the total number on the roll up to the end of April 1893 is four hundred and seventy-seven. There are in addition to the above, seventeen honorary and two corresponding members.

Obituary.—The following is a list of members lost through death

Honorary Member:

	Elected.	Died.
Owen, Prof. Sir Richard, K.C.B., F.R.S.	1879,	Dec. 18, 1892

Ordinary Members:

Cracknell, E. C., M. Inst. C.E.,	1865,	Jan. 14, 1893
Halliday, Hon. William, M.L.C.,	1891,	Aug. 25, 1892
Harrison, L. M.,	1877,	May, 1892
Hunt, Robert, C.M.G., F.G.S.,	1878,	Sep. 27, 1892
Starkey, J. T.	1881,	Nov. 21, 1892
Tulloh, W. H.	1875,	Sep. 30, 1892

Professor Sir Richard Owen, one of the most distinguished scientific men of this century, died at the age of eighty-eight years. His labours in the departments of zoology and anatomy are of world-wide reputation. He wrote the quarto-volumes of the Catalogue of the Hunterian Museum; the great work with its one hundred and sixty-eight plates on odontology; the anatomy of the vertebrates; the four volumes which contain the memoirs on British fossil reptiles; the twenty-five memoirs on the Dinornis; the five memoirs on the osteology of the marsupials; the essays on the fossil mammals of Australia, and the fossil reptiles of South Africa; and many other valuable works which I have not time to refer to. From 1834 to 1856 he was Hunterian Professor to the Royal College of Surgeons, he was also for a long time Fullerian Professor to the Royal Institution. He wrote a manual of Palæontology, and contributed to Orr's Circle of Sciences and the famous Cyclopædia of Anatomy and Physiology. From 1856 to 1884 he was Superintendent of the Natural History Departments of the British Museum. He served on Royal Commissions, was Chairman of a Jury at Paris Exhibition; President of the British Association in 1857, and the first President of the Microscopical Section. Of the honours conferred upon him the most notable are the Royal (1842) and the Copley (1846) Medals of the

Royal Society, the Légion d' Honneur 1855, the Foreign Associateship of the Institute of France (1859), and the Prussian Ordre pour le Mérite (1851); he was one of the eight zoologists and physiologists who are the foreign members of the American Academy; he was decorated by the King of Italy and the Emperor of Brazil; he was in various ways connected with innumerable scientific societies, and a doctor of several universities.

Mr. EDWARD CHARLES CRACKNELL was born at Rochester, England in 1831, and was educated at Oxford. In 1848 he went to London and devoted himself to scientific pursuits. In November 1855 in company with Mr. Charles Todd, C.M.G. (head of the South Australian Post and Telegraph Departments), Mr. Cracknell came to Adelaide, and took up the duties of Assistant-Superintendent of Telegraphs. In 1858 he was appointed Assistant-Superintendent of Telegraphs in New South Wales, and in 1861 on the retirement of Captain Martindale, he was appointed to the position of Superintendent. He introduced into Australia the duplex and quadruplex systems, and deserves the credit of organising the present service. He took a great interest in the Torpedo or Submarine Miners Corps; he received a commission as lieutenant in 1874, and attained the rank of Lieutenant Colonel Commanding in 1886. He was a member of the Institution of Civil Engineers, and of the Institution of Electrical Engineers of England, and was the first president of the Electric Club of Sydney. He was elected a member of the Council of the Royal Society five times, viz., in 1867, 1868, 1872, 1875, and 1879, and read two papers before the Society:—

July 14, 1869—On the Electric Telegraph between England and India, and how to connect the Australian Colonies with the Telegraphic Systems of Europe and America.

July 20, 1874—On Duplex Telegraphy.

The illness which proved fatal was caused through over exertion during an all day parade; he was buried with military honours.

WM. HALLIDAY, M.L.C., was born in 1827 at Dumfries in Scotland, he arrived in Victoria from England in 1852, and entered the employment of Messrs. Wilson Brothers, then large squatters in Victoria. Subsequently he came to New South Wales, where he purchased the property known as Brookong. Mr. Halliday took a close interest in connection with the affairs of the Colony, and was appointed a member of the Legislative Council in 1885. He held the Commission of the Peace in Victoria and New South Wales, and was a liberal subscriber to local charities.

Robert Hunt, c.m.g., was born in London in 1830, he was appointed chief clerk of the bullion office in the Sydney Mint in July 1853, and served in the melting and refining departments till September 1870; he was then transferred to the Melbourne Mint as superintendent of the bullion office under General Sir Edward Ward, where he remained until June 1876. On the departure of Sir Edward on leave of absence, Mr. Hunt was appointed Acting Deputy Master, which position he held until the end of 1877, when he was appointed Deputy Master of the Mint at Sydney. He was a member of the Council of the Royal Society from 1880 until his death, and was Hon. Treasurer since the year 1885. He was made a c.m.g. in 1888. Mr. Hunt displayed a warm interest in philanthropic matters and was for some years Honorary Treasurer of Prince Alfred Hospital. He was a Trustee and took great interest in the Australian Museum.

It is not usual for the President of this Society to refer to the death of anyone not a member, but I am sure that you will all agree with me in expressing profound regret at the great loss which science has sustained in the death of the Rev. Dr. Woolls. I am aware that a full reference will be made to his life and work in the Proceedings of the Linnean Society of New South Wales, of which he was Vice-President. He passed away at the ripe age of seventy-nine years, and he was working at his favourite science of botany up till within a few days of his death. His practical and extensive knowledge of New South Wales plants was only equalled by the kindness with which he freely imparted his information to others.

Meetings.—During the past year eight general meetings have been held, at which twenty papers were read, viz.—

1892.

May 4. (1) Presidential Address by H. C. Russell, B.A., C.M.G., F.R.S.

June 1. (2) On the Importance and Nature of the Oceanic Languages, by Sidney H. Ray.

,, (3) On certain Geometrical Operations—Part 1, by G. Fleuri.

,, (4) A determination of the Magnetic Elements at the Physical Laboratory, University of Sydney, by C. Coleridge Farr, B.Sc.

,, (5) Analyses of some of the Well, Spring, Mineral, and Artesian Waters of New South Wales, and their probable value for Irrigation and other purposes, by John C. H. Mingaye, F.C.S., M.A.I.M.E.

July 6. (6) Ventilation of Sewers and Drains, by John M. Smail, M. Inst. C.E.

Aug. 3. (7) Flying-Machine Work and the $\frac{1}{6}$ 1 H.P. Steam Motor weighing $3\frac{1}{4}$ lbs, by Lawrence Hargrave.

,, (8) The Venom of the Australian Black Snake *(Pseudechis porphyriacus)*, by C. J. Martin, M.B., B.Sc., and J. McGarvie Smith.

Sep. 7. (9) On the effect which Settlement in Australia has produced upon Indigenous Vegetation, by Alex. G. Hamilton.

Nov. 2. (10) Some Folk-songs and Myths from Samoa. Translated by the Rev. G. Pratt, with introduction and notes by John Fraser, LL.D.

,, (11) Preliminary Note on Limestone occurring near Sydney, by Henry G. Smith, Communicated by J. H. Maiden, F.C.S., F.L.S.

,, (12) Hail Storms, by H. C. Russell, B.A., C.M.G., F.R.S.

Dec. 7. (13) Observations on Shell-heaps and Shell-beds. Significance and importance of the record they afford, by E. J. Statham, A.I.C.E.

Dec. 7. (14) Notes on the recent Cholera Epidemic in Germany, by B. Schwarzbach, M.D. *Würzburg*, L.F.P. & S. *Glas.*

„ (15) On Native Copper Iodide (Marshite) and other Minerals from Broken Hill, New South Wales, by C. W. Marsh. Communicated by Prof. Liversidge, M.A., F.R.S.

„ (16) On the Comet in the Constellation Andromeda, by John Tebbutt, F.R.A.S. &c.

„ (17) Results of Observations of Wolf's Comet (II.) 1891, Swift's Comet (I.) 1892, and Winnecke's Periodical Comet 1892, at Windsor, New South Wales, by John Tebbutt, F.R.A.S.

„ (18) On the Languages of Oceania, by J. Fraser, B.A., LL.D.

„ (19) Notes on some Australian Stone Weapons, by Prof. Liversidge, M.A., F.R.S.

„ (20) Is Mars inhabited? by H. C. Russell, B.A., C.M.G., F.R.S.

Exhibits at General Monthly Meetings.—

1892.

June 1—Photographs of Sun-spots by Mr. H. C. Russell.

July 6—Model of the Cowra Bridge by Mr. Robert Hickson.

„ —Weather Forecasting Diagram by Mr. H. C. Russell.

Aug. 3—A new form of Blowpipe apparatus by Mr. W. M. Hamlet.

„ —Photograph of Winnecke's Comet by Mr. H. C. Russell.

Sept. 7—Coloured drawings illustrating the various modes of burial practised by natives of the Alligator River, Northern Territory, by Mr. C. Hedley.

„ —An improved form of apparatus for demonstrating the nature of a sound-wave by Prof. Anderson Stuart.

Oct. 5—A Steam Engine for a Flying Machine by Mr. Lawrence Hargrave.

„ —Drawings of the Planet Mars.

Nov. 2—Two Extensometers to measure $\frac{1}{10000}$ part of an inch in connection with the testing of the elastic limit and modulus of elasticity of materials by Prof. Warren.

Nov. 2—A series of photographs and micro-photographs illustrating the geology of New South Wales by the Rev. J. Milne Curran.

Dec. 7—Australian Stone Weapons by Prof. Liversidge.

,, —Implements &c. from the South Sea Islands by Mr. C. A. Benbow.

Sectional Meetings.—A very important branch of the work done by the Royal Society consists in the establishment of Sections for the more detailed consideration of scientific and professional subjects. The Sections at present in active operation are as follows:—

Chemical and Geological Section.
Civil and Mechanical Engineering Section.
Medical Section.
Microscopical Section.

The meetings of the Sections are held monthly, and are open to all the members of the Society. The papers, exhibits, and discussions for the last year demonstrate the thorough character of the work undertaken, and the attendances throughout have been most satisfactory. Here the various subjects are dealt with in a more special and technical manner than would be possible at the general meetings. I am personally most interested in the Engineering Section, which has been during the two years of its existence remarkably successful. I hope that during the coming Session the papers and discussions will be equal to those of the past.

Library.—The amount expended upon the Library during the past year was £240 5s. 2d., this included for books and periodicals £128 17s. 1d., binding £73 18s. 1d., and large cedar bookcase £37 10s. Apart from the usual periodicals subscribed to, sixty-two volumes and fourteen parts were purchased at a cost of £42 18s. The Society was unable to obtain any back volumes to complete serial publications, with the exception of Vols. I., II., IV. and V. of the Proceedings of the Royal Colonial Institute, and Vol. I. of the Transactions of the Philosophical Institute of

Victoria. In addition to the usual books bound for the library shelves, one hundred and seventy-five volumes of incomplete sets of American and Continental scientific publications have been placed in cloth covers, thus rendering them available for reference, —three hundred and sixty volumes in all have been thus treated, and it is hoped that the remainder will be completed this year.

Exchanges and Publications.—During the past year we have exchanged our volume with three hundred and ninety-two kindred societies, receiving in return one hundred and seventy-one volumes, seven hundred and thirty-nine parts, seventy-seven pamphlets, fifty-eight reports, thirty-one meteorological charts and diagrams, four hydrographic charts, one photograph, and one engraving,—a total of one thousand and eighty-two publications. Twenty-one societies have been added to the Exchange List as follows:— 1. Académie des Sciences, Cracow. 2. Naturwissenschaftlicher Verein für Steiermark in Graz. 3. Société Géologique de Normandie, Havre. 4. Faculté des Sciences de Marseille. 5. Société des Sciences Naturelles de l'Ouest de la France, Nantes. 6. Wurttembergischer Verein für Handelsgeographie, Stuttgart. 7. Literary and Historical Society, Quebec. 8. Institute of Jamaica, Kingston. 9. Royal Geographical Society of Australasia—N. S. Wales Branch. 10. Royal Geographical Society of Australasia—South Australian Branch. 11. Royal Geographical Society of Australasia—Victorian Branch. 12. Geological Survey of Queensland. 13. Geological Survey of South Australia. 14. Geological Survey of Tasmania. 15. Geological Survey of Western Australia. 16. St. Andrew's University, Scotland. 17. Colonial Museum, Haarlem. 18. United States Artillery School, Fort Monroe, Va. 19. Wisconsin Academy of Sciences, Arts and Letters, Madison. 20. American Institute of Mining Engineers, N.Y. 21. Geological Society of America, Rochester, N.Y.

Clarke Medal.—At the meeting of the Council on the 30th November last, it was resolved that the Clarke Memorial Medal for 1893 be awarded to Prof. Ralph Tate, F.G.S., F.L.S., University, Adelaide, in recognition of his long continued scientific labours, and more particularly of his valuable contributions to the Geology and Palæontology of Great Britain, and the Natural History and Geology of South Australia.

Honorary Member.—At the General Monthly Meeting of the Society held 2nd November last, on the recommendation of the Council, William Huggins, D.C.L., LL.D., Ph.D., F.R.S., 90 Upper Tulse Hill, London, was unanimously elected an Honorary Member of the Society, in recognition of his distinguished scientific researches in astronomical spectroscopy, and more particularly on account of the leading part always taken by him in the development and application of methods of applying the spectroscope to the increase of our knowledge of the composition, condition, and motions of celestial objects.

Original Researches.—In continuation of the practice originated in 1881, to publish yearly a list of subjects peculiar to Australia, the investigation of which would be of great interest and value to the Colony, the Council invited original contributions, and offered its medal together with a grant of £25 for the best original paper on the following subjects, viz. :—

Series XI.—*To be sent in not later than 1st May, 1892.*

No. 37—On the Iron Ore Deposits of New South Wales.

No. 38—On the Effect which Settlement in Australia has produced upon Indigenous Vegetation.

No. 39—On the Coals and Coal Measures of Australasia.

No papers were received on the first subject, No. 37. One paper was received on the last subject, No. 39, but the Council did not consider it of sufficient merit to receive the award. Six papers were received on No. 38, "On the Effect which Settlement in Australia has produced upon Indigenous Vegetation," and at its meeting on the 5th October, 1892, the Council awarded the prize of £25 and the Society's medal to the successful competitor, viz. :—Mr. Alex. G. Hamilton, Public School, Mt. Kembla.

The list of subjects for prizes now offered is :—

Series XII.—*To be sent in not later than 1st May, 1893.*

No. 40—Upon the Weapons, Utensils, and Manufactures of the Aborigines of Australia and Tasmania.

No. 41—On the Effect of the Australian Climate upon the Physical Development of the Australian-born Population.

No. 42—On the Injuries occasioned by Insect Pests upon Introduced Trees.

Series XIII.—*To be sent in not later than 1st May, 1894.*

No. 43—On the Timbers of New South Wales, with special reference to their fitness for use in construction, manufactures, and other similar purposes.

No. 44—On the Raised Sea-beaches and Kitchen Middens on the Coast of New South Wales.

No. 45—On the Aboriginal Rock Carvings and Paintings in New South Wales.

Series XIV.—*To be sent in not later than 1st May, 1895.*

No. 46—On the Silver Ore Deposits of New South Wales.

No. 47—On the physiological action of the poison of any Australian Snake, Spider, or Tick.

No. 48—On the Chemistry of the Australian Gums and Resins.

The competition is in no way confined to members of the Society, nor to residents in Australia, but is open to all without any restriction whatever, excepting that a prize will not be awarded to a member of the Council for the time being; neither will an award be made for a mere compilation, however meritorious in its way. The communication, to be successful, must be either wholly or in part the result of original observation or research on the part of the contributor. The Society is fully sensible that the money value of the Prize will not repay an investigator for the expenditure of his time and labour, but it is hoped that the honour will be regarded as a sufficient inducement and reward. The successful papers will be published in the Society's annual volume. Fifty reprint copies will be furnished to the author free of expense. Competitors are requested to write upon foolscap paper—on one side only. A motto must be used instead of the writer's name, and each paper must be accompanied by a sealed envelope bearing the motto outside, and containing the writer's name and address inside. All communications to be addressed to the Honorary Secretaries.

Abercromby Fund.—It will be remembered that at the December meeting of last Session, a sum of £100 was placed in the hands of our Council by the Hon. Ralph Abercromby, with the object of promoting the study of some phases of Australian weather. Since then a Committee has been appointed consisting of the Hon. Ralph Abercromby, Professor Liversidge, Professor David, and Mr. Russell, to carry out the donor's wishes, and one subject for a prize essay has been chosen and competition invited under the following conditions :—

The distinguished Meteorologist, the Hon. Ralph Abercromby, has given to the Royal Society of New South Wales the sum of £100, which is to be offered as prizes, with the object of bringing about exhaustive studies of certain features of Australian weather. So far only one feature has been selected, and a prize is now offered of £25 for an exhaustive study of our well known "southerly burster." It is understood that no essay which does not deal fully with the following points will be considered :— 1. The motions of the various strata of clouds for some hours preceding, at the time of, and following the "burster." 2. The weather conditions which lead up to and follow the "burster," with weather charts of Australia for the day of and day following it. 3. The general conditions which modify the character of the "burster." 4. The area of the "burster" and its track. 5. Barograph traces shewing the changes of pressure during the "burster." 6. The direction and character of wind preceding it. 7. The relation of "bursters" to rainfall. 8. The essay must not exceed fifty pages of foolscap. 9. The essay must be sent in not later than 31st March, 1894. 10. A photograph of each "burster" described, giving a characteristic view of the *cloud-roll* should if possible be sent with the essay. The essay must embody studies of several "bursters," and must be chiefly the result of original research of the author, but authors are not debarred from availing themselves of any available information published or otherwise on the subject.

Original Scientific Research.—I will now direct your attention to some of the scientific work which has been accomplished in the Colony during the past year, or is still in progress. At the University Biological Laboratory, Prof. Haswell has been chiefly engaged in some investigations on the structure and affinities of some of the lower groups of *Vermes*. These have proved interesting, as they have resulted in the establishment of a more intimate connection than was previously supposed to exist between the classes *Turbellaria* and *Trematoda*. *Temnocephala*, a dweller for the most part on the surface of Australian crayfishes, proves to be almost as much a Rhabdocœle *Turbellarian* as a *Trematode*, and can only arbitrarily be assigned to the one or the other of these two classes; and the same may be said to hold good of *Actinodactylus*, an entirely new type, occurring in the gill-chambers of the Gippsland burrowing crayfish. The detailed account of *Temnocephala* and *Actinodactylus* will appear in the forthcoming Macleay Memorial Volume.

Short papers on various points have been published during the year in the "*Zoologischer Anzeiger*," and the "*Abhandlungen der Naturfordschenden Gesellschaft in Halle.*" Among the "Jottings from the Biological Laboratory," published during the year, are "Notes on the occurrence of a Flagellate Infusorian as an intra-cellular parasite," "On the occurrence of a second species of *Phoronis* in Port Jackson," and "On an Alloiocœle *Turbellarian* inhabiting the underground waters of Canterbury, New Zealand."

Professor Wilson and Dr. Martin, at the University Medical School, have in hand the following papers for the Macleay Memorial Volume:—"On some points in the anatomy of the muzzle of the *Ornithorhynchus*," "On the rod-like tactile organs in the skin of the muzzle of the *Ornithorhynchus*."

Two papers by Professor Wilson are in course of publication in the Transactions of the Intercolonial Medical Congress of Australasia; one "On the development of the central canal of the spinal cord in the lamb," and the other upon "A number of variations in human anatomy." A first contribution to the myology of *Notoryctes*, by the same author, will shortly appear in the Proceedings of the Royal Society of South Australia.

Professor Wilson has recently written a short abstract on the Craniology of the Australian Aborigines, which was appended to Dr. Fraser's account of that race, published by the Government Printer for the Chicago Exhibition.

Professor Threlfall has been engaged in the Physical Laboratory on the following matters, in most of which he has had the assistance of senior students and of Miss F. Martin, to whom he is particularly obliged for most constant assistance :—

Nitrogen.—He has finally proved that this gas cannot be condensed like oxygen by any known kind of electrical discharge. It can, however, be caused to combine with mercury directly, forming a substance which was originally studied by Plantamour, from the action of ammonia on mercuric oxide, as mentioned last year. The mercury nitride is found to be irreversibly dissociable in a peculiar manner. An account of this work was published in the *Philosophical Magazine* for January, 1893.

Sulphur.—A most exhaustive study of the electrical properties of pure sulphur has been made in conjunction with Mr. Brearley and Mr. Allen (Exhibition Scholar of the University of Adelaide). Data were obtained upon the resistance, mode and condition, residual effect of charge and specific inductive capacity for different modifications of pure sulphur. Some of the dielectric properties are so remarkable as to promise to render sulphur of importance in practical electrical work in the near future. An account of the theory and construction of sensitive galvanometers forms a part of the paper. The galvanometer constructed by Prof. Threlfall some years ago is quite successful, and he is enabled to measure currents of the order .— 10^{-12} ampères, and so push the examination of sulphur much further than would otherwise have been possible. It is believed that this investigation is the first thorough and precise examination that has ever been made on the electrical properties of a pure non-metallic substance. This work has been written out, but is not yet published.

Electro-magnetic Mechanisms.—A method has been devised of obtaining complete information as to the electric and magnetic behaviour of one type of such a mechanism during action. From the data obtained, Mr. Pollock has been able to deduce some interesting facts as to the efficiency and sources of loss in such mechanisms, in addition to the work done last year.

Magnetic Traction.—An investigation of the principles of magnetic traction has been just completed from what is believed to be a novel point of view. The predictions of theory have been shown to agree (with one remarkable exception) with experiment, and a new method of calculating the forces between magnetic poles has been reduced to a form suitable for easy computations.

Gravity Meter.—Mr. Pollock's investigations of the secular variations and temperature corrections of the instrument have been sufficiently satisfactory to embolden Professor Threlfall to design, (with the assistance of Mr. Cook), a practical and portable form of instrument, which is in course of construction in the workshop as opportunity offers, and which is about half-way on the road to completion. The accuracy arrived at is about the same as that obtainable by good pendulum experiments.

Professor Liversidge, during the year, has been occupied in arranging the chemistry and metallurgical work in connection with the new course in mining engineering. At the Hobart meeting of the Australasian Association for the Advancement of Science, he read two papers, one "On the presence of Magnetite in certain minerals and rocks," and another "On Iron rust possessing magnetic properties." He also read a paper before this Society "On Native Weapons." He is at present investigating the mode of occurrence and crystallization of gold, in addition to his researches upon the minerals of New South Wales.

Dr. Martin and Mr. J. McGarvie Smith have in the Physiological Laboratory at the University, and at Mr. Smith's private laboratory, Woollahra, demonstrated the nature of, and separated the toxic principles contained in Australian snake venom, and investigated the various conditions which are capable of altering or destroying its virulence. Since then Dr. Martin has been engaged in further chemical research of an interesting nature dealing with the same subject, and also has gone far to answer the question "How does it act?" by means of the most accurate methods of experiment known to modern physiological science. These investigations into the action of snake venom have been greatly assisted by the generous aid of the New South Wales Branch of the British Medical Association in granting £50 to assist in defraying expenses. In addition to the above, during the past year he has been engaged in completing an investigation into some points in the dynamics of the circulation, more especially concerning the pressure in the systemic and pulmonary veins under various conditions.

In the Geological Department at the University of Sydney, in addition to the usual practical work for teaching purposes, a certain amount of research work has been accomplished. Geological Excursions have been held to Euroka Creek, near Penrith, the Pyrmont Sandstone Quarries, and the Bulli Coal Mine; and during the September vacation the Third Year students were taken to Kiama for a fortnight for the purpose of collecting rocks and fossils, and constructing geological maps and sections of the surrounding district. At Euroka Creek conclusive evidence was obtained of the intrusive character of the circular mass of eruptive rock about one-quarter-mile in diameter, which forms the amphi-theatrical depression amongst the Hawkesbury Sandstone Hills, known as Euroka Farm.

At the Bulli Coal Mine some fine specimens of secondarily formed crystals of epsomite were obtained from a dolerite dyke, which had intersected the coal measures. At the Pyrmont Quarry it was ascertained that between the bed of sandstone known to the quarrymen as the "bottom block" and the top of a bed of shale immediately underlying it, there occurred a well-marked layer of barytes, exhibiting on its surfaces a number of large well-formed crystals; the layer was about half-an-inch in thickness. Mr. Smith, the Mineralogist to the Technological Museum, had a short time previous recorded a somewhat similar occurrence of barytes in Hawkesbury Sandstone, near Cook's River.

During the Geological Examination of the Kiama District, a sketch map and sections were prepared showing the relation of the highly interesting series of volcanic rocks of that neighbourhood to the Bulli coal-measures, and also to the associated marine strata. The details of this examination, when elaborated, are intended to form the subject of a paper for the Society during this year. A brief summary, however, of the conclusions already deduced may be given here. Towards the close of that portion of the Permo-Carboniferous period, when a shallow ocean extended from Ulladulla on the south, to Port Stephens on the north, and inland as far as Mittagong, Rydal, and Somerton, near Gunnedah, volcanic eruptions of a violent paroxysmal character broke out in the neighbourhood of Kiama. The approach of the lavas, which flowed from the centres of these eruptions, is heralded by the presence in the uppermost of the marine Permo-Carboniferous mudstones of large lumps of lava and isolated crystals of black augite, bedded side by side with marine shells.

Solid sheets of basic lava succeed, the highly brecciated character of which considered in conjunction with the presence of numerous and very large amygdaloids, implies that the lava flowed into the ocean, where the steam, generated by the contact of the molten rock with the sea water, occasioned a series of violent explosions, which completely shattered in places the already partially cooled crust in the upper portion of the lava flow. South of Kiama there is evidence that there were three lava flows of this kind, probably almost synchronous, each newer flow over-riding its predecessor, and each having a thickness of from thirteen to twenty feet. The phase of the eruption then changed, and volcanic dusts alone were outpoured. These were blown high into the air, so that when they settled down they covered a considerable area with a layer of red tuff twenty feet deep. In the next phase of the same eruption, or at the commencement of a second eruption, which must have succeeded the first after only a short interval of time, sheets of lava having a total thickness of two hundred and sixty feet rolled down and completely buried the first bed of red tuffs. It is in this massive sheet of basalt that the Kiama Blowhole is situated. A second bed of red tuff was then formed having a thickness of from one hundred to two hundred feet. This bed can be traced from the Cambewarra Range, above Nowra, on the south, to a mile beyond Wollongong on the north, a distance of about fifty miles; and these two points are by no means the extreme limits of the tuff bed. The eruption, therefore, which produced it was probably on a far grander scale than the celebrated eruption of Tarawera, in New Zealand, in 1886.

Evidence collected last year points clearly to the fact that all the above described members of the volcanic series were erupted before the formation of any portion of the Bulli coal-measures. There followed an immense outflow of lava, which formed the thickest sheet as yet known in New South Wales, its thickness being about six hundred feet. This lava (an andesitic dolerite), appears to have been also older than the Bulli coal-measures. The relation of the still newer lavas above the andesitic dolerite to the Bulli coal-measures has not yet been worked out; but the evidence proves that after the Bulli coal-measures had formed above the volcanic series, both coal-measures and lavas were intersected by doleritic dykes, which have either coked or destroyed large areas of coal in the Illawarra coal-field.

At a still later period, the Illawarra coal-field was further disrupted and intersected by a newer set of dykes, some of which, as pointed out by Mr. Evans, the manager of the Bulli Coal Mine, have cut their way completely through the older dykes. Microscopic sections of the dykes, prepared in the Geological Laboratory, show that the dolerites of which they are composed contain sanidine, and they may therefore be possibly related to the mass of intrusive syenite near Mittagong, which contains a similar felspar.

Several interesting sections of glass slags from the Camperdown Glass-works, Sydney, have lately been prepared by the students. These sections show some well-developed microlites arranged in sheaf-like or fibrous radial aggregates, closely resembling similar structures in lavas.

An examination of a collection of fossils, obtained some years ago in the Vegetable Creek District of New England, has led to the discovery in them of the shell *Productus*, so that a very large area occupied by rocks containing these fossils will now need to be coloured on the geological map as Carboniferous instead of Silurian, as coloured at present. This alteration will harmonise the geological maps of New South Wales and Queensland along the valley of the Dumaresq River, where previously a great discrepancy existed.

A recent examination in company with Mr. E. F. Pittman, the Government Geologist, of the country in the neighbourhood of Rydal, has led to the discovery that *Lepidodendron* occurs in situ in the Devonian rocks associated with *Spirifera disjuncta*, a shell of undoubted Devonian age. Mr. Clunies Ross, B.Sc., of Bathurst, has recently made a similar discovery nearer Bathurst, and thus the question as to whether *Lepidodendron* in New South Wales descends into Devonian strata or not may be considered as definitely settled. These discoveries confirm the views as to the geological age of the above plant in New South Wales, held by the Rev. W. B. Clarke, F.R.S., and the late Government Geologist, Mr. C. S. Wilkinson, F.G.S.

Astronomical Photography.—The work accomplished at the Observatory under Mr. H. C. Russell, Astronomer of New South Wales, may be briefly summarised as follows :—The past year has been cloudy and unfavourable, so much so that only one night in five has been fine enough for photography, and many of these only fine for one or two hours. By securing photographs upon every available night, four hundred and seventy have been obtained. The star camera has been almost confined to the catalogue plates of part of the survey of the whole heavens; but in December an important experiment was made, it was shown that a photograph of a comet with surrounding stars can be taken in five (5) minutes and thus is secured a permanent record of the comet's position with reference to surrounding stars, which can be measured with extreme accuracy. In this way the comet's position is determined from each star with as much accuracy as it could be by the old method in an hour, even when large telescopes are used. One photograph, then, taken in five minutes will fix the comet's place with as much accuracy as can be attained by many hours' work with a large telescope; this is obviously an important adaptation of photography, for the saving of time, and for the possibility it affords of fixing a comet's position in cloudy weather.

One remarkable cluster of stars, 3315 in Herschel's list, has been subjected to a searching examination with the star camera to see if any nebulous matter could be found amongst the stars, but none has been found by long exposures of eight hours, and with the most sensitive plates we have ever used. The stars stand outlined on a background of space. Herschel called this object "a glorious cluster of immense magnitude, the most brilliant object of the kind I have ever seen; there are at least two hundred stars in it." But its magnificence when photographed under the searching power of the large star camera may be judged from the fact that the camera records more than ten times as many stars as Herschel said. Meridian observations and double star work have also been carried out during the year, and a number of new double stars discovered.

Meteorology.—The daily weather charts published at the Observatory for four and a half years, have been submitted to careful examination, and some very important facts brought to light.

Mr. Russell has published the results in an elaborate paper before the Royal Meteorological Society. It is there shown that Australian weather, south of Latitude 20°, is the product of a regular series of anticyclones moving rapidly (four hundred miles per day) from west to east. These anticyclones travel across Australia in from six to seven days, generally seven, and since each part of them is marked by its own weather, we have the well known fact of recurring weather in seven day periods explained, and the moon is once more relieved of the responsibility of causing it. It is also shown that the persistent dry weather for many months past is caused by the character of the cyclones, which by their modifications bring dry or wet weather, also that this investigation explains why the best meteorological atlases show a fixed anticyclone on Western Australia, which does not exist; altogether it is perhaps the most important paper that has yet been published upon the meteorology of Australia.

The question—whence the *anticyclones* and their *peculiarities* and *latitudes?* conditions which *control our weather*, is now being investigated with good prospect. The question is of the greatest importance, and is receiving the attention which it deserves.

During the year the Observatory has published a map of the Colony, showing isotherms of mean temperature for each degree. The following have also been published—General Meteorological Results 1880 to 1884 inclusive, the same for 1890. Rain and River Results for 1891. A new edition of the Physical Geography and Climate of New South Wales. Results of the Transit of Venus 1874. Results of observations with the Meridian Instrument for three years. Results of Double Star Measures and the Daily Weather Charts. Four thousand four hundred and twenty copies of the books and pamphlets published have been distributed to various institutions and observatories, and more than one thousand additions to the library have been received in exchange.

The current-paper service has yielded some interesting facts during the year. On January 31, 1892, the captain of the S.S. *Port Adelaide* when in Latitude 46° 4′ south and Longitude 103°

14′ east, threw over a bottle containing one of these papers, and on March 3, 1893, it was picked up on the east coast of New Zealand in Latitude 44° 0′, Longitude 172° 20′ east, having travelled, even if it took the shortest road, three thousand six hundred miles, or at the rate of nine miles per day. Another thrown over by the captain of the S.S. *Port Caroline*, on August 14, 1892, in Latitude 44° 6′ south and Longitude 105° 46′ east, was picked up at sea in Latitude 41° 31′ south and Longitude 130° 32′ east, having made one thousand two hundred miles at the rate of six miles per day.

Mr. J. H. Maiden, F.C.S., F.L.S., Curator of the Technological Museum, has prepared the first part of a valuable Bibliography of Australian Botany, in which he has made the very scattered literature of this subject available for ready reference. He read a paper at the Hobart meeting of the Australasian Association for the Advancement of Science "On the exudations from Australian species of *Pittosporum*." He also read the following papers: "On *Panax* gum," before the Linnean Society of N. S. Wales; and "Some of the pale Hardwoods of New South Wales," before the Sydney Architectural Association. He prepared a report "On the Vegetable Exudations collected by the Elder Exploring Expedition," for the Royal Society of South Australia, in which it is shown that the indurated sap of the Dogwood (*Myoporum platycarpum*) is identical with the manna of commerce.

Mr. W. W. Froggatt, of the Technological Museum, has prepared the following papers during 1892 :—

(1) "Notes on Australian *Cynipidæ*, with descriptions of several new species," Part 1.—Proc. Linn. Soc. N. S. Wales, Vol. VII. (Ser. 2). March 30, 1892.

(2) "Catalogue of the described *Hymenoptera* of Australia," Part 2. —Proc. Linn. Soc. N. S. Wales, Vol. VII. (Ser. 2). May 25, 1892.

(3) "Gall-making *Buprestidæ*."—Proc. Linn. Soc. N. S. Wales, Vol. VII. (Ser. 2). 1892.

(4) "Notes on the Family *Brachyscelidæ*, with some account of their parasites, and descriptions of new species."—Proc. Linn. Soc. N. S. Wales, Vol. VII (Ser. 2), September 21, 1892.

(5) "*Hymenoptera.*" Elder Exploring Expedition, Report on Collection.—Trans. Royal Society of South Australia. 1892.

The various papers written by the members of the staff of the Australian Museum are as follows :—

J. Douglas Ogilby.

(1) "Description of three new Australian Lizards."—Records Australian Museum, Vol. II., No. 1.

(2) "On some undescribed Reptiles and Fishes from Australia." Records Australian Museum, Vol. II., No. 2.

C. Hedley, F.L.S.

"On the structure and affinities of *Panda atomata*, Gray." Records Australian Museum, Vol. II, No. 2.

John Brazier, C.M.Z.S., F.L.S.

"Catalogue of the Marine Shells of Australia and Tasmania. *Cephalopoda* and *Pteropoda.*" Australian Museum Catalogue, No. 15. 1892.

A. J. North, F.L.S.

(1) "Supplement to the Descriptive Catalogue of Nests and Eggs of Birds found breeding in Australia and Tasmania." Records Australian Museum, Vol. II. Part 1. April, 1892.

(2) "Additions to the Avifaunas of Tasmania, and Norfolk and Lord Howe Islands."—Records Australian Museum, Vol. II., Part 3.

(3) "Notes on the nidification of *Manucodia comrii*, Sclater." (Comrie's manucode).—Records Australian Museum, Vol. II., Part 2.

Metals and Minerals.—I am indebted to the Deputy Master of the Mint for the following interesting data :—The estimated production of gold in the Colony of New South Wales during the year 1892 was not marked by any increase as compared with the figures for 1891, being 147,263 ounces of the value of £534,352, as against 153,336 ounces of the value of £558,306; but the output has been fairly well maintained. The weight of gold received at the Sydney Branch of the Royal Mint in the year 1892 was 785,208 ounces, the value of which was determined at £2,780,829. To this large sum Queensland contributed £2,015,549 and New Zealand £223,937. Of the total weight ninety per cent. was in the form of bullion, six and one-third per cent consisted of retorted gold, and three and two-thirds of alluvial. It may be of interest to compare these proportions with those of the year 1873, when the bullion was only twenty-seven per cent. while that of retorted gold was twenty-nine per cent., and of alluvial no less than forty-four per cent. The weight of alluvial coined in 1873 was 189,758 ounces, and in 1892 only 28,711 ounces. During the last twenty years the percentage of alluvial gold has also steadily diminished, and this must be attributed to the rich alluvial fields having gradually been worked out to a great extent, but principally to the advancement in the methods of treating quartz and other ores which science has since introduced.

The annual report of the Under Secretary for Mines furnishes much valuable information which the time at my disposal for this address will only allow me to refer to very briefly. The number of applications to lease Crown lands for mining purposes during 1892, including applications for special gold leases was one thousand and sixty-eight, being one thousand one hundred and forty-two less than the number in 1891. The total value of the metals and minerals won during the year 1892 was £5,305,815, being a decrease of £1,348,195 on the value won during the year 1891. The value of the gold won, however, is the greatest on record, viz. £569,178. This value represents the gold received by the mint and that exported. The decrease in the value of the metals and minerals for 1892 occurs mainly in silver and silver-lead ores, which together amount to £1,141,753, and this I consider is accounted for by the disastrous strike in Broken Hill. The total value of minerals produced in the Colony up to the end of 1892 is £98,842,779.

Diamond Drills.—The demand for diamond drills was not nearly so great in 1892 as in previous years, yet the aggregate depth bored was four thousand one hundred and thirty-nine feet at a cost of 16s. $10\frac{7}{16}$d. per foot.

The Government Geologist, Mr. Pittman, has furnished a valuable report on the geological occurrence of the Broken Hill ore-deposits, in which he shows the geological formation and origin of the Broken Hill lode and the saddle reefs of Bendigo appear to be analogous in several important respects, and that if this analogy hold, the eastern and western legs of the Broken Hill lode may be expected to thin out in depth. Also that there is a possibility of other similarly shaped lodes being found more or less vertically underneath the Broken Hill lode, which might be tested by putting down diamond drill bores through the cap of what is locally known as the "intrusion." Another report of Mr. Pittman's gives some interesting facts and figures on the mode of manufacture and quality of coke made in New South Wales, which shows:—1. That there is room for material improvement in the manufacture of colonial coke, both in the direction of reducing the ash, and increasing the density or capacity for resisting pressure, and these improvements can best be achieved by a more perfect system of coal washing, and by the use of a more modern type of coke oven. 2. That some of the cokes at present manufactured in New South Wales are nearly equal (as regards ash), to the average of the imported cokes in use at the Broken Hill smelting works. 3. That several of the cokes at present manufactured in New South Wales are superior (as regards percentage of ash), to some of the imported cokes in use at Broken Hill. 4. That in regard to strength or capacity for resisting pressure, the cokes manufactured in New South Wales are superior to some of the imported cokes at present in use at Broken Hill.

I consider that the high crushing resistance of the New South Wales cokes (as shown by my experiments in the University testing machine), justifies the more extended use of coke-concrete in the floors of bridges and buildings where strength and lightness combined are necessary. The crushing resistance of the New South Wales cokes varied from one thousand one hundred and twelve to three thousand one hundred and twenty-five pounds per square inch, while the greatest strength of the imported cokes tested was only seven hundred and sixty-five pounds per square inch.

Mr. J. B. Jaquet, A.R.S.M., F.G.S., has during the past year completed his geological survey of Broken Hill, and has furnished reports upon the Nuntherungie silver-field, the platinum deposits near Broken Hill, and the opal-fields at White Cliffs near Wilcannia.

Mr. Robert Etheridge, Jun., has done a large amount of useful work in determinative and descriptive palæontology during the year, and has published another valuable memoir on the carboniferous and permo-carboniferous invertebrata of New South Wales. Mr. Etheridge has written about twenty papers this year for the Records of the Geological Survey, the Linnean Society, and other societies, the titles of which would occupy more space than I can afford for this address.

Mr. C. W. Marsh of Broken Hill has discovered a new mineral having a definite crystalline form, and consisting of iodide of copper. Professor Liversidge has given to this mineral the name "Marshite" in honour of the discoverer.

Appointment of Metallurgist.—In June, 1886, it was decided that efforts should be made to secure the services of a thoroughly competent metallurgist, to take charge of the metallurgical works to be established on a suitable site in Sydney. Advertisements were published, and inquiries instituted in Europe and America, which resulted in a number of applications. A Board was appointed to make a selection, consisting of Mr. Cosmo Newbery, C.M.G., of Melbourne, Professors Liversidge and David, Dr.

Leibius, Mr. Pittman, and Mr. Harrie Wood. The Board appointed Mr. James Taylor, who has arrived in New South Wales and commenced his duties. The Board also advised that on account of the costliness of erecting smelting works and carrying on smelting operations for the purpose of satisfactorily testing bulk samples of ores, the Government should not in the first instance erect such works, but should erect suitable crushing and concentrating apparatus, sampling-floors, and appliances for the extraction of gold, silver, and other metals by processes other than smelting, and that persons duly authorised be allowed to see the working of any process he may use in the extraction of metals from ores and the separation of metals so extracted.

School of Mines.—The necessity for the establishment of a complete School of Mines has long been recognised by those who realize the enormous value of our mineral resources, and the failure of so much mining enterprise for want of sufficient technical knowledge. The fact that up to the end of 1892 the total value of metals and minerals won nearly reached one hundred millions sterling speaks for itself. A complete course in mining engineering was contemplated by the Senate of the University in 1883, when the engineering department was established, and mining engineering has always been associated with civil and mechanical engineering in the certificates and degrees offered by the University, as may be seen by referring to the Calendars since 1883. The necessity for a mining school at the University has always been warmly advocated by Professor Liversidge. The Senate was, however, unable to provide for the necessary teaching until the year 1892, when lectureships were founded in mining and metallurgy. This year a demonstrator has been appointed in the department of geology chiefly for mineralogy and petrology. Hence we have now a complete School of Mines established at the University; and it should be noted that the extra expenditure incurred, in addition to that of the teaching staff which already existed, was only about £950 a year. If a distinct School of Mines had been established independent of the University, of equal efficiency, the annual cost could not have been less than £7,000, while there would have been the initial cost of buildings, for lecture rooms laboratories and also the cost of apparatus and appliances, all of which existed at the University. Taking the University mining school in conjunction with the metallurgical works proposed to be established by Government, in which students may obtain valuable practical knowledge under able supervision, it is clear that there is now no longer any necessity for students to leave the Colony in order to qualify themselves as mining engineers.

Considering our School of Mines as the training ground for our future mining engineers, I think it must be conceded that the advantages derived by our students in studying the theory and practice of mining, under the special conditions and circumstances which are peculiar to this Colony, should render them better able to cope with the difficulties in mining work which present themselves in New South Wales, than mining engineers trained in other countries where these conditions and circumstances are necessarily less perfectly realised. The same argument applies with equal force to other branches of engineering, and should secure a preference for Australian trained engineers for Australian work. In regard to the nature and extent of the instruction undertaken by the University Mining School and at the Sydney Technical College, there need not be any overlapping, as the instruction provided at the Technical College, Sydney, and at the various mining centres is of great importance, and should meet the wants of those engaged in mining pursuits, and those who from deficiency in preliminary scientific training, means, and other causes, are unable to devote the time necessary to obtain a degree in mining engineering, and I fully concur with the report recently issued by the Board appointed to consider the subject in connection with the Department of Mines, "that special facilities in the shape of bursaries be provided for successful students of the Technical College, in order to enable them to complete their education by graduating in mining engineering at the University."

It will not be out of place for me to repeat here what I stated in my address on Engineering Education, delivered at the meetings of the Engineering Section of the Australasian Association for the Advancement of Science, held in Melbourne in 1890:—"The function of the Technical Colleges (such as those in Sydney and Melbourne), is to deal with the technical education of artisans, and for the Universities to deal with the professions. Both are equally important, and each should be encouraged by Government and other endowments to enable it to do its special work efficiently, and the two should be united in such a manner that they will work harmoniously together." During the time which has elapsed since delivering this address, I have become more than ever convinced of the truth of the words quoted, and I consider that the recognition of the proper functions of the Technical College and the University of Sydney, both in mining and in other branches of engineering, would be a great advantage to both institutions, and would result in a very large saving in expenditure.

The experience of the numerous engineering schools in America shows that graduates in mining engineering as a rule find profitable employment more readily than those in other branches of engineering, and it appears to me in these days of keen competition in every profession, and the evils of overcrowding which become more apparent in times of depression, that mining engineering in New South Wales offers a fair field for remunerative work in the future, which should not be lost sight of.

Department of Agriculture.—The pathologist, Dr. N. A. Cobb, has commenced a systematic enquiry into the nomenclature of wheat. He has collected all the wheats cultivated in Australia, and has grown them side by side in experimental plots, and has devised a scheme of describing and illustrating them all for reference purposes. Full notes have been made of the comparative value of each for resisting rust and for milling purposes. He has also investigated all kinds of plant diseases affecting fruit trees of all kinds, and has published the results of these investigations. He has devoted especial attention to the subject of "Take-all" in wheat, and his original investigations have been published in the *Agricultural Gazette* issued by the department. In order to investigate the life-history of worms in sheep, he has commenced work in a small laboratory fitted up near Moss Vale by the Stock Department. His scheme of operation consists in examining the fodder plants for their microscopic fauna, and comparing the same with the larval stages of worms parasitical in sheep, an entirely new line of work, from which interesting and important results have already been obtained which will be published in due time. Dr. Cobb has determined that the losses in crops throughout New South Wales due to plant diseases, average annually no less than a quarter of a million sterling, from which can be gathered the value of the work being undertaken by this branch of the department.

The chemist of the department, Mr. F. B. Guthrie, has been engaged upon a systematic examination of many of the typical soils of the Colony, of which he has done seventy. He has made a complete examination of all the fertilisers used in New South Wales, with a view to having them valued for commercial purposes on a fixed basis. He has examined a large number of milks in order to arrive at a fair standard for adoption by the different factories and dairymen's associations throughout the Colony. He has determined the feeding value of a number of samples of ensilage and other foods used for cattle, also the gluten percentage of a number of wheats noted for their rust-resistant qualities, but not appreciated by the millers. He has also conducted a series of original investigations upon the Darling Pea, *Swainsona galegifolia*, with a view to determining, if possible, the causes of the evil effects produced in sheep, horses, and cattle, which have taken to this food and have become indigo eaters, as they are called.

The botanist of the department, Mr. F. Turner, has published an illustrated work on the "Forage Plants of Australia," the first Australian work dealing with that important subject, and in the columns of the *Agricultural Gazette*, descriptions and illustrations of thirty-seven of the principal Australian grasses. A series of illustrated articles on new commercial crops has also been published, and has done good in directing attention to new industries suitable for our farming operations. The botanist has initiated a scheme of experiments with the principal native grasses of Australia, to be grown side by side under equal conditions, with many of the best exotic grasses that have been introduced into this Colony.

In the Entomological Department, Mr. A. Sidney Olliff has made a most valuable collection of noxious and beneficial insects. During the past year about three hundred different insects have been bred in the laboratory, and many of them are now preserved in their several stages for future display. Apart from the species bred, the additions to the collection have been considerable, amounting to not less than the following estimate :—Coleoptera three thousand two hundred; Lepidoptera, nine hundred and thirty; Orthoptera, fifty-nine; Neuroptera, forty-five; Hymenoptera, one thousand three hundred and seventy-five; Diptera, four hundred and twenty-five; Hemiptera and Homoptera, nine hundred; unmounted specimens in spirits of wine, about one thousand three hundred; and various microscopic preparations. A considerable number of notes and papers dealing with the life-histories and habits of various injurious and beneficial insects, have been published in the *Agricultural Gazette of New South Wales* for 1893, of which the following is a summary :—Woolly Aphis or American Blight *(Schizoneura lanigera)*; Pear-tree Slug *(Selandria cerasi)*; Salt-bush Scale *(Pulvinaria maskelli)*; Crickets *(Gryllus servillei)* injuring fruit-trees; Bronzy Orange Bug *(Oncoscelis sulciventris)*; Cherry-tree Borer *(Cryptophasa unipunctata)*; Introduction of the Fig Insect *(Blastophaga psenes)* into Australia; Gayton's Bee-disease at Lismore; Walking-stick Insect *(Acrophylla tessellata)* destroying Forest-trees; Orange-stem Borer *(Uracanthus cryptophagus)*; Mussel Scale *(Mytilaspis pomorum)*; Pernicious Scale *(Aspidiotus perniciosus)* on Pear; Greedy Scale *(Aspidiotus rapax)* on Pear and Apple; Banded Pumpkin Beetle *(Aulacophora hilaris)*; Two-spotted Monolepta *(M. rosea*, Blk.); Potato Moth (*Lita solanella)* destroying tobacco;

Migratory Locust *(Acrydium migratorium).* The Codling Moth; its life-history and habits (being a revised and enlarged edition of a paper previously published in the *Agricultural Gazette).*

Public Works: Railway Progress.—Nothing is so intimately connected with the commercial, industrial, and social life of the world as the great railway systems that run like arteries through all lands settled by progressive populations. One great feature of the railways has been the consistent and steady improvement that has been made in regard to the spreading out in the first place of the iron ways, and then internally in the improvement of the permanent way, the bettering of the rolling stock, and the methods taken to ensure the safe working of the traffic, and to preserve from any danger the many millions of passengers who are carried annually.

The earliest and latest railway appliances show wonderful changes in a comparatively short period. Contrast the young giant invented by Stephenson with the latest powerful engines running on the railways of our own Colony; the light iron rails resting on stone blocks, with the substantial road of to-day; the open four-wheeled coaches of the Liverpool and Manchester Railway of 1830, with the latest Pullman Cars; the earliest goods waggons, with the most modern waggons of to-day; the very primitive signals of early days, with the complete system of signals and interlocking now in use. To attempt to give a history of the enormous development that has taken place would occupy too much time, and I shall therefore content myself by dealing with the improvements that have been made within the last few years in our local railway world.

Probably the work of the greatest magnitude, and one that therefore most calls for attention, has been the quadruplication of the suburban line between Redfern and Homebush, which has only been opened as a completed work during the last few months. Yearly seventeen millions of passenger journeys are made over our suburban lines, the greater portion being made between Homebush and Sydney; and when it is remembered that the single pair of rails had formerly to bear the traffic out of Sydney not only for the local suburban stations, with the necessarily frequent-stopping trains, but also the through traffic to the south, west, and north of the Colony, as well as the goods to and from Sydney, it can be seen how urgently a quadruplication of the road was required.

Until the quadruplication was inaugurated and carried out by the Commissioners, four lines only existed between Redfern station and Illawarra junction, a distance of one mile thirty-eight chains; two being for the main suburban, and two for the Illawarra line. The Commissioners having apparently recognised that the lines as they then existed were inadequate to the requirements of the business done, decided to carry the four roads on to Homebush. I have ascertained that the first contract was let on the 30th October, 1890, and the whole work was completed and opened for traffic on the 1st July, 1892. Owing to the limited area available at the various stations, and to the extremely valuable properties adjoining the same, it was found advisable to reconstruct the platforms and station buildings to a very great extent, and advantage was taken of the opportunity to design these upon the most modern principles, introducing the "barrier" system for passengers, whereby there is only one means of ingress and egress to the platforms at each station, thus enabling a thorough check to be kept upon the tickets.

The works in connection with the quadruplication were very heavy, and comprised a number of bridges and viaducts. For bridges carrying vehicular traffic over the railway, the design consists generally of wrought iron girders and jack arches, differing according to the nature of the approaches. In several cases cast iron girders have been used in the construction of these road bridges, which were made in the Colony, and contributed very materially in expediting the completion of the work.

The permanent way received great attention, owing to the heavy and increasing traffic, and consists of eighty pounds bull-headed rails, with forty-two pounds cast iron chairs on ironbark sleepers nine feet by ten inches by five inches; the bottom ballast is sandstone four inches gauge nine inches thick, and the top ballast is bluestone two and a half inches gauge laid to a depth of six inches under the sleepers and brought up to two inches above.

An outsider is unaware of the great economy in what is termed "cutting out" a grade; but as the strength of a chain is measured by its weakest link, so in like manner the economical working of a length of railway is determined by its steepest grades. For instance, taking the line from Singleton to Murrurundi, on account of the existence of grades of one in thirty-three and one in forty-four the load of an ordinary engine was formerly limited to twenty-one waggons, but since the grades have been reduced to one in seventy the load has, I am informed, risen to thirty-eight waggons. I have been favoured with the statement of a week's working between these points, which shows an estimated saving in the train miles run at the rate of twenty-seven thousand four hundred and four miles per annum between the points mentioned, as a practical result of the improvement of the grades.

Considerable attention has been paid to the improvement of grades and curves in other places. Those that have been carried out on the Southern line, between Granville and Picton, have been reduced from one in sixty-six to one in one hundred; on the Western line, between Dubbo and Minore, the grades have been reduced from one in fifty-five to one in seventy. Between Lawson and Wentworth Falls, about half-a-mile of one in thirty-three has been cut out and a grade of one in seventy-three substituted. In many places where eight chain reverse curves occurred on the Blue Mountains, these have been improved by making extensive deviations with transition curves. To enable the traffic to be worked economically and expeditiously, the Lapstone Hill Zig-Zag has also been cut out by a deviation which admits of heavier train loads, and also saves the time which formerly was required by the stops on the Zig-Zag. The most important part of this undertaking is a tunnel, which is thirty-two chains long. The permanent way consists of eighty pound T rails, laid as already described.

The safe working of a railway intimately concerns all travellers, and few probably have observed the extent of the safety appliances at present in use on our lines, or the vast improvements that have been made in this direction during the last few years. To the uninitiated passenger the sounding of the engine whistle, the movement of a signal, or the varying coloured lights exhibited by night, seem to embrace all that apparently is necessary to enable the train, with its living freight, to travel over the rails in safety.

The interlocking of points and signals, which provides for the economical and safe working of station yards, junctions, and sidings, has been largely extended, at the present time being in use at about three hundred places, or fifty-five per cent. of the total number. By this system the points and signals at stations and junctions are manipulated either from an elevated signal-box, lever frame fixed on platform, or ground levers, controlled by keys or rod locking from the main apparatus, which places the whole of the points and signals under the control of one man, giving almost absolute safety. The points of outlying sidings are secured by what is known as the Annett's lock, the key of which is attached either to the "staff" or "tablet," so that it is impossible for a second train to be on that part of the line while the siding is being used, and ensures that the points must be properly set and locked before the staff or tablet key can be removed for the train to continue on its journey.

Most travellers are familiar with the rows of rods and wires, with their innumerable cranks, wheels, and rollers by which the gear is actuated; but the arrangement known as the "absolute block system" is to most persons an absolute mystery. Briefly, the block system means the dividing of a line of railway into sections, all of which are in electrical communication with one another, the object of which is to prevent more than one train at a time being in any section. This is accomplished on double lines by what are called "block instruments," by which means a telegraphic communication is established between each section, and the various signals such as "line clear," "train on line," or other information as to the description or position of each train is given from one box to another. The instruments consist of movable lettered discs and bells, and are worked under a special code of "beats on the bell," or otherwise. On the single line, where the risk of collision is obviously increased, and where greater precautions are necessary, other means are adopted, such as the "staff and ticket," "electric staff," and "electric tablet," which ensures that no engine or train shall leave one station for another unless the driver is in possession of either a wood or metal staff, a ticket, or a metal disc or tablet.

When the Commissioners took office they at once saw the necessity for improving the primitive method of working the traffic. The increase of traffic, and the necessity for providing greater means of safety, has led within the last few years to the adoption of more modern safety appliances, with the result that the "absolute block system" on double lines has been extended over the whole of the passenger lines, increasing from twenty-eight miles at the end of 1888, to one hundred and fifty-two miles at the present date; while on single lines the electric staff and tablet, which are both also absolute blocks, has been provided over seven hundred and twenty-two miles of line, superseding the old staff and ticket system. The lines included in these systems embrace the Great Southern, South Coast, and North Coast throughout; the Great Western as far as Dubbo, and the Great Northern as far as Tamworth.

Electricity now plays an important part in the safe working of the railway. This is effected under an electric system of working the tablet or electric staff. The authority an engine-driver has to obtain before he can proceed on a section is either a metal tablet or staff, taken from a machine controlled by electricity; each section of the line, which may be ten miles more or less in length, having a similar machine at each end, and the tablet or staff cannot be taken from the instrument at any station without the concurrence of the station-master at the station to which the train is going to proceed. For instance, assume a section between A and B; there is an instrument at each station containing a number of iron tablets or staffs. These two instruments are electrically interlocked, the one with the other, in such a manner that A cannot obtain a tablet from his instrument without permission from B; nor can B get one from his machine without the concurrence of A. When one tablet or staff has been withdrawn from either instrument, neither the station-master at A nor the station-master at B can obtain another until the one already removed has been restored, and until this has been done the section between A and B is completely locked up. Now, as no train is allowed to proceed from A to B (or *vice versa*) without carrying the tablet, it is evident that only one train can be on that section of single line at one time.

Under the old staff system, unless the trains ran with regularity there always existed a possibility that the train staff would not be in possession of the station which first required the use of the road, and as no means existed to restore the staff to the station requiring it, recourse had to be made to a system of procuring a "line clear" message to permit of the train passing over the section.

By the electric tablet or staff any desired number of trains can be despatched consecutively in either direction, there being a number of tablets or staffs in the instruments at both ends of the section, but only one can be obtained at once, consequently only one train can be in that section of line at one time, and what is known as the "absolute block" is maintained.

The progress made since 1888 may be better explained by the following table, which shows the advances made yearly:—

	Double Line.	Single Line.
October, 1888 ...	28 miles ...	Nil. miles
October, 1889 ...	51 ,, ...	81 ,,

	Double Line.	Single Line.
October, 1890 ...	72 miles ...	190 miles
October, 1891 ...	121 ,, ...	248 ,,
October, 1892 ...	149 ,, ...	657 ,,
March, 1893 ...	152 ,, ...	722 ,,

Locomotive Engines.—During the last year a number of engines have been introduced of exceptional power for passenger and freight service; the object aimed at being the economical working of the traffic over the heavy grades and sharp curves, which are characteristic of our railway system. Formerly two engines were employed for passenger trains, whereas now, one engine not only does the work better, but effects a very large saving in working expenses. Twelve of these engines were made by the Baldwin Engine Company, America, and fifty by Messrs. Beyer & Peacock of Manchester, England. As the power developed by these engines in hauling trains up steep grades is probably greater than has been accomplished by engines working under similar conditions in other parts of the world, a few facts and figures concerning them may be interesting to the members of this Society. One of the engines made by the American firm was carefully tested on the steep grades of one in forty and one in thirty between Picton and Mittagong on the Southern Line, and the maximum performance during the trial consisted in hauling a train weighing one hundred and fifty-six tons (in addition to the weight of the engine and tender), up a long grade of one in forty at a speed of nineteen and a half miles an hour. The indicated horse power obtained from diagrams taken throughout the trial averaged eight hnndred and eighty, while the maximum-horse power developed was nine hundred and twenty-five. A trial of one of the English engines was made on the Sutherland Bank, Illawarra Line, where a train weighing two hundred and twenty-five tons (in addition to the weight of the engine and tender), was hauled up a grade of one in forty-two, at a speed of twenty miles an hour. The indicated horse power developed averaged one thousand and nineteen, while the maximum indicated horse power was one thousand and eighty, which I think exceeds the performance of passenger engines in any part of the world. The ordinary load of these engines over the Southern Lines is one hundred and sixty-five tons, and the speed attained daily on the one in forty grade is twenty-two and a half miles an hour, and on the one in thirty grade the speed falls to eighteen and a half miles an hour. Both the American and English engine consist of six coupled wheels, and a double bogie in front on four wheels, ten wheels in all. The weight of the American engine and tender, in steam, is ninety-three tons; and of the English engine eighty-eight and a half tons.

The Commissioners are making an enormous improvement in the safety of working heavy goods trains by fitting them with the new Westinghouse automatic quick acting freight brake. This brake is a most powerful appliance, as will be seen by the results obtained during an exhaustive trial which took place in 1891. A long train of loaded trucks weighing five hundred and eighty-nine tons, travelling at a speed of thirty-four and a half miles an hour, was stopped on a level line in a distance of four hundred and seventy-nine feet. On a down grade of one in thirty, a train weighing two hundred and fifty-eight tons, travelling at twenty-four miles an hour, was stopped in two hundred and ninety-seven feet. This brake is five times as powerful as ordinary hand brakes, and is very necessary for controlling the speed of heavy trains down steep gradients, as well as stopping in case of an emergency in the shortest possible space. The whole of the rolling stock is not yet fitted, but the work will be completed, I understand, as soon as possible.

Railways in Progress—The railway works in progress at the beginning of the year 1892, under Mr. H. Deane, Engineer-in-Chief for Railway Construction, were as follows:—Nyngan to Cobar, eighty-two miles; Culcairn to Corowa, forty-seven miles; Kiama to Nowra, twenty-two miles; Milson's Point Extension, two and three-quarter miles; Lismore to the Tweed, forty miles. Of the above, Nyngan to Cobar was opened for traffic on the 1st

July, and the Culcairn to Corowa on the 3rd October. The former is a light cheap railway, a large portion of the earthworks consisting of mere forming, the fencing is left out except at the extreme ends, and the rails are sixty pounds to the yard. The ruling grade is one in one hundred. The Culcairn to Corowa line is also comparatively cheap, costing about £4,000 per mile, but the undulation of the ground did not permit of so much 'forming' and the line is fenced throughout. The rails are as in the last mentioned, steel flat bottomed sixty pounds to the yard. The Kiama to Nowra line is one of the most interesting now in progress, as not only does it pass through very rich and fertile country, but the works themselves are varied in character. There are five tunnels, all of them laid with concrete, and two iron bridges—one on a curve over Terralong street in Kiama, and the other a single span over the South Coast road near Gerringong. The terminus of the line is on the north side of the Shoalhaven River opposite Nowra. The Milson's Point extension brings the present North Shore Railway down to Port Jackson. It is a double line throughout, laid with seventy-one and a half pound rails, each thirty feet long with twelve sleepers to the pair of rails, bottom ballast of coarse sandstone, top of bluestone, the height from formation to rail level is one foot nine inches. The ruling grade is one in fifty, and the sharpest curve, of which there are several, of ten chains radius; without such curve a heavier gradient must have been adopted. The ends of the curves are in all cases tapered carefully on to the straight. There are two tunnels, the longer one under Blue's Point Road is on a reversed curve, and the accurate meeting of the two headings during construction was a feat for which the engineers in the field deserve the highest credit as it was a most difficult piece of setting out. The other works of note are two steel girder bridges on brick abutments, and two brick viaducts and the terminal station at Milson's Point, which is constructed partly on the solid ground, partly protected by a heavy sea-wall and partly built on ironbark piles sheathed with Muntz metal.

The Lismore-Tweed Railway is part of the Grafton to the Tweed Railway, which was first submitted to Parliament as long ago as 1884. It passes through some of the most fertile country in New South Wales, the vegetation being most luxuriant in character and unequalled anywhere in the Colony. The works are for the most part heavy in character, the country being difficult for railway construction—the flats are subject to floods, so that heavy embankments are necessary to keep the line at all times out of the water, and the higher ground consists of spurs too sharp to get round, and to get through which heavy cuttings, and in some cases tunnels, have to be driven. At the beginning of 1892 about forty miles of line had been opened up, viz., from Lismore to Mullumbimby on the Brunswick. During the year however the last contract was let, and the works are now in hand as far as the Tweed. There are eight tunnels on the works between Lismore and the Tweed, and ten bridges with steel super structure resting on cast iron or concrete pieces and abutments. As an engineering work this line presents greater points of interest than most of the railways hitherto constructed in this Colony. The central point of the line is Cavanba the Government township at Byron Bay, which even now is a fair port, but when the breakwater is constructed may be expected to form the most important harbour on the north coast, and the second in the whole Colony to Sydney.

In addition to the above mentioned lines the following were taken in hand last year, and rapid progress is being made :—1. Marrickville to Burwood Road, a double line, four and a half miles long, forming portion of the much talked of St. Peter's to Liverpool loop line. The permanent way of this line will be similar to that described for the Milson's Point extension. The works are heavy, and include a bridge of iron and steel over Cook's River at Canterbury; the curves are easy and the ruling grade one in one hundred. 2. Molong to Parkes and Forbes railway, seventy-two miles long, a line of the less substantial class, with sixty pound steel rails; the earthworks near Porcupine Gap are heavy. The timber openings are designed to carry the heaviest locomotives in use. The ruling grade is one in sixty. 3. Cootamundra to Temora, forty miles long, a line of similar character but less expensive, as the country is easier.

Some of the Tramway works in hand are well worthy of notice. There are two extensions of the cable system—North Shore Tramway to Falcon-street and Lane Cove Road. The construction of this work has necessitated the enlargement and rearrangement of the present power plant; the engines and gearing which with the exception of a few parts were made by Messrs. Hudson Brothers, are well worth inspection, as they appear to be of excellent design with the latest modern improvements introduced. The King and Ocean-street Tramway is probably the most difficult example of cable tramway design in the world; for a combination of crookedness of route and undulation of level it has no equal. The design of permanent way is arranged to suit the Vogel gripper, which gives a top instead of a side grip; the tunnel is very shallow and therefore economical in cost. The power plant of about eight hundred horse power will be placed in Rushcutters Bay, and will be made in the Colony by Messrs. Hudson Brothers. The plant will be sufficiently powerful to work some future extensions of the system.

I may mention here that a steamboat has just been finished by the Mort's Dock Engineering Company from the designs of Mr. W. Cruickshank, M.I.M.E., Chief Surveyor to the Marine Board. The boat is intended for the pilot service, and is fitted with all the modern improvements. It is named the s.s. *Captain Cook* and the principal dimensions are as follows:—Length between perpendiculars one hundred and fifty-five feet, beam moulded twenty-five feet, depth moulded fifteen feet, built of steel to Lloyd's 100 A1 Class. Flush deck with bridge amidships, raised forecastle, clipper bow and elliptic stem, schooner rig. Engines triple expansion type, having cylinders sixteen inches, twenty-five inches, and forty-one inches diameter, thirty inches stroke, the high and intermediate cylinders are fitted with piston valves, and the low pressure cylinder with a double ported D valve. The cooling surface in the condenser is one thousand one hundred and fifty square feet, air pump, single acting, fifteen inches diameter, fifteen inches stroke, circulating pump, double acting, eight inches diameter, fifteen inches stroke, two feed pumps, three inches diameter, fifteen inches stroke, and two bilge pumps of the same dimensions. The whole of these pumps are driven by levers from the low pressure crosshead. The reversing gear is actuated by one of Brown's patent steam and hydraulic reversing engines. Steam is supplied at one hundred and sixty pounds pressure from a boiler fourteen feet nine inches inside diameter, eleven feet six inches long, having three Fox's patent furnaces each four feet diameter and two hundred and forty-six tubes three and a half inches diameter. The shell plates are $1\frac{5}{16}''$ thick, and the end plates seven-eighths inch. The longitudinal seams are butt jointed, with in and outside straps treble rivetted, rivets one and a quarter inches diameter. A donkey boiler is also provided nine feet high, four feet six inches diameter. For circulating the water in the main boiler a large duplex pump is fitted, also a donkey pump. The ship is fitted throughout with the electric light, and a search light of twelve thousand candle-power. She will also be of service in case of fire on vessels or wharves, and for salvage operations, having a powerful fire pump capable of delivering thirty-six thousand gallons per hour. For all the auxiliary engines the steam pressure is reduced to ninety pounds by one of Auld's patent reducing valves. For automatically controlling the main engines in heavy weather Dunlop's patent governor is fitted. The highest indicated horse power so far attained is eight hundred and thirty-five. The work reflects great credit upon the designer and Mort's Dock Engineering Company.

Harbours and Rivers.—Mr. Cecil Darley, M. Inst. C.E., has supplied me with particulars of the work done during the year in connection with the harbours and rivers of the Colony, from which it appears that the necessity at present for restricting the expenditure of public moneys usually payable from loans is somewhat limiting the extent of harbour improvement works along the coast, nevertheless some important works are in progress. Commencing in the north—

On the Tweed River important river improvement works are in progress, and are already showing very satisfactory results. Nearly two miles of stone training walls have been constructed, chiefly along the concave bank of the river; parallel with the walls, a sand pump dredge is at work cutting a channel and depositing the silt behind, thus in one operation dredging a channel and reclaiming land. About two miles of good direct channel, with a depth of from twelve to sixteen feet of water is now available, where formerly there only existed a very tortuous channel, carrying but as many inches of water.

On the Richmond River, the scheme outlined by Sir John Coode is being carried out and is making fair progress. On the north side a breakwater has already been run out for a distance of one thousand six hundred and fifty feet, leaving about nine hundred feet still to be completed to reach the limit proposed by Sir John Coode to which the breakwater should be extended in the first instance. On the south side, the southern training wall has been extended about three thousand three hundred and fifty feet, and now reaches the point where the southern breakwater proper may be said to commence; this will have to be extended three thousand two hundred feet to reach the end of the first section of Sir John Coode's proposal. This work cannot be carried on very expeditiously, seeing that all the stone has to be loaded into punts and brought down the river a distance of eighteen miles. Fair progress is, however, being made, and as more appliances shortly to be available are brought into use, the work will no doubt advance in a satisfactory manner. Already the works so far complete have a marked influence for good in maintaining a deeper and straighter entrance to the river, which has hitherto been the dread of all masters trading to the Richmond.

At the Clarence River a contract has been let for a portion of the scheme outlined by Sir John Coode, it being proposed to construct the long southern training wall only in the first instance. This will be constructed by tipping stone from an elevated timber staging on piles, the stone being brought up to about half tide level. The first stone was tipped into the wall last month. The quarry is about four miles from the work, but is connected direct by a railroad.

Various river improvement works are taking place on the Bellinger and Nambucca Rivers; and at Trial Bay the breakwater to enclose a space to form a harbour of refuge is in progress by prison labour. This work is in a very exposed situation, and in deep water, so that the apparent progress is not very marked.

At Newcastle the principal works in progress are confined to dredging, and removal of rocks near the entrance of the harbour at a point locally known as the Black Buoy Reef. The situation is exposed, and the current being very strong, it would have been a most difficult and costly undertaking to remove it by the ordinary process of drilling, blasting, and lifting by divers, so it was determined to procure what is known as Lobnitz's Patent Rock-cutting Plant; the iron cutter bars (of which three are at work at one time), each weigh eight tons and are in various lengths up to about forty feet; they have a heavy steel chisel-shaped cutting edge, and are raised by steam power and allowed to drop from a height of from eight to ten feet by releasing a trigger, as in the ordinary pile-driving monkey. The whole machinery, which is necessarily of an unusually substantial and heavy nature, was made by the patentee, and erected on a large iron punt constructed in this harbour. The machine is doing good work in cutting and pulverizing the rock, and leaving it in a state in which it can be easily removed by an ordinary ladder or grab dredge.

In connection with the harbour works, dredging plays a most important part, as the commercial prosperity of New South Wales depends so largely upon the facilities afforded for river and coastal traffic that the Parliament cheerfully votes from revenue over £100,000 annually for dredging expenses, an amount not excessive when it is considered that operations have to be carried on at twenty-one ports and rivers on a sea-board of six hundred miles, extending from the Victorian to the Queensland border. Employment is found for about four hundred men on the fourteen ladder dredges, nineteen grab bucket machines, seven suction dredges, twenty-one tugs, and ninety punts, continuously worked by the Harbours and Rivers Department in increasing harbour accommodation, deepening river channels, reclaiming land, and removing the enormous quantities of silt deposit left by floods. The estimated value of the dredging plant exceeds £500,000.

The application of the centrifugal pump to dredging purposes having passed the experimental stage of development, the New South Wales Government, in 1888, resolved to cease building bucket dredges, and to adopt the pump system. Already six powerful suction dredges are at work, with conspicuous success, one at each of the following ports or rivers:—Sydney Harbour, Newcastle Harbour, Myall River, Nambucca River, Clarence River, and Tweed River. Two additional machines are nearly completed at the Fitzroy Dock.

Not only has the actual cost of dredging been reduced one-half by the adoption, where practicable, of the new system, but (incidental to the pumping) large areas of valuable land have been reclaimed by the material deposited at a cost of 2d. per ton, which under the old method of working could only be utilised by hand labour at about 8d. per ton, four times the cost of spreading it, as now, direct from the pump.

In crowded harbours, where it is undesirable to impede navigation by mooring a pipe-line on pontoons from the suction dredge, the ladder dredges have to be used, but by a method first adopted in this Colony, the silt instead of being dumped at sea can be utilised for reclamation by being deposited alongside a suction dredge to be pumped on shore. Large areas have been so treated at the following places :—

White Bay (half done by hand labour) ...	about	$12\frac{1}{2}$	acres.
Snail's Bay (two-thirds done by hand labour)	„	$5\frac{1}{2}$	„
Leichhardt (two-thirds completed, all by sand pump)	„	$73\frac{3}{4}$	„
Careening Cove (wholly by sand pump) ...	„	$3\frac{3}{4}$	„
Neutral Bay (wholly by sand pump)	„	$7\frac{1}{2}$	„

The last-named place has just been converted from an insanitary foreshore into a health promoting park in the short space of six weeks, by pumping on shore one hundred thousand tons of silt lifted by ladder dredges and dumped alongside the *Neptune*, instead of (as previously) being towed to sea.

Mr. Hickson, M. Inst. C.E, Commissioner and Engineer-in-Chief for Roads, Bridges and Sewerage, has kindly supplied me with the following particulars of the work done in his department :— The Colony is divided into eight districts, seven of these embrace generally the eastern and central divisions, while the eighth covers most of the thinly populated west. The total area under the control of the department is two hundred and three thousand seven hundred and six square miles.

Roads.—Two hundred and seventy-one miles of new metalled roads were formed during the year, while twenty-six thousand four hundred and seventy-seven miles of road have been dealt with and maintained. The most important of the new roads constructed during 1892 are in the north, the Don Dorrigo road running from the Bellinger River to the rich tablelands in the New England District, and that from Coff's Harbour to give access to the scrub lands of the upper Orara. These roads will open up valuable country hitherto almost inaccessible. Other roads have been construced to improve the facilities for access to the rich mountain scrub lands on the Richmond, Brunswick, and Tweed Rivers, and from the railway line towards the west. In the southern coast districts attention has been principally paid to improving the location and grading of the old roads, fifty-eight miles having been formed, fifty-one miles formed and metalled, and sixty miles surveyed and graded. Of the new roads in the western and south-western districts, perhaps the most important is the mountain road between Tumut Valley and Kiandra, formed in heavy side cutting for twenty miles. In ascending the Talbingo Mountains it rises two thousand five hundred feet in five and a half miles. This road besides opening up country hitherto inaccessible from Tumut, forms a means of direct communication between the south-east coast and the south-western interior; a branch three miles in length connects the Yarrangobilly Caves with the main road. In many districts great difficulty is experienced in obtaining satisfactory material for ballasting. The cost of metal is prohibitive; vitrified clay, sand, and a red soil found in some parts have been used with fair success, while recently a corduroy of pine saplings covered with nine to twelve inches of the soil from side drains has been tried, and though not yet fully tested is expected to prove very satisfactory. In constructing roads in the drought-infested area, every opportunity is seized of forming them in embankment, with storm overflows, so that they shall serve as dams for the conservation of water, and this policy has been amply justified by its results.

Bridges.—The total length of bridges and culverts under the control of the department is about one hundred and thirteen miles; one hundred and fifty-six bridges and one thousand two hundred and ninety-six culverts were built during the year 1892. The majority of these are of a simple character spanning the small coastal rivers and creeks, but several very substantial and elegant structures have been erected, as for example those over the Hunter River at Elderslie and Aberdeen, over the Lachlan River at Forbes, and over the Murray River at Mulwala, Tintaldra and Corowa. Others such as the Tocumwal Bridge over the Murray, and the Wilcannia and Wentworth Bridges over the Darling are now in course of construction. The majority of the larger bridges are of the lattice type with eighteen feet roadway. Where on coastal rivers sailing vessels have to pass, the leaf type of lifting bridge with a clear opening of forty feet is adopted, in which the lifting span is hinged at one end and raised by means of chains passing over timber towers and connected to balance weights, so geared that one man can raise the span in ten minutes. In rivers in the interior where traffic is carried on by means of steamers and barges, the opening span is raised by wire ropes passing over towers at the four corners. The clear width of opening is fifty feet, and the lift twenty-five feet above flood level. The lift span is of steel and is raised by machinery carried on the top of the towers; one man is required, the lift taking five minutes. One hundred punts and ferries are under the control of the department, six of which are worked by steam. The latest addition is that for the Hunter River at Hexham, which on its trial trip gave a speed of seven and a half miles per hour.

Sewerage.—The total length of sewers completed or in progress at the end of 1892 in connection with the sewerage of Sydney and its suburbs was 4835·47 chains, and of storm water channels 954·41 or a total length of seventy-two miles 29·88 chains. Of this length five miles 10·61 chains of sewers and three miles 20·55 chains of storm water channels were completed during the year, while on the 31st December, four miles 52·13 chains of sewers and four miles 7·29 chains of storm water channels were still in progress. Amongst the most important of the sewers completed was the extension of the George-street West sewer, through the Glebe to Annandale (with its branches) which will ultimately tap the whole of Leichhardt and Balmain. It is unfortunate that owing to the present depression it has been found impossible to proceed with the reticulation of this district, as if this could be done it would not only be a boon to the residents, but would render the trunk sewers already constructed, revenue producing. An extension of the Prince Alfred Hospital sewer through Camperdown to Liberty-street Newtown has also been completed. It is designed to drain Camperdown, and parts of Newtown and Petersham; some portions of the latter areas have already been reticulated. In the eastern suburbs a branch from the main Bondi sewer to Elizabeth Bay and Potts' Point was finished, which with the Victoria-street branch already constructed, will completely drain that locality.

Of the contracts in progress the most important are the two embracing the tunnels and aqueducts on the main western outfall sewer to the sewage farm at Botany; these form the key to the whole western drainage; they extend from the farm to the pen-stock chamber at the Warren, where the western, northern, and eastern branches unite, a distance of 90·6 chains. The sewer will be carried by three circular ducts, each six feet in diameter, and will cross three valleys on brick arches, and two iron and steel bridges span the Woolli Creek and Cook's River respectively. In the eastern suburbs, the first contract of the Waverley and Woollahra branch sewer is practically completed; it extends from the Bondi sewer to the end of Denison-street Randwick, and will drain the western slopes of that borough. Its extension to the Randwick race-course and the Kensington Estate is contemplated. The Darling Point branch from the main Bondi sewer has also been undertaken, and its construction is well advanced. In view of the fact that the sewerage system would necessarily take some years to complete, it was resolved to at once construct a system of storm water channels supplementary to the scheme, which would in the mean time serve to reduce to a minimum the nuisance arising from the discharge of house slops and defiled water into the street gutters, besides expeditiously carrying off flood waters. The Iron Cove and Long Cove Creeks on the northern slopes, and several areas on the southern slopes subject to sudden flood, have been dealt with during the year. At the end of 1892 eleven miles seventy-four and a half chains of these channels had been constructed or were in progress, the length completed during the year being three miles twenty-one chains.

Irrigation and Water Conservation.—The importance of the part which water conservation and irrigation must hold in the development of the Colony, has long been universally admitted.

Those who have given even a moderate amount of thought to this subject have not failed to see that the British law of riparian rights completely blocks the path of irrigation enterprise. In England, questions relating to irrigation are practically unknown; but river conservancy for purposes of navigation, drainage, and reclamation, is a matter of great public moment, and for the determination of questions relating to even these matters the cumbrous law referred to is an expensive failure. France has a larger extent of land under irrigation, subject to suitable laws and regulations; but irrespective of this, it would probably be no exaggeration to state that in regard to its laws for and method of dealing with river conservancy it is half-a-century ahead of England.

Among European countries, the conditions of Spain are probably nearer than any other to those of the western districts of New South Wales. In both cases the rainfall is light, the climate in summer hot and dry, and the discharge of the rivers more or less uncertain. Irrigation in Spain has for many centuries been regarded as a matter of the first importance, and the laws bearing on it have been framed with such care and comprehensiveness, that they were in a large measure adopted as the best model for dealing with the great irrigation systems in India.

In New South Wales we have the successful legislation of Spain, Italy, France, and India, to guide us, and the ancient bungling of England, and the recent bungling of America, to act as warnings. There are doubtless differences of opinion as to points of detail, but it is very generally admitted that the State should be regarded as the owner of all great natural supplies of water, and that it should so administer these supplies as to make them of most benefit to the public. As the law stands, every dam on every river and creek in the Colony exists on sufferance only, and the same remark applies to the numerous pumping engines which enterprising settlers are using for irrigation purposes on every important river, and also on some creeks in the western districts. When any landowner or lessee of land thinks, or professes to think, that the continued existence of a dam in his neighbourhood is detrimental to his interests, he does not appeal to the law, but adopts "the good old rule, the simple plan" of collecting a mob of men and proceeding to cut the dam. If the owner of the dam has timely warning he also, knowing the futility of appealing to the law, collects a mob of men if possible more numerous than the attacking party. This is the old style, which has not yet disappeared, but as it is now generally known that the spirit of the law is opposed to any work for conserving or utilising the waters which run to waste in our rivers, the risk involved in the construction of any work for conserving these waters is generally sufficient to prevent the undertaking of any such work. Such a state of affairs is, to say the least, most unsatisfactory.

In the absence of legislation, the construction of large irrigation works which would utilize an important portion of the waters of our rivers cannot be proceeded with. The attention of the Water Conservation Department has hitherto been chiefly confined to carrying out systems of surveys and levelling, together with gauging the discharge of the rivers. This preliminary work, which may now be considered as almost complete, is shown in an elaborate series of contour plans, which include all the great alluvial plains west of the Dividing Range. The information thus collected must form the groundwork of all the great projects which can be carried out for utilizing the waters of our western rivers.

The nature and scope of the schemes which are specially recommended in the cases of the Murray, Murrumbidgee, Darling, and Macquarie Rivers have already been made public; but owing chiefly to the exceptionally favourable character of recent seasons, these schemes have attracted much less attention than their importance demanded. It is in some respects unfortunate that a very large proportion of the land which can be irrigated most easily and economically and with the best results has been alienated. This remark applies particularly to the land which can be irrigated from the Murray and the Murrumbidgee. The conditions are remarkably favourable to irrigation from both of these rivers. In the case of the proposed Lower Murrumbidgee Southern Canal, the head of which would be about a mile below Narrandera, no weir is required, but merely regulating gates to prevent excessive inflow of flood waters to the canal. Mr. McKinney estimates that the cost of the whole system of canals proposed in this case, for the irrigation of the districts bounded on the north by the Murrumbidgee River, and on the south by the Billabong Creek and Edwards River, and including work for filling Lake Urana would be £548,000. This is for a system of canals which would carry 2,000 cubic feet of water per second. It is worth while to consider what these figures mean. The capital outlay on a flow of one cubic foot per second is £274. Assuming that interest on the capital expended would be four per cent. and the cost of maintenance three per cent.—a very high rate—the cost of water per cubic foot per second for a year would be slightly over £19. This supply, on the evidence collected by Mr. McKinney, can be depended on throughout the spring months, and a diminished supply can be obtained throughout the greater part of the other seasons. When in Southern California, Mr. Deakin ascertained that the capitalized value of a cubic foot of water per second in perpetuity was reckoned at £8,000. Now there are many points of similarity between the conditions existing in California and those in New South Wales, and there are some points of difference. Admitting all the latter, it may be asked whether if a cubic foot of water per second is worth £8,000 in California, the same quantity should not be worth £274 or even double that sum in the western plains of this Colony?

The last river reported on by Mr. McKinney (in this case in conjunction with Mr. Ward), was the Darling. It proves that so far as regards the practicability of large irrigation schemes, the conditions of the Darling are much less favourable than those of the Murray or the Murrumbidgee; but by combining the interests of irrigation and navigation, it is claimed that on the river Darling there is a great field for remunerative engineering work.

Of the work carried out by the Water Conservation Department, the most important is the crib-work overshot weir on the River Lachlan, the object of which is to divert a portion of the waters of that river down the Willandra Billabong, an important natural effluent of the Lachlan, through which, in 1870, the flood waters of this river reached a point within about thirty miles of the waters of the River Darling. The weir has proved a most useful work, and though constructed under most disadvantageous circumstances, the work is a decided success. Constructed in friable alluvium resting on a great deposit of sand, it was not quite complete when the great flood of 1890 passed over it and stopped further work for months. After that a series of moderate floods interrupted the work repeatedly; but the work, including an earthen dam across the Lachlan and the improvement of the first six miles of the Willandra Billabong have been completed at a gross cost of about £10,000. It is now reckoned that permanent water will be maintained in the Willandra Billabong throughout a length of two hundred miles, while in addition the weir holds back a supply in the Lachlan to a distance of over twelve miles. The improvement of Yanko Creek is a work of the same description, and has proved extremely beneficial to a large tract of rich country.

In regard to underground water supply, a bore is being put down under this Department at Coonamble. The immediate object is to afford a supply of water to that town; but it is expected that if successful it will lead to much further enterprise of the same description in that district, thereby promoting settlement and enhancing the value of Crown lands.

I will conclude this long address by thanking you for the patient attention with which you have listened to it, and in vacating the Chair in favour of the newly elected President, Prof. Anderson Stuart, I need not say anything by way of introduction, as he is so well known to the members of this Society. I am sure that the Society will prosper under his able direction, and I ask that you will give him the same support which has always been accorded to me.

LIGHT RAILWAYS FOR NEW SOUTH WALES.

By Charles Ormsby Burge, M. Inst. C.E.
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[*Read before the Engineering Section of the Royal Society of N.S. Wales, December 21, 1892.*]

The question of light railways has been often to the front, not only in New South Wales, but in all countries where there is any railway construction at all; but it has become more especially pressing latterly, when the difficulty of raising loans for public works has increased, and the necessity has arisen for opening up new districts at the lowest possible first cost. The meaning of the term "light railways" has almost as many variations as the sorts and conditions of men who do not hesitate to give their opinions on the matter. It seems to some people extraordinary why engineers cannot design a railway which shall have light rails, steep gradients, light works and light working expenses, nearly all of which things are necessarily more or less antagonistic to each other.

People in the country say, why cannot we have a tramway like the Sydney ones? all we want is a train of one or two vehicles and a small engine, not knowing or apparently caring, as other people have to pay, that such an arrangement is just about as expensive a one for a country line as could possibly be devised for working, giving the maximum of wages with the minimum of loads.

Nevertheless there are points which it is the purpose of this paper to show, in which our railway construction, as hitherto carried out, can be considerably cheapened, and made more appropriate to the light traffic in outlying districts for which such lines, in the future, must be provided. The author of this communication has had to do, either in survey, construction, or maintenance, with heavy and light railways of all kinds, from the five feet nine inch gauge of Spain, five feet six inch gauge of India, five feet three inch gauge of Ireland, four feet eight and a-half inch gauge of England and New South Wales, three feet six inch gauge of the Cape Colony, down to the one foot eleven and a-half inch gauge of North Wales, so that some knowledge of the subject may be expected to be brought to bear upon it.

The engineer, in designing such a cheap system of lines as those now in question, has to deal with and satisfy four, more or less, distinct sets of people, whose interests are not always identical, at least from their own several points of view, and therein lies his chief difficulty. First and chiefly, there is the whole colony as represented by the Government, and, it may be added, its creditors. Secondly, the people of the district to be served. Thirdly and fourthly, the locomotive and traffic branches of the railway department. The Colony, as a whole, wants the value of its lands increased, and the interest of its debt to be met, and its credit upheld, by satisfactory dividends; and a question as to this arises whether, if cheap construction does in some points involve greater working expenses, it is not advisable to incur such heavier working expenses, and save interest to the same amount. In other words, if, by saving £100 of the capital expenditure, and therefore say £4 annually in interest, we incur £4 additional annual working expenses, though the immediate financial result is exactly the same, would it improve the credit of the colony by lessening its voracity for loan assistance? This however is a financial question, outside the scope of this paper, and it is merely adverted to, to show how many sides there are to questions like this.

The question of the advantage of raising the value of lands is so obvious that it need hardly be touched upon, but it is evident that even where branch railways do not pay their own expenses and interest, still they may be a source of income indirectly from the increased value of unsold land, and increased trade and population, large populations being obviously governed at a much cheaper proportionate rate than small ones. It is a question, if these sources of income could be tabulated and credited, how many of the branch lines now regarded as non-paying from the Railway Commissioners' necessarily partial outlook, might be looked upon as at all events meeting their expenses and interest. Again, even taking railway receipts alone on the credit side, though there is a considerable list of non-paying lines in the Commissioners' reports, it is to be presumed that the figures given are the results of setting the passengers and goods receipts for the particular mileage of the branch, and those alone, against the corresponding working expenses of that mileage only. It may be impossible, and undoubtedly it would entail great trouble, to do otherwise, but clearly a more equitable plan would be to credit the branch also with the extra profits which its contributions bring to the main line. These contributions can easily be conceived to be carried over the small mileage of the branch at a loss, but over the longer mileage of the main line at a gain. A main line more or less fully occupied is a machine working up to its full capacity, and therefore working economically; a branch line is often the reverse. A dozen waggon-loads of traffic can be shunted on to the main line from a branch, and run over the main line with very slight extra cost, while they are paid for at their mileage rate. In fact it might cost two pence or three pence per ton per mile to carry these waggons over the short mileage of the branch, while the same waggons might be drawn over the long mileage of the main line for a fraction of a farthing of actual nett additional expenditure.

As regards the national creditor, while the construction of absolutely hopelessly non-paying lines is against his, as it is against all, interests, it does not follow that it is necessary for a line to pay more than its working expenses and interest to satisfy him. The indirect gains to the Government already alluded to in a larger population and production, are distinct advantages to his security, even supposing that, what is after all only a subdivision of the cost of production, namely :—its short carriage to the main line, is proportionately heavy.

With regard to the other three sets of interests with which the constructing engineer has to deal, if a lighter class of railway than has hitherto been in use, has to be provided, they will, each of them, have to give way, on some points, for the general good.

The people of the district to be served must be content with slower speed, irregular running to time, less accommodation at stations and goods sheds, and notwithstanding getting less, they must be prepared to pay more, than those using the main lines, to cover the extra cost of working. At present, the people of a district, such as those now under consideration, have to pay indirectly the coach drivers' wages, the feed of the horses, etc., and the coach proprietor's interest on his capital, which surely is generally more than the modest four per cent. which the British capitalist demands; and in the case of goods, they have to pay like charges to the waggoner. They may fairly then be asked to pay that which, though more than others do on the main lines, is still a large reduction on their present charges. Of course this matter has its limits, as if too high charges were made the development of the district would cease, and the ultimate increase of traffic, and lowering of rates to correspond, would never be arrived at. But there is certainly a great margin of difference between the ordinary road charge of six pence to one shilling per mile for passengers and one shilling to one shilling and six pence per ton per mile for goods, and the ordinary, or even increased, railway rates, intensified as this contrast is by the frequent interruption to road traffic by the weather, which practically does not exist in the case of the railway. It has been proposed, instead of the people who use the line paying for the extra cost of its use, which is of course the fairest way, to tax the whole district either by an extension of the betterment principle, or by a rate. As to the betterment, as applied to the whole district benefited, in most country lines the purchase of the land occupied by the railway is a very insignificant item of its cost, and there does not seem to be any intelligent reason why the district should pay for the land which is a necessary requirement, any more than for the sleepers or ballast, or any other material which contributes to the result. As to an acreage rate, it may be remarked, in passing, that an average rate of three pence per acre per annum, levied on all lands within ten miles of a line costing £4,000 per mile, would pay the full interest on its cost, not counting any contributions from townships, which however might pay interest for the first ten miles of the branch, which generally is of no benefit to its neighbours. Such a tax would cost little to collect, as the machinery exists already in the gathering in of the sheep tax. So much for the district.

Next, the locomotive department has to be dealt with. If we are to have true light railways, not those in which lightness of cost of construction is to be more than balanced by exhausting maintenance, and other annual expenditure, locomotive engineers must design engines that will turn round sharp corners so as to enable sharp curves to be used, and thus minimise works, even though such engines entail more complication of machinery and more parts to keep in repair than the ordinary types. In connexion with this, it may be mentioned, that two estimates were recently made for a considerable length of line in this colony through a moderately rough country, taking curves of twelve chains radius for one, and six chains for the other. One half the earthwork and one-third of the culvert work were saved, and the grades improved on the sharper curved line, the length being increased thirteen per cent. and the saving in cost on the original mileage amounted to about £2,400 per mile. Now if we take as an example a line of this kind of fifty miles long, and assume say half of this £2,400, that is to say £1,200 per mile to be saved, we have £1,200 × 50 equal £60,000, the interest of which, at four per cent., is £2,400 per annum. Now supposing two engines, which is an outside estimate, to be in use on such a branch, and the total annual repairs per engine under ordinary circumstances to be £350, that is to say £700 for the two, and, by reason of the complication introduced, fifty per cent extra repairs to be required, still the balance in favour of the cheaper line would be enormous.

Increased train resistance by sharper ruling curvature need hardly be considered, as this would probably be more than compensated by the easing of grades, which the extra length involved by the greater curvature would entail. It has been found also that the tires of rolling stock do not suffer much by curvature, the flanges get worn instead of the treads; that is the chief difference. As regards grades, it is like asking incompatible things to say that an engine is to be flexible and also that all or nearly all the wheels are to be coupled drivers, so as not only to utilize all weight for adhesion, but to lighten load on a single pair of wheels, and thus to enable the constructing engineer to increase his grades and lighten his works and permanent way. Nevertheless it must be done, if we are to have light railways in heavy country. In fact we want an engine as like a snake as possible, sinuous in motion and using all its length for adhesion and propulsion. Some time ago there were some successful experiments made in obtaining adhesion by means of a current of electricity from wheel to rail, but nothing seems to have resulted from it. If such a contrivance were effectual without counterbalancing defects, it would do more to make light railways possible in undulating country than anything else. The author is quite aware of the evil of introducing additional types and of limiting, as regards engines, the economical advantages of reserving the branch lines as asylums for aged and infirm locomotives unfit for the main line service, but this latter disadvantage tends to disappear, as the present policy, which is no doubt a good one, is to increase the power and weight of main line engines to such a degree as to render it hopeless to use them eventually on any line having any pretension to be called a light line at all, and there are a good many existing substantial branch lines which could use them up with slow speeds.

As regards the traffic department: if we are to have such light railways as this paper contemplates, passenger stations, in the existing sense of the word, must be cut out, the guards doing for the most part what is now done by the station masters. Shelter will be only provided for goods, and that only which is absolutely necessary to prevent damage. As slow travelling only is in view, signals and interlocking, the latter being a most expensive item, would be unnecessary. Passenger platforms should be abolished, as is done in America generally, even on main lines, travellers entering and leaving the train at rail level, and junction arrangements must be reduced to a minimum. Fencing should generally be dispensed with, and where the line cuts through a boundary fence separating holdings, a cheap cattle stop or gridiron as used in the United States, would sufficiently prevent trespass. On the Cape railways, where the author had several years' experience, fencing was successfully dispensed with, and in India, a curious instance may be quoted, also within the author's actual experience, in which, to use a hibernicism, the worse fence was found to be the better, leading to the inference that none at all would be better still. The Madras railway, a system of over eight hundred miles, was closely fenced throughout with iron posts and wire, or with aloes. Notwithstanding that there was a heavy fine inflicted by law on all owners of cattle which trespassed, gates were constantly left open, and cattle, attracted by the protected herbage within, being unable to get away at the side, on account of the formidable fence, were frequently overtaken and killed by trains. On the East Indian line, which was very badly fenced by a mere ditch and mound, straying cattle, though not generally willing to cross it, did so freely when a whistling engine was behind them, so that the statistics shewed, that the cattle run over, per train mile, was very much less on the badly fenced line. Most of the newer lines in India are unfenced.

And now having enumerated the principal concessions to be made by the several interests concerned, it will be pointed out in what way cheapness of construction may be arrived at by thus lessening the obligations of the constructing engineer. It is necessary, in order to do this, to divide the contemplated lines roughly into two classes. Firstly, those which pass through as heavy country as that which it is possible to locate what may be called a light railway at all; for there are districts, and in New South Wales especially, through which no conceivable line is possible except with heavy earthworks, tunnels and viaducts. This class would therefore comprise lines through moderate undulating country only, and where either no large river bridges occur or, where they do, existing road bridges can be availed of without serious additional expense. Secondly, those lines which are entirely or chiefly on the surface, such as in most of the Riverina and western plains.

Now as to Class 1. The question of curves is very important, and the probability is, from what has been already said, that if the locomotive designers meet us, nearly half of the earthwork and one quarter to one-third of the culvert work might thus be saved; items which form, in many of this class of line, a large proportion of the total cost. As to the practicability of sharp curves on the standard guage, the following instances may be quoted. In Mr. Mosse's paper "Minutes of Proceedings Institution of Civil Engineers, Vol. LXXXV.," it is stated that "In America, with a gauge of four feet eight and a-half inches, curves of from three hundred and thirty to four hundred feet radius" (five to six chains) "are traversed by four wheel coupled engines having a wheel base of six or six and a half feet," and he states that, on the Nana Oya extension of the Ceylon railway, gauge five feet six inches . . . a large portion of the curves vary from five to eight chains radii, and are worked by engines having six wheels coupled four feet five inches in diameter with a wheel base of nine feet six inches, but as the leading drivers are flangeless the fixed wheel base is four feet five inches. The bogie has however a wheel base of six feet. The resident engineer reports that these engines work remarkably well, with practically no flange wear; they are a perfect success for working on five chain curves. In the same volume, in Mr. Gordon's paper, Forney's type of engine is described as having four coupled drivers forty-two inches diameter, working round curves of ninety feet, or less than one and a-half chain radius, on the New York Elevated (standard gauge) Railway, and also as much used on suburban lines in the United States. The following is quoted from the same authority. "The most eminent and experienced American engineers however attach more importance to the free use of curvature even of great sharpness" (than to steep grading) "in attaining economical construction for cheap lines." A table is given below of curves actually employed in four feet eight and a-half inch roads :—

New York, New Haven and Hartford	6·21	chains radius.
Lehigh and Susquehanna	4·60 to 5·80	,,
Baltimore and Ohio	4·50 to 6·0	,,
Virginia Central	3·60 to 4·50	,,
Pittsburgh, Fort Wayne and Chicago	3·73	,,

Enough has been said to shew that, as regards sharp curves, locomotive and construction engineers can meet one another on common ground.

As to the question of steep grades, a special design of locomotive for light lines, where such grades are necessary, is indispensable, but independently of this, the following considerations suggest themselves. There has latterly been a strong set of opinion in this Colony against heavy grades, arising perhaps from their former rather indiscriminate use in more or less important lines ; but we should be cautious in insisting on easy grading everywhere; proportion having been rather lost sight of in this matter. Nobody is more convinced than the author of this paper that, on main lines and heavy traffic branches, easy grades should prevail, and that large expense may be economically incurred to attain them. In a recent instance it was estimated that an expenditure of £53,000 in reducing the ruling grade of a portion of the main Southern Line from one in thirty to one in forty, would result in a saving of about £9,000 a year, even with the existing traffic, and, with the increase of the future, still more saving would follow. On the London and North Western, on the Liverpool and Manchester Section, one thousand one hundred and twenty-eight trains are moved per day. It is evident that, if the slight reduction in ruling grades were made on such a section which would enable one extra vehicle to be taken in each train, and, assuming the average train to consist of thirty vehicles, the number of trains could be reduced by about thirty-seven over each mile every day, over the thirty-one and a-half miles. This would amount to a reduction in running train miles of one thousand one hundred and sixty-five daily, which would represent about £15,000 per annum.

Now take a small branch of our system, say the Cootamundra to Gundagai, thirty-four miles, where there is an average of about two and a-half trains moved daily, as against the one thousand one hundred and twenty-eight of the London and North Western section referred to. It is clear that even if the present ruling grade of one in fifty, which is good for say twenty-two vehicles, were increased to one in forty, with sixteen vehicles, the trains moved, to carry the same daily traffic, would be only increased by one, or taking the running expenses at even double the English rate, £887 per annum additional would be incurred, and if the time of the trains' crew is not at present fully occupied, as is likely, probably very much less. Now £887 capitalized at four per cent. represents £22,175 or £652 per mile. So that if £652 or more, per mile could have been saved by adopting one in forty instead of one in fifty, it would have been justifiable to do so. As the country, in this particular instance, is flat, probably not even that amount would have been saved by keeping closer to the surface, and of course, in this as in nearly all cases, the traffic realized cannot be accurately determined beforehand. The instance therefore is only brought forward as an illustration. The conclusion therefore is, that in dealing with such light railways as those in which an average traffic, probably of one train per day each way, can only be reckoned on, considerable boldness in steep grading, if money is to be saved by it in the first instance, may be displayed. Culverts and bridges would be modified by the closer alignment to surface which the adoption of steep grades and sharp curves imply, and their consideration, in this light, closes that of those items which are affected by the roughness of the country.

We now come to the lines through flat country, and to the works common to both classes. Earthwork may be reduced to what is called forming, but in a great many instances flooding may rise above it, and this contingency must be put up with. Culverts and bridges, apart from their modification as already mentioned, by the closer surfacing in the rougher country, cannot be much lightened from the present types. The difference between the dimensions of an ordinary small timber bridge to carry a heavy, and a light engine, could only apply to the beams, and not to the generally more expensive substructure, and is so trifling as to be practically out of consideration, and in masonry culverts the same may be said. Very large bridges are not in question, as they would not be encountered in any line contemplated in this paper as a light railway.

The lightening of permanent way should chiefly take the form of diminishing the number of the sleepers, and certainly not their size or quality. As regards their size, among other items which go to make up the cost of a sleeper there are :—1. Choice of a suitable tree to cut down. 2. Hewing into shape. 3. Clearing and making tracks to get the sleeper from the forest to the line. 4. Handling, possibly two or three times, unloading, and laying in the road. Now a great deal of the cost of these are, within limits, entirely independent of the size of the sleeper, and if the bearing surface of the road can be diminished it is certainly more economical to do so by reducing the number, than the size of the sleepers, assuming that the safe limit of rail span is not exceeded.

There are strong economical reasons why quality should be maintained. Some people argue that sleepers cut down at random from the neighbouring bush, would be so much cheaper in cost that this would over-balance the extra cost of the more frequent renewals, but this is not so. An ordinary bush half round sleeper would certainly cost half as much as the first-class iron bark one which is in use at present, and would not last half the time, so that, when the labour of renewal is added, the financial result of the supply of the so called cheap sleeper would be eventual loss. This has been amply proved by the ascertained life of inferior sleepers on the Mudgee, and on the Great Northern Line, north of Tamworth, which have had to be taken up after ten years, the first class ironbark ordinarily lasting twenty-two to twenty-five years; moreover, the fastenings would not hold so well, and, independently of renewal, maintenance would be thus increased. It may be said that in America, sleepers are often cut from the nearest forest, but that is because generally in such cases they have no timber fairly accessible of the magnificent kind we have, or it is certain it would be used. In a discussion on this subject at the Institution of Civil Engineers, Vol. LXXXV, Mr., now Sir Benjamin Baker, said that on the Erie railroad, the price for sleepers was three shillings and three pence for oak, lasting seven years, two shillings and ninepence for chestnut, lasting five years, and one shilling and ninepence for hemlock, lasting three and a-half years; the average was therefore about sixpence per annum per sleeper for renewals. Now our ironbark sleepers will cost on an average about four shillings and sixpence, and last over twenty years, which will give about twopence farthing per annum, besides saving the labour of three to six relayings.

So called economy must not take therefore the form of the supply of inferior material in sleepers, the best being emphatically the cheapest. But if light engines be used their number may be reduced. The bearing area of the sleepers on the ballast on the New South Wales railways is about twelve thousand square feet per mile. On the Midland, and London and North Western this area is fourteen thousand five hundred and twenty and thirteen thousand two hundred square feet respectively, but very high speeds have to be dealt with in these cases. On the narrow gauge railways in India the same area is eight thousand square feet, on those of the Cape Colony it is nine thousand two hundred and forty square feet, and on the Festiniog two feet gauge, about six thousand five hundred square feet. The author is no advocate for a change of gauge, as will be shewn later, but there seems no reason why the supporting power, as represented by the area of contact of the sleeper with the ballast, should not be reduced in the same proportion as the weight on the axle is reduced.

The true criterion of a light line is the weight per axle it has to bear, and not the distance between the rails, or gauge, in fact a narrow gauge line might be nearly as heavy as a broader gauge one in this respect. For example, the gauge of the Indian branch lines is seventy per cent. greater than that of the Festiniog line, but the bearing surface is only twenty-eight per cent. greater. The gauge of the New South Wales lines is one hundred and forty-four per cent. greater than the Festiniog line, but the bearing surface is only ninety-two per cent. more. The Festiniog line of two feet gauge carries five tons on an axle, while the Lombardy four feet eight and a-half inches gauge light lines carry only four and a-half tons per axle, the bearing surface being only slightly more. Now reducing the number of the sleepers is the best way of lightening the road, as, should the axle weights be increased by growth of traffic, or other cause, subsequently, the addition of extra sleepers is comparatively easy and cheap.

Diminishing ballast is also a convenient way of lightening the road; ballast serves not only as a means of drainage for the sleepers, and as a cushion between the load and the formation, but distributes the load through the sleeper, carrying it down to a wider base on the formation, as it spreads out; the deeper the ballast under sleeper level the wider therefore this base is, of course, under each sleeper. This reduction of ballast also has the advantage of enabling reversion to a heavier construction being conveniently and cheaply made when a stronger road is required.

On the other hand, caution should be used in diminishing the weight of the rail, the strength of the rail decreasing much more rapidly than its weight and cost. Should we find our traffic increasing beyond the power of the rail to bear it, we have, assuming no addition to the number of the sleepers, to take up what may be comparatively unworn rails and replace them with heavier ones, an operation costing, with the extra freights, probably quite as much as the difference in original cost between light and heavy rails. The difference between the cost of a sixty pound and forty-five pound rail, at present prices, does not amount to more than about four to five per cent. on the total cost of even the cheapest line, and looking at it in another way, the saving in interest, at say four per cent. by adopting the lighter rail would be between £6 and £7 per annum per mile, but against this would be the extra labour in maintaining the lighter road.

Now looking at the advantages of the heavier rail, in holding up the road, and taking the labour of maintenance at £60 to £70 per annum per mile, it is certain that more than ten per cent would have to be added to the last figures in the case of the lighter rail. Then, independently of strength, there is the greater life as regards wear of the heavier rail, and, what is not often considered, its greater advantage in the carriage of material and ballast during construction, over unfinished road beds, possibly in this alone recovering a considerable portion of its first cost.

The actual bearing surface of the sleepers per mile should be fixed by the maximum weight on an axle, and some actual examples may guide us in this. On the Indian narrow gauge lines, seven tons on an axle are supported by two thousand sleepers per mile of eight thousand square feet bearing surface, forty-one pound rails being used. In the Cape, the author worked thirty ton tank engines, having nearly eight tons on an axle, on one thousand seven hundred and sixty sleepers per mile, having a bearing surface of nine thousand two hundred and forty square feet, forty-five pound iron rails being used, these latter were then as dear as sixty pound steel rails are now. On the Festiniog one foot eleven and a half inch gauge, the axle weight is five tons, the bearing surface about six thousand five hundred square feet per mile, and the rail forty-eight and two-thirds pounds. In New South Wales, if a few vehicles, mostly unsuited for light traffic, were excluded, the axle weight, exclusive of locomotives, would not exceed eight tons on an axle, and is generally much less ; if therefore suitable engines could be designed to have no greater axle weight than say eight tons, a permanent way equal in bearing power to that of the Cape lines would be sufficient.

Taking the standard gauge eight feet sleepers as against the seven feet Cape ones, their other dimensions being the same, it will be found that sixty pound rails with one thousand five hundred and forty sleepers to the mile will be rather stronger than the Cape permanent way with the same bearing surface, and with the advantage of having the strength more concentrated in the rails as already advocated.* The Cape rails were of iron, whereas the present sixty pound rails are of steel, which gives another advantage to the road now advocated.

Now as to ballast, in the sense of increasing bearing surface on the formation. The present bearing surface of sleepers in New South Wales is twelve thousand square feet per mile, and, if the ballast may be taken to spread out at say one and a-half to one slope, the six inches depth which is now the standard under the nine inch wide sleeper, trebles the bearing on the formation, which is approximately therefore thirty-six thousand square feet per mile. If we reduce the maximum axle weight by about one half of that now imposed on the road, which is the proposal, we may reduce the latter item one half, or to eighteen thousand, and this divided by one thousand five hundred and forty the proposed number of sleepers will give nearly twelve square feet under each sleeper or equivalent to three inches depth of ballast.

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* The comparison of forty-five pound rails with one thousand seven hundred and sixty sleepers to the mile, as against sixty pound rails with one thousand five hundred and forty sleepers is arrived at in the following way. The weights of these rails are as three to four, and as the stiffness of rails of same material with same distance between supports, varies approximately as square of weight of rail; therefore stiffness of forty-five pounds rail : stiffness of sixty pounds rail : : 9 : 16. Now, if required stiffness be taken as represented by 9, and as the stiffness of any rail varies inversely as the cube of the distance between the supports, or what is the same thing, directly as the cube of the number of sleepers per mile, then, if N be the required equivalent number,

16 (the stiffness of 60lb rail with 1760 sleepers) : 9 : : $1760^3 : N^3$

$$\text{and } N = \sqrt[3]{\frac{9 \times 1760^3}{16}} = 1453$$

so that a sixty pound rail with one thousand four hundred and fifty-three supports per mile would be as stiff as a forty-five pounds one with one thousand seven hundred and sixty; but to preserve same bearing surface of sleepers as the forty-five pound road, with which it is compared, namely nine thousand two hundred and forty square feet per mile, we must have one thousand five hundred and forty sleepers, so we have a slight excess of stiffness in the sixty pound road proposed.

Another item which might be reduced is the fastenings of rail to sleeper, and this is one of those parts which can be readily increased in strength to meet possible enlargement of traffic. For such a load and speed as that now contemplated four half pound dog spikes per sleeper alone without screws, even in soft wood sleepers, have been used successfully, but as heavier rails are in question it would be better to provide screws at the joints. This would reduce the present weight of all the fastenings from eight tons three hundred weight, to six tons fifteen hundred weight, per mile.

Taking these reductions into consideration, and at rates taken from estimates, on a fair system of averages not including extreme or exceptional cases, of lines aggregating over two thousand miles, we may arrive at the following limits of cost, the first column shewing results under the most favourable circumstances, and the second those where the reverse is the case. As it is most unlikely that either of these conditions will apply to all items, the probable cost will generally lie between the two.

The price of steel rails and the freight from sea-board to destination, which are both variable items, are taken together at £7 per ton in both columns; it is obvious that if the outside probable limits of these were taken the range between the lower and higher estimate might be separated still more by £400 or £500 per mile. As to these estimates, it may be said that, owing to the absorption of practically all public works by the Government in this colony, the experience as to cost of railway work here is almost exclusively in the possession of the Public Works Department, and that experience may be fairly said to be especially trustworthy, being based on the lowest tenders of numerously competing practical contractors for many years back.

Estimated cost per mile exclusive of land and rolling stock :—

	£		£
Earthwork	300	to	1,500
Culverts	25	to	260
Timber Bridges	80	to	700
Road Diversions	20	to	100

Permanent Way:—	£		
Ballast 1,100 cubic yards	275		
Rails	660		
Fastenings	92		
Sleepers	346		
Laying	154		
Sidings 4 per cent. on above items	61		
Points and Crossings	18	£	£
		1,606	1,606
Shelter for Goods		20	20
Water Supply		15 to	60
Cattle Stops in lieu of Fencing		20 to	40
Triangles in lieu of Turntables		24	24
Engine Shed, etc.		20 to	40
		2,130 to	4,350
Engineering and Contingencies 10 per cent. ...		213 to	435
		£2,343 to	£4,785

Allowing for difference of requirements, debits and credits, to make the comparison fair, £3,343 per mile was the actual expenditure on an average light section twenty-five miles long under the author's superintendence at the Cape, having the same weight to carry. This, though of narrower gauge, has the same supporting power on the sleepers as the above, but more ballast, there being ten inches under the rail, amounting to two thousand four hundred and sixty-four cubic yards per mile; reducing the ballast to same basis as above would bring the cost down to £3,166 per mile. There has been constructed a considerable mileage of light surface tramways or railways on the level plains of Lombardy, on the standard gauge, having many features analogous to those proposed in this paper, and costing on a average about £2,750 per mile, but they have a bearing surface of between seven thousand and eight thousand square feet only, per mile, and are called on to support only about four and a-half tons on an axle, which would be too light for New South Wales waggon and coaching stock. It must also be remembered that wages in Lombardy are about one third of those in this colony, while the work done for them, from the author's own experience, is from seventy-five to ninety per cent. of that of an Englishman. The northern Italians differ widely from the southerns in this respect. In fact high wages and cheap railways are antagonistic elements.

There is no doubt that safe railways can be made cheaper than the minimum here set forth, even in this country, but it will be with the disadvantages of being insufficient to carry the present carriage and waggon stock, without very heavy charges for maintenance ; or, by constructing with inferior material, with the same result in more frequent renewals. Policy might possibly shew that a more important diminution of capital expenditure and interest might be obtained by this proceeding, but it is one that should be entered on with full knowledge of its results.

A paper on light railways can hardly conclude without alluding to the proposals which have been made to add to the drawback of break of gauge already experienced by Australian intercolonial lines, by introducing a gauge smaller than the standard one for future branch lines of this colony. This paper embodies the results of experience on nearly all gauges, and expresses no preference for any one of them; each has its appropriate function to which it is applied, but it desires to express a strong opinion against mixing them, in one country or colony. A long and fruitless discussion took place, a few years ago, at the Institution of Civil Engineers on the relative merits of the two Indian gauges, after several years' experience of both ; but there need be no hesitation in saying that, notwithstanding the number of distinguished authorities who took part in it, there was absolutely no result of the slightest good to anybody, from it.

They were comparing two essentially different things. The broad gauge lines were carrying main line traffic, were bridged across wide rivers for such essential connection with capital towns, etc., as their conditions demanded, and they had an average age of seventeen and a-half years, implying many renewals of way and stock. The narrow gauge lines were chiefly branches, most of which would not have been made at all, if large rivers or other engineering difficulties had to be met, and they were only five and a-half years old, with consequently little or no renewals. It was like asking which is better, an ocean steamer, or a ferry boat, without stating whether you want to cross the Atlantic or the Thames.

There was "much throwing about of brains," as Shakespeare says, on that occasion. In fact the solitary fact in the whole of the paper, that would be of any use to any controversy on the subject, was the uncontradicted statement, which was certainly not to be expected, that the proportion of paying to dead load was slightly in favour of the broad gauge. But the excellence of any particular non-standard gauge is not now in question, unless the advantages of it are shewn to over-balance the drawbacks of the break, and it will now be briefly stated what such drawbacks are:

First, there is the cost of transhipment, which perhaps is the least important. This amounts to four pence per ton on an average on the Irish lines, and taking difference of wages into account, would probably be seven pence here, equivalent to about seven miles of haulage. Now on every branch railway there is about ten miles of it, next the parent line, which, though it has to be constructed, is wholly unprofitable as a feeder, the local traffic still going to the main line direct. Should transhipment of goods and cattle be necessary at the junction, this unprofitable distance is thus practically increased to seventeen miles, a goodly proportion of many a branch.

Secondly, there is the shutting out of the branch as an asylum for old rolling stock. A serious objection to the present proposals of this paper is the closing of the branch lines to old locomotive stock, but a break of gauge would increase this objection enormously by closing them to all stock. An idea of this may be formed from the fact that on June 30, 1892, while there were on the New South Wales lines four hundred and eighty-nine engines, there were eleven thousand five hundred and nine carriages and waggons.

Thirdly, everyone knows that traffic on all lines varies with the seasons. Not only is the wool traffic intermittent, and at different times in each district, but even the occurrence of races, agricultural shows, etc., makes an important variation in the business to be done. On standard gauge branches, the want of rolling stock on one, may be met by the superfluity of another, or of the main line, and an average stock suffices for the whole. If narrow gauge branches existed, isolated from each other, either every branch would have to be provided with its maximum requirements, which might be wanted only for one month in the year, with the extra stock lying idle between times, or, during pressure, the wants of the traffic could not be met, to the great loss of the department and the dissatisfaction of the public.

Fourthly, the last drawback to be mentioned is perhaps the most fatal of all. In the Railway Commissioners' report for the year ending June 1890, out of a total of four hundred and forty-two engines running all over the lines no less than two hundred and twenty were put through the main repairing shops at Eveleigh and Newcastle for repairs. In the year ending June 30, 1891, out of four hundred and thirty-nine, two hundred and seventy-two were so dealt with, and in the last year's report out of four hundred and eighty-nine, two hundred and thirty were repaired in the main shops. Now the Commissioners know their business better than to bring no less than fifty-three per cent. of their engines for repairs, up to Sydney and Newcastle, unless it is clearly more economical to do so, and this is intelligible, because it saves multiplying expensive machinery, and maintaining highly paid artisans in outlying districts, where they might not be fully employed, whereas the engines are probably utilized in their journeys to the shed and back. With regard to coaching, goods, and cattle stock, out of an average stock of ten thousand nine hundred and forty-six vehicles, for the three years mentioned, no less than sixty-six per cent. were through the two main shops for repairs. After deducting from these figures the stock which in any case, from their nearness, would have gone to the Sydney and Newcastle shops for repairs, small and great, there still would remain a very large percentage (for the above figures are exclusive of what are called mere running repairs), of all classes of stock being brought up to head quarters, for repair, from branch lines.

Now in the case of break of gauge, either expensive repairing shops with all their appliances would have to be established with a staff of skilled mechanics at every small branch ; or else the branch engines and other stock wanting heavier repairs would have to be loaded up, on specially made trucks, and carried to and fro, as dead weight, to head quarters.

Those who advocate narrow gauge branches will have therefore to show that their advantages over-balance these drawbacks, and in this connection, it may be repeated that the lightness or cheapness of a railway does not so much depend upon the mere width between its rails, as upon the axle weight it has to carry, and the speed of its traffic. It is no argument to say that branches, with change of gauge, have served their purpose in France and in Ireland, unless it is also shewn that, if they had been of the standard gauge of those countries, they would not have served their purpose better ; and even if this were proved in favour of the break, it would not be a conclusive argument in the case of places so differently circumstanced as these Colonies are from those older lands. We have a population in this country of perhaps three or four to the square mile, they have probably three hundred or four hundred, the latter indicating an amount of traffic sufficient to neutralize, to a large extent, the evils of isolation. It is comparing things which are totally unlike; it is the special care of this paper to compare like with like, as far as possible, and to take the opposite course is likely to lead to very false conclusions. Isolation, which is intensified by smallness of traffic, is the great objection to break of gauge; it is a popular objection to the narrower gauges that they are insufficient for their work, but this is a mistake, certainly as regards the traffic of any branch in New South Wales, as the author's experience with such lines shews them to be ample. The little Festiniog line used to carry over four hundred tons per day. The objection is not to the insufficiency, but to the isolation.

The conclusion therefore, which this paper maintains is, that, generally, considerable cheapening of branch line construction can be made by lessening requirements and by improved locomotive design; but that there is a limit, beyond which any considerable cheapening in capital expenditure will be more than overbalanced by excessive working expenses. An attempt has been also made to indicate what that limit is, as far as can be done, without having the ever varying circumstances of each particular project in view. In conclusion, the author would add that he presents this paper with the full concurrence of the Engineer-in-Chief for Railways, who however is not necessarily in agreement with it in every particular.

FLYING-MACHINE MOTORS AND CELLULAR KITES.

By Lawrence Hargrave.

[With Plates I. – IV.]

[*Read before the Royal Society of N. S. Wales, June 7, 1893.*]

No. 18 Engine (*Plate* I.) is the second steam motor for a flying-machine made by the writer. Its total weight without spirits, water, or body plane, is five pounds eleven ounces. This weight includes six feet nine inches of one and a-half inch by one-quarter inch redwood forming the strut for the body plane.

Eleven different burners have been tried. The most reliable arrangement is to put all the spirit on at once. The flame is steadier than that of No. 17, in consequence of the spirit being heated by its own flame before it has passed between some of the turns of the water boiler. The flame striking the water boiler first has a tendency to vary the supply of heat to the spirit holder. Some of the first burners were supplied with spirit by a feed pump.

Four boilers have been made. The one shown in *Plate* I has three coils, 1·6 in., 2·6 in. and 3·6 in. respective diameters, made of twenty-one feet of copper pipe, ·25 in. external, and ·18 in. internal diameters, weighing thirty-seven ounces. It is now known that a coil of equal capacity can be made weighing only eight ounces, and still be excessively strong.

The cylinder of No. 18 is 2 inches diameter, and the stroke is 2·52 in. The feed pump ram is ·266 in. diameter. The piston valves are ·3 in. diameter. The $\frac{1}{16}$ in. steel linkwork and brackets on the cylinder bottom are too light, and will not stand the rough usage required of them.

The wings are fourteen inches from the fulcrum to the inner edge of the paper surface. The paper is twenty-two inches long, four inches wide at the inner end, and nine inches wide at the tip. The dimensions are the same as in No. 17 with the addition of thirty-two and a-half square inches area at the tip of each wing.

On one occasion this motor evaporated 14·7 cubic inches of water with 4·13 cubic inches of spirit in forty seconds. During a portion of the time it was working at a speed of one hundred and seventy-one double vibrations per minute. The indigram shows a nett mean pressure of 95·6 lbs. per square inch, which makes the maximum indicated horse power ·653. Could this speed be relied on continuously for a few minutes, the comparison between Nos. 17 and 18 would stand thus :—

No. 17 with 5 oz. of fuel and water indicates ·169 H. P. and weighs 3¼ lbs.
No. 18 „ 21 oz. „ „ „ ·653 H. P. „ 7 lbs.

That is, roughly, the weight of motor has been doubled and the power increased fourfold.

Comparing the area of wings, the speed of the engines and the wing arcs being nearly the same, the extra ·48 H.P. is absorbed in driving the sixty-five square inches of extra surface at the tips of the wings. The following tabular statement of some of the results of No. 18 will be a guide to anyone experimenting with engines of this size and quality of workmanship :—

Date of Trial 1892.	Spirits burnt, Cubic inches.	Water pumped, Cubic inches.	Double vibrations.	Time—Seconds.
Nov. 25	4·13	14·7	74	40
Dec. 5	3·03	15·57	104	80
„ 7	3·46	23·78	248	240
„ 7	3·46	19·0	152	116
„ 10	3·46	20·76	160	140
„ 14	3·46	10·81	100	70
„ 14	3·03	13·84	85	63
„ 16	3·46	30·27	206	152
„ 16	3·46	12·9	100	56

Some thrust diagrams were taken from No. 18, showing that 1·75 double vibrations per second produced a thrust of one pound. It takes 2·36 double vibrations per second of No. 17 to produce one pound of thrust.

Three steam two-bladed screw motors (*Plate* 2), were made; the screw arms being hollow with steam jet holes 5.5 in. from the boss and the jets reacted at right angles to the direction the blades were moving in. When the water was pumped into the boiler by hand, a thrust of over half a pound was obtained, but the bearing soon got hot and stuck. When a feed pump was attached, driven by an eccentric on the boss of the screw, the speed of revolution was reduced so much that the motor was practically ineffective, besides which there was great difficulty in getting a very small pump to work at a high speed.

Before beginning another motor it was thought advisable to try whether a better disposition of the supporting surface, or body-plane as the writer terms it, could not be found out; and at the same time to see if any foundation could be discovered for the assertion that birds utilize the wind in soaring. No amount of observation of birds will solve the soaring problem; it can alone be done by making some form of apparatus that will advance against the wind without losing its elevation.

The expense of constructing and erecting a large whirling machine similar to Prof. Langley's or Mr. H. S. Maxim's being too great, and knowledge of the fact that planes or other things moving at the end of an arm through still air are not under the same conditions as bodies flying in disturbed air, determined the selection of kites as the best means to the desired end.

Plates 3 *and* 4, are some of the kites, and are sufficient to indicate the extent of the field now open for experiment. The novelty, if any, consists in the combination of two well known facts.

First, that the necessary surface for supporting heavy weights may be composed of parallel strips superposed with an interval between them. (Described by Wenham in 1866 and adopted by Stringfellow in 1868. The writer made an experiment in 1889 with superposed planes, but failed to show that any additional support was obtained. Prof. Langley showed by inference that there is an additional support, pages 33 and 47 of "Experiments in Ærodynamics," 1891.)

Second, that two planes separated by an interval in the direction of motion are more stable than when conjoined. (Patented by Danjard in 1871, made and exhibited by D. S. Brown in 1874.)*

The form the complete kite assumes is like two pieces of honeycomb put on the ends of a stick, the stick being parallel to the axes of the cells. The cells may be of any section or number; the rectangular cells are easiest to make, and, if the stick or strut between the two sets is placed centrally, as in kites B. C., it is immaterial which side is up. Practically, the top or bottom is determined by imperfections in the construction. This is of particular advantage for flying-machines driven by a single screw. The rectangular form of cell is also collapsible when one diagonal tie is disconnected.

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* In "The American Engineer and Railroad Journal" Vol. LXVII., No. 3, Mr. O. Chanute states, that, Mr. H. F. Phillips patented in 1890 an ærial vehicle with superposed surfaces in two or more series, the surfaces might be fifteen feet long, six inches wide, and two inches apart; no mention being made of vertical surface which the writer finds essential to stability. Prof. Langley shows that the distance apart of the superposed surfaces cannot, with advantage, be less than eighty-three per cent. of the width of the planes.

These kites have a fine angle of incidence, so that they correspond with the flying-machines they are meant to represent, and differ from the kites of our youth, which we recollect floating at an angle of about 45°, in which position the lift and drift are about equal. The fine angle makes the lift largely exceed the drift and brings the kite so that the upper part of the string is nearly vertical. Theoretically, if the kite is perfect in construction and the wind steady, the string could be attached infinitely near the centre of the stick, and the kite would fly very near the zenith. It is obvious that any number of kites may be strung together on the same line, and that there is no limit to the weight that may be buoyed up in a breeze by means of light and hand tackle.

The next step is clear enough, namely, that a flying-machine with acres of surface can be safely got underway, or anchored and hauled to the ground by means of the string of kites. If the string of kites gets into contrary currents of air, kites and suspended weight may be disconnected from the earth and will remain supported, drifting in a resultant direction determined by the force of each current and the number of kites exposed to it.

Kites E. and F. are of equal weight and area. In E. the horizontal surfaces are curved, with the convex sides up; F. has all the surfaces plain. Roughly, E. pulls twice as hard on the string as F. does. So that a flying-machine with curved surfaces would be better than one with a flat body plane, if the form could be made with the same weight of material. This is proved in another, the old windmill, shown in the paper last year; this was fitted with four flat sails which could be changed for four curved ones. When the flat sails are turned so that they and the axis are in two planes no rotation takes place. But when the curved sails are put on symmetrically with the chords of the curves and the axis in two planes, there is a slow and powerful rotation in the direction of the convex sides of the sails. Rotation ceases when the sails are twisted in their sockets, so that the wind is tangential to the curve of the sails about three-fourths of their width from the forward edge.

There is no doubt that the wind drawing into and striking the concave side of the sail is more powerful than the current impinging direct on to the forward part of the concave side, although the hollow surface is altogether masked by the rounded surface. Both the kite and the windmill experiments refer to moving air passing stationary bodies.

When the kites E. and F. are discharged from the crossbow in calm air, they both have the same trajectory. It is difficult to imagine a more convincing or simpler proof that the laws governing the motion of a body through still air are distinct from those that determine its action when moving through wind. Evidently a machine with curved surfaces flying against the wind would come to grief if the wind fell calm, unless provision had been made for either increasing the surface or the driving power. No experiments have been made here yet to determine what support disturbed air gives to surfaces travelling in the same direction and faster than the wind. We are therefore on sure ground when we make our surfaces as flat as possible, and of sufficient size to support the machine in calm air; should the air become disturbed, the same horizontal speed by log could then be maintained by reducing the driving power and the angle of incidence.

As to the solution of the soaring problem, the only fact observed is, that on a gusty day, kites E. and F. both shoot up nearly overhead and slack the string into a deep bight, then drift away to leeward until the string brings them up again. This wants careful and undisturbed observation—the writer unfortunately had to experiment in public. It is clear that the wind must be considered as volumes of air of different densities.

Kite Z. has four flat planes four inches by fifteen inches. The angle between each pair of planes is 108°. A similar one with curved sails was difficult to adjust; both flew fairly well but they cannot be compared with the cellular form for steadiness; and it is certain that the numerous accidents that have happened to the india-rubber, and compressed air driven machines have been solely due to imperfections in the flat or V-shaped body planes.

PARTICULARS OF KITES.

Name.	No. of cells in each section.	Length of each cell parallel to the connecting stick.	Breadth of each cell horizontally at right angles to the stick.	Height of each cell vertically at right angles to the stick.	Radius of curv'd horizontal surface.	Length of the stick between the sections.	Material of which the surfaces are made.	Point of attachment of string is distant from forward section	Weight of kite in ounces.
A	7	2″	*3·75″	*3·75″		24″	paper	4″	2·5
B	1	4·5″	†13″	†13″		30″	aluminium	11″	14·75
C	16	3″	3″	3″		22″	cardboard	6·5″	10·5
D	3	4″	13·13″	4″	4·5″	31·63″	wood & paper	12″	11·
E	1	4″	10·7″	6·25″	4·5″	21·25″	wood & paper	7·25″	3·25
F	1	4″	10·7″	6·25″		21·25″	wood & paper	7·25″	3·25

* Distorted cylinder. † Cylindrical.

The motor exhibited embodies all the latest improvements, notably the boiler, which is a fourteen feet length of one-quarter inch solid drawn copper pipe, which has been reduced from one and a-half pounds to thirteen and a-half ounces at one cut by the cutter, which is also exhibited. This is one of those trifles that render it possible to use the ordinary materials of commerce without having to send to Europe for the finished article specially drawn to gauge. By using the cutter, the job was done in one and a-half hour ; by sending home for it the pipe might have been here in four months. The hollow steel screw shaft 10·8 m. diameter and ·3 m. gauge seems to be all that is required. The sample shown was tested to destruction ; one hundred and forty pounds at two inch radius wrung it as you see.

NOTES AND ANALYSIS OF A METALLIC METEORITE FROM MOONBI, NEAR TAMWORTH, N. S. WALES.

By JOHN C. H. MINGAYE, F.C.S., M.A.I.M.E., Analyst and Assayer to the Department of Mines.

[With Plates V. and VI.]

[Read before the Royal Society of N. S. Wales, June 7, 1893.]

THIS meteorite was discovered by a Mr. Langston about twelve months ago, on the top of one of the ridges of the main Moonbi Range, about eighteen miles from Moonbi township, on the Northern Railway Line. It attracted attention from the fact that all the country around is of granite formation. The meteorite was not embedded, but was found lying on the surface, and had been probably placed in that position by the blacks of that neighbourhood.

An average sample of the meteorite in the form of a fine powder obtained by boring a hole in it, was sent by the Government Geologist (Mr. E. F. Pittman, A.R.S.M.), to the laboratory for analysis on the 24th March, 1892. The total weight of the meteorite was about twenty-nine pounds, the specific gravity of the mass being 7·681; the specific gravity of fragments was found to be slightly higher, viz., 7·833 at 15·5° C.

The following is the result of an analysis :—

Chemical Composition—

Metallic Iron	91·350
Metallic Nickel	7·886
Metallic Cobalt	·564
Metallic Copper	a minute trace
Metallic Tin	·003
Metallic Chromium	trace
Carbon (Graphite)	·068
Combined Carbon	trace

Silica	·039
Sulphur	absent
Phosphorus	·217
Oxygen	trace
	100·127

The surface is coated with a black hard skin of magnetic oxide of iron, about the thickness of ordinary writing paper.

The occluded gases were kindly determined by Mr. W. M. Hamlet, F.I.C., F.C.S., but as I found out afterwards that the meteorite had been heated in a blacksmith's forge, prior to reaching the Department of Mines, the results obtained are of little value, although showing the presence of occluded gases; the amount would have no doubt been much higher if the meteorite had not been heated.

Occluded Gases—

100 grammes gave 55·37 cc. of gas at 0° C. and 760 mm. pressure

Hydrogen	31·42	,,	,,
Nitrogen	23·95	,,	,,
	55·37		

The composition of this meteorite is somewhat similar to one found at Bingera,* New South Wales, but containing less iron, and more nickel. It may be described as a metallic meteorite of the class known as siderites.

I am indebted to the Rev. J. Milne Curran, F.G.S., for particulars as to the finding of the meteorite, he having kindly made enquiries during a visit to the district.

* Minerals of New South Wales—Prof. Liversidge, p. 218.

PLANTS WITH THEIR HABITATS,

Discovered to be indigenous to this Colony since the publication of the Handbook of the Flora of New South Wales; chiefly furnished by Baron von Mueller, from unpublished Herbarium notes.

By Charles Moore, F.L.S., &c.

[*Read before the Royal Society of N. S. Wales, June 7, 1893.*]

Ficus platypoda, Cunn.—Benth. Fl. Austr. iii. 169. North-western interior.

Atriplex lobativalve, F.v.M.—Victorian Naturalist, April 1893. Murray River.

Bassia longicuspis, F.v.M.—Victorian Naturalist, April 1893. Murray River.

Bassia tricornis, F.v.M.—Benth. Fl. Austr. v. 191 (as *Chenolea*). Murray River.

Kochia planifolia, F.v.M.—Benth. Fl. Austr. v. 187. Murray River.

Crotalaria Cunninghamii, R. Br.—Benth. Fl. Austr. ii. 182. Near Grey Range.

Potentilla anserina, Linn.—Benth. Fl. Austr. ii. 429. Table-land south of Cooma.

Decaspermum paniculatum, Baill.—Benth. Fl. Austr. iii. 279. Richmond River.

Hakea Bakeriana, F.v.M. & Maiden—Proc. Linn. Soc., N.S.W. 1893. Wallsend, near Newcastle.

Grevillea Barklyana, F.v.M.—Benth. Fl. Austr. V. 436. Southern parts of Dividing Range.

Xylomelum salicinum, Cunn.—Benth. Fl. Austr. V. 408. Warrego River.

Coprosma repens, J. Hook.—Benth. Fl. Austr. iii. 430 (as *C. pumila).* Mount Kosciusko Range.

ASTER PICRIDIFOLIUS, F.v.M.—Benth. Fl. Austr. iii. 487 (as *Olearia).* Murray River.

CUSCUTA TASMANICA, Engelm.—Benth. Fl. Austr. iv. 441. Murray River.

BRACHYLOMA SCORTECHINII, F.v.M.—Fragm. Phytogr. xi. 126. Point Danger.

CYMODOCEA ZOSTERIFOLIA, F.v.M.—Benth. Fl. Austr. vii. 177 (as *C. antarctica).* Twofold Bay.

SCHŒNUS CAPILLARIS, F.v.M.—Benth. Fl. Austr. vii. 377 (as *Elynanthus capillaceus).* Twofold Bay.

ANDROPOGON ANNULATUS, Forsk.—Benth. Fl. Austr. vii. 531 Northern interior.

ANDROPOGON EXALTATUS, R. Br.—Benth. Fl. Austr. vii. 532. Northern interior.

ISCHÆMUM LAXUM, R. Br.—Benth. Fl. Austr. vii. 522. Near Tamworth.

PSILOTUM COMPLANATUM, R. Br.—Benth. Fl. Austr. vii. 682. Richmond River.

ANGIOPTERIS EVECTA, Hoffm.—Benth. Fl. Austr. vii. 694. Mount Sea View.

MARATTIA FRAXINEA, Smith—Benth. Fl. Austr. vii. 695. Mount Sea View.

CYSTOPTERIS FRAGILIS, Bernh.—Benth. Fl. Austr. vii. 752. Sources of Genoa River.

DESCRIPTION OF A NEW MYRTACEOUS TREE INDIGENOUS TO NEW SOUTH WALES.

EUGENIA PARVIFOLIA, C. Moore.

A tall compact bushy shrub or small tree, quite glabrous, with pinkish coloured young shoots. Leaves ovate-lanceolate, one to one and a-half inches long, tapering to a long but obtuse point. Flowers white, small, in short racemes, terminal, or more rarely in the upper axils, generally in pairs on the slender pedicels. Calyx-lobes and petals five, the calyx much attenuated towards the base. Fruits coral-red, pear-shaped but flat at the top, almost turbinate, about half inch an long; seeds globular, solitary in the fruit.

Habitat Richmond River, in thick brush forests.

A handsome, neat, compact growing tree, distinguished from all other New South Wales species of the genus by the pear-shaped bright red fruits.

ON THE WHIP-WORM OF THE RAT'S LIVER.

By Thos. L. Bancroft, M.B. *Edin.*

[With Plates VII. and VIII.]

Communicated by J. H. Maiden, F.L.S., &c.

[*Read before the Royal Society of N. S. Wales, June 7, 1893.*]

Early in 1891, masses of worm eggs were discovered in the liver of the common rat; to the naked eye they appeared like the psorospermal nodules of *Coccidium oviforme.* Almost every rat had its liver so affected, even individuals of two months old were not exempt. White rats in my possession were free from this parasite, which was a fortunate circumstance, allowing of feeding experiments to be made upon them with the prospect of following the worm through its different stages. At an early period of this investigation no parent worms were found in the livers. Livers containing eggs were given to white rats and were eaten by them; their dung afterwards contained the eggs unchanged. Several months later these rats were killed, and search made for the parasite, but no trace of it could be found; evidently some further development of the egg was needed. Healthy rats living with affected ones in cages do not contract the disease.

On April 2nd, 1891, some egg masses were put into water and examined microscopically every few days, but up to three months, when the experiment was abandoned for a time, no change had manifested itself. No further examination was made until on July 6th, 1892; the yelk substance was then seen to have differentiated into a worm, which was coiled up in a figure of eight; gentle pressure of the cover glass caused expulsion of the embryos; fig. 1 shews the mature eggs, fig. 2 after pressure of the cover glass.

Two white rats were fed with the mature eggs on August 23, 24, 25, 1892; in three weeks these rats were seen to be ill, they suffered from dyspnœa, were emaciated, refused food and had diarrhœa; on September 19, one was killed, and on September 22, the other died; their livers were diseased to an extent far exceeding anything previously seen, due of course to the large number of eggs which had been swallowed. The liver was pale yellow in colour, and was riddled with long thread-like worms and contained their eggs in thousands. The worms when microscopically examined were seen to be the parents of the eggs; it was impossible to dissect out a specimen unmutilated, so intricately were they intertwined and attached to the liver substance. I succeeded best by squeezing pieces of the liver between two plates of glass, and afterwards teasing them under water with needles. Hardening the liver previously in alcohol increases the difficulty; livers of very young rats are the best for this purpose.

Many feeding experiments have been made, and with the result that if a large number of eggs are given, the rats die in three to four weeks; if only a small number of eggs they recover, and if their livers be examined some months later, they will be found to have regained the normal state, but have white spots [egg masses] dotted over them.

If a piece of the liver in which the *Trichocephalus* is burrowing to deposit its eggs be hardened and sections cut, many of the cells are seen to be in process of absorption, many have entirely disappeared, connective tissue elements taking their place. Those cells, which have not atrophied, are increased in size and have large nuclei, probably due to extra work being thrown upon them, either as scavengers of the dead cells or in carrying on the normal function of the liver, see Fig. 7. Atrophy of the cells is due to pressure of the worms, and seems to occur without cloudy swelling or fatty degeneration; the protoplasm becomes absorbed, nothing being left but the enlarged nucleus, this then becomes fainter and fainter until it has disappeared. Extravasation of blood occurs along the tracks of some of the worms. Pieces of the worm are seen throughout the liver substance, apparently not following any particular vessels, although the great mass of eggs seem to be deposited in the portal canals, frequently in the hepatic artery. During the invasion of the worms the liver is in a state of acute atrophy, but after they have deposited their eggs, died, and been absorbed, which takes two or three weeks, the organ rapidly recovers itself, and but for the resultant cirrhosis, presents a normal appearance. Fibrinous pericarditis was present in those that were seriously affected by the parasite, and probably accounts for the dyspnœa, which is so marked a feature.

The eggs die and become calcareous if a long interval elapse between infection and the rat's death. One rat was examined six months after having been fed with a small number of mature eggs, and many of the eggs in its liver were found in a calcareous state. The eggs having been deposited in the liver remain there until the death of the rat; they never seem to occasion abscesses, nor pass to the intestine by the bile duct. Eggs in water placed in the sun die, and their protoplasm contracts to a ball. No experiments have yet been made to try if maturity can be hastened by recourse to the incubator.

To ascertain how soon the eggs mature in water in the shade, the following experiment was made :—On July 13, 1892, some eggs were put into water, and on September 1, they were examined but no apparent change had occurred :—on October 11 they were again examined, the protoplasm was noticed to be altered slightly, in some it appeared to have divided into four :—on November 24 the alteration was more pronounced, and in many faint traces of the embryo worms could be seen :—on December 12, perfect worms were visible. In five months therefore the worms appear, still they are even then not mature, for great pressure is required to cause their extrusion from the shells.

It appears that after maturing, the worms do not escape from the shells whilst in water, and they live for a considerable time; at the time of writing, April 17, 1893, the eggs placed in water two years ago are still alive. Several experiments were made to trace the embryos after their introduction to the stomach of a rat. It was thought that they would live for a time in the intestinal tract. Rats were fed with eggs and killed in two days, in seven, and in fourteen days, but these experiments did not give me much information. No trace whatever could be found of the worms until a fortnight had elapsed after feeding, when they were seen to be in the liver, not mature however. It would appear then that the embryos find their way to the liver at an early date and there develop to maturity, pair, and after impregnation the females lay their eggs; the worms then die.

I have hitherto, neither been able to find the presence of *Trichocephalus nodosus* in the intestinal canal, nor of *Trichosoma crassicauda* in the bladder of rats. No account is given by Cobbold or Leuckart, in their excellent treatises on worms, of a parasite similar to the subject of this paper. Had they been acquainted with it they would, in all probability, have made mention of it. I have no opportunity, living in Brisbane, to consult many works on helminthology, to find out if this parasite had been described. Mr. Henry Tryon has kindly searched through what books there are in the Brisbane Museum, and has found one reference apparently to it, viz.:—(in the "American Microscopical Journal" of 1889, Vol. x. pp. 193 - 196, E. A. Bulloch had found the ova of a *Trichocephalus* in the liver of a rat, which he regarded as those of *Trichocephalus dispar*). If the subject of this paper be new, I propose to name it *Trichocephalus hepaticus*. In length the eggs are 55μ and 30μ to 35μ in breadth, they have a perforation at each end; mature eggs are exactly the same size. The yelk substance is divided in the undeveloped eggs, but all markings disappear and the yelk is homogeneous in structure in those thoroughly developed. The embryo when extruded from the shells measure 156μ in length and 7μ in breadth, with one end blunter than the other; five micro-millimètres from the ends, one extremity which probably is the head, is 3μ across, whilst the other is 5μ; there is no intestinal canal, the protoplasm is transparent at places whilst at others there are numerous highly refractive particles, probably of a fatty nature.

The parent worms are one and a-half to two inches (40 – 50 mm) long, white in colour, with one portion tapered gradually to an extremely fine lash, the termination of which is invisible to the naked eye, being only 7μ to 10μ across at the head. The body is tapered for half its length in the male, but for only a third in the female. The skin shows very fine striæ, the whole structure of the body is more delicate than that of *Trichocephalus dispar*, and more resembles that of the genus *Filaria.* The genital pore is situated 6 or 7 mm. from the head, there is a membraneous funnel-shaped vulva. The male organ is prolonged from the caudal extremity and appears to consist of a membraneous sheath without any spicule. Width of middle of body of mature females 100μ to 120μ, across tail of females, which is blunt 65μ, across tail of males 28μ.

EXPLANATION OF PLATES.

Plate VII.

Fig. 1—Mature eggs (alive) × 160.

Fig. 2—The same, cover glass pressed down to expel embryos.

Fig. 3—A mature egg (alive) × 650.

Fig. 7—Is a photograph of a section of the diseased liver hardened in Muller's fluid, stained by logwood and mounted in canada balsam; it was taken by Zeiss' apochromatic objective 2·0 mm. 1·40 apert. and the No. 2 projection eye-piece on an Ilford isochromatic plate, × 270.

Plate VIII.

Fig. 4—A section of liver shewing masses of eggs × 50.

Figs. 5 and 6—Eggs from liver (alive), some with divided yelk not quite developed, magnified respectively 300 and 400 diameters.

SMALL WHIRLWINDS.

By Hugh Charles Kiddle, Public School, Walbundrie, N.S.W.

[*Read before tne Royal Society of N. S. Wales, June 7, 1893.*]

It is a matter of common remark that numerous small whirlwinds are noticeable, during the summer months, in that portion of New South Wales which lies to the westward of the Great Dividing Range. These small whirlwinds, or dust whirls as they are commonly called, are not peculiar to Australia; they have been observed on the plains of India, and in other portions of the world during certain seasons of the year. As I am unaware whether meteorologists have given these phenomena a place in Australian "weatherology," further than that they exist, I submit the result of observations made during the months of January, February and March, in this Southern Riverina District.

At first sight, and to a casual observer, these whirls seem to be very erratic in their motion and appearance, light winds and warm weather being the only apparent requisites for their brief existence; but if the whirls that are seen in this district may be taken as a type of those that are seen elsewhere, I conclude that they appear under very definite circumstances.

The most prominent characteristics that I have observed in connection with these whirls are:—

Firstly—The difference in their appearance according as the weather happens to be windy or calm.

Secondly—The difference of direction in which they revolve on their axes.

Thirdly—The atmospheric conditions at the time they appear.

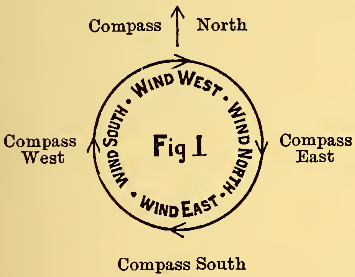
Fourthly—The effects produced on them by coming in contact with external bodies.

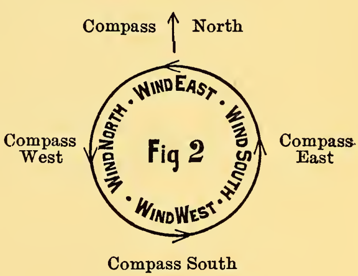
I will deal with each of these characteristics in detail. With regard to the difference in their appearance, I find that these small whirls may pass over clean grass without any visible vortex column, and that their aspect depends very much upon the nature of the loose material they pass over, for instance, if one cross a dusty road, instantly the vortex is outlined in dust swept up from the road ; if dry loose grass or leaves be in its path, the grass or leaves serve to make evident to the eye what is going on. Their appearance then, depends firstly, upon the matter they gather up, and secondly, upon the overhead wind current, as will appear farther on. I take it for granted that those whirls that are seen during calm weather may be taken as a type of the others, so I will describe the appearance of one as seen on a dusty road. The base is generally about two feet in diameter, and the column ascends to a height varying from forty to one hundred feet or more, as measured by the eye only. These whirls seldom remain stationary, however, as even in apparently calm weather, there is a slow progressive motion. After the dust, or other loose material has been passed, and the supply from below thus cut off, the head of the column is still visible, revolving the particles of dust etc., till they are carried out of sight.

When there is a light or moderate breeze blowing, these whirls have a progressive motion, estimated at a rate as high as twenty miles an hour, during a moderate to fresh breeze. The column is not so clearly defined as in calm weather, being shorter and broader in appearance, and, as a rule, not exceeding twenty or thirty feet in height. At this altitude the head of the whirl appears to be carried forward bodily and broken. This may be accounted for by assuming that at a certain height the directive force of the wind is greater than the rotatory force of whirl about its axis, consequently the particles of dust etc. in the head of the whirl are carried forward, and present a broader appearance as they are (again) scattered by the wind.

This widening out at the head is not characteristic of the "windy weather" whirl only, as I have observed some whirls, and large ones too, during calm weather, which presented the same appearance. These appeared to be about two feet in diameter at the base, and increasing in width with altitude, gave the appearance of an inverted cone. These cannot be considered as parallel cases, however, as although the visible effects resemble one another, the causes are different, there being wind in one case, calm in the other. A description of the appearance of these whirls can only be considered general, however, as each particular one has its own peculiarities derived from the nature of the locality over which it passes, and the condition of the wind, if any, at the time, as previously alluded to.

The second characteristic, viz., the difference of the directions in which these whirls revolve on their axes—relatively—is by far the more important, and is peculiar and difficult to investigate. The observer may see two of these whirls appear, within a few minutes, in nearly the same place, each revolving on its axis in an opposite direction to the other. If one be represented as revolving right handedly, as in Fig. 1, then the other will be revolving in a left handed direction as in Fig. 2.





Now, in order to conform to the general law of storms for the Southern Hemisphere, a whirl produced by an ascending current of air should revolve in a right handed direction, or in the same direction as the hands of a watch, as in Fig. 1. The whirls seen in this district, however, are very erratic in their rotatory motions, and it was this apparent disregard for the manner in which they ought to revolve, in order to follow the general law, that attracted my attention to them in the first instance, and prompted the question : how is this irregularity to be accounted for ? To strike an average of all the whirls, large and small, that I saw during the period of observation, I estimate that about fifty per cent. turned from right to left, and fifty per cent. from left to right. The nature of my duties in Half-time Schools prevented me taking barometrical readings with all the whirls I observed, but on the subjoined list I have noted those that I was enabled to record fully.

Date.	Hour.	Bar.	Wind.	Force.	Motion. Rt.	Motion. Left	Remarks.
Jan. 16	3 p.m.	...	calm		...	1	very fierce; stood in it, did not disperse, 2 ft. base, alt. 150 ft.
„ 24	noon	...	N.N.W.	mod.	...	1	very large and fierce
Mar. 12	8 a.m.	29·54	S.S.W.				
	noon	29·50	S.W.	light	...	1	wind variable, afternoon.
„ 15	5 p.m.	29·31	N.W.	light	...	5	chasing one another round in a ring, ultimately conjoined, dispersed among bushes; left handed.
„ 16	4 p.m.	29·17	N.W.	light	...	1	broken among bush.
„ 20	noon	29·33	N.W. to S.W.	var.	...	1	probably eddy, opposite currents.
„ 21	2 p.m.	29·30	S.W. to W.	fresh	...	...	in Albury, many eddies, street corners.
„ 25	noon	29·31	West	var.	...	2	dispersed on standing in them.
„ 26	10 a.m.		variable from		...	1	both small; prob.
	noon	29·32	N.W. to S.W.		...	1	opposite currents.
	10 p.m.	29·38					
„ 27	noon	29·37	S.S.E.	mod.	1	...	very fierce, 4ft. base 15ft alt., viewed it 100 yards through bush
„ 28	7 a.m.	29·35	South	light	1	...	walked in it, did not
	11 a.m.	...	East	and	1		disperse.
	noon	...	North	var.	1	...	very fierce, 6ft across
	noon	...	North		...	1	80ft alt., opposite currents.
April 4	10 a.m.	...	West		1	1	at Germanton, wind light at surface; clouds travelling opposite directions
„ 19	noon	29·30	West		1		and ascending.
„ 20	4 p.m.	29·26	variable from E.-N.W.-W.		3	...	small and travelling as per wind record respectively.

The barometrical readings are from an Aneroid, compared at Sydney Observatory last July, hence are taken as locally correct for an altitude of seven hundred feet above sea level. During the month of February, I had no opportunity of observing whirls at times that I could note the barometrical readings, which accounts for that month being unrecorded on the above table.

With this explanation, I will proceed to summarize from those that were practically observed. On looking over the table, and taking the five whirls seen on March 15th—which conjoined and then proceeded onwards as one left handed whirl—to represent one of the phenomena only, it gives a total of nine whirls which revolved in a right-handed direction, and ten that were left-handed. Although but few have been tabulated, this result gives a colour to my rough estimate of fifty per cent. each way, which was deduced from all the small whirls and eddies that I have observed for a long time before these special observations were made.

If the "Remarks" column of my table be perused carefully, it it will be noted that I have marked the words "opposite currents" against certain whirls; at the same time the "wind" column is marked as "variable." My reason for doing so is that on those particular days I was so struck with the peculiar form of the generally small whirls observed, that I came to the conclusion they were nothing more or less than mere eddies. Some seemed to run a considerable distance along the ground before they were definitely formed. They dispersed immediately on coming in contact with a bush or tree, or any other obstruction. This feature led me to sub-classify them under the same heading, and with this object I divided them into (*a*) whirls formed by ascending currents of air, and (*b*) those whirls which were eddies produced by variable winds, or in other words, opposing currents of air.

Now when two opposing currents of air meet, the stronger wind will control the direction in which eddies, produced thereby, revolve. Hence these eddies may revolve either right-handedly or left-handedly without causing any surprise at their apparent irregularity. This fact, however, does not throw any light on the reason for whirls, produced by ascending currents, revolving either way indifferently. Although the majority of such whirls revolve right-handedly (or in the same direction as the hands of a watch move), yet I have seen others, which showed every sign of being purely ascending currents of air, revolve in a left-handed direction, or decidedly the wrong way for the theory. The whirl seen on January 16th, 1893, at Burrumbuttock, is an instance. Wind light from west all forenoon, no barometrical reading. About three o'clock p.m. on that day, I heard a rustle amongst the leaves, and, on looking out saw a whirl two or three feet in diameter, revolving at a great rate, in a left-handed direction (Fig. 2), about twenty yards in front of the door. As the whirl seemed almost stationary—it being then calm—I walked over, and stepped into the middle of it, to see if a centre was perceptible, but did not discover any. I remained standing in the whirl for upwards of a minute or so; but this seemed to have no effect on it as the rotation was as brisk as ever after I stepped out again; in fact had never decreased. The whirl was revolving at the time on hard ground, the few dry leaves on it being spun round in a circle about six feet in diameter. A light air which sprang up, carried the whirl in a S.E. direction. Passing along that side of the school on which the windows are, it strewed the floor with leaves etc. A few yards past the school the whirl turned to the south, and crossed a dusty road at right angles. While passing over the dust, the whirlwind, which had hitherto only made its effects visible a few feet above the ground, now made its presence known by sucking up the dust in a spiral column to the height of about one hundred and twenty feet at the least, as calculated by eye measurement. The column was very clear and distinct, and increased slightly in width as it ascended. After the dust pool was passed, the particles which had been drawn up were seen revolving till the altitude rendered them imperceptible.

The distance passed over by this whirl from the time I first saw it, till it crossed the road was about forty yards, the time occupied in traversing that distance being about fifteen minutes. The whirl then crossed a brush fence, through a clump of dead timber, and was lost to sight on the clear grass country. This was a good type of the calm weather whirl. From the fact of it being calm, and that the whirl did not disperse on my standing in it, I classified it as caused by an ascending current of air. On January 24, 1893, in the same spot as I have just described, I witnessed a fine specimen of the "windy weather" whirl. It revolved left handedly, and as the breeze was steady from N.N.W., I classified it as caused by an ascending current of air also.

This whirl also crossed the road previously mentioned, and the dust was sucked up as before. At the height of about thirty feet, however, the head of the whirl was broken and dispersed, being carried bodily forward in a cloud of dust. Having noticed this as a general effect common to all whirls of this class, I formed the conclusion, as hitherto stated, that the directive force of the wind was greater than the rotatory force of the whirl, and that when this was the case the whirl would be dispersed. Many small whirls that I noticed only rose a few feet above the surface, and were dispersed by the wind before they had travelled many yards. Thus it may be concluded that whether a whirl is caused by an ascending current of air, or in an eddy caused by opposing currents, the force of the wind is an important item with respect to their existence. If the force of the wind be moderate to fresh, the eddy or whirl produced will be soon dispersed, as may be seen by those produced at street corners, etc., on windy days. If the force be greater, the whirls will be dispersed as soon as formed. In making this statement I refer principally to "variable" winds, for if two steady currents of air meet each other obliquely, there is no reason why eddies produced thereby should not exist till they disperse themselves. It must also be borne in mind that those destructive tornado hailstorms, which visit us periodically with high winds, belong to an entirely different section of cyclonic disturbances.

Thus it may be seen that to thoroughly investigate our second section is a difficult matter, and the result arrived at from my observations is that whirls which are caused by ascending currents of air should (but do not always), revolve right handedly, while those that are produced by opposing winds may revolve indifferently in either direction.

The third section, viz., the atmospheric conditions at the time these whirls appear, must be subdivided into (*a*) prevailing winds, (*b*) height of barometer. (*a*) These whirls nearly always occur when the wind is between the north and south-west points of the compass, and are very seldom seen when the wind is blowing from the north-east or south-east quadrants. Generally speaking it may be said that they occur with the westerly winds; which, it must be remembered, is also the prevailing direction of our summer winds. (*b*) During the early part of March I noticed no whirls at all. At the same time the barometer was exceptionally high in this district. The highest local reading noted was on March 11, 1893, when the

Aneroid barometer stood at Burrumbuttock	29·54,	altitude	700 ft.
Standard barometer stood at Albury	29·61,	,,	531 ft.
,, ,, Wagga Wagga	29·56,	,,	610 ft.

This high pressure period was coincident with the cyclonic disturbance which, after passing the New Hebrides, visited our Australian coasts with south-east gales. Possibly our high pressure was directly caused by the air being heaped up by the cyclone on its outer edge while progressing, but whether or not, my object in alluding to this circumstance is to point out that a high barometer is not a favourable condition for the formation of these whirls. The average local reading from my tabulated list, on page 94, is 29·30 in. for this district. Our westerly winds are accompanied with low barometrical readings as a rule, and as I have already said that these dust whirls are usually seen when the prevailing wind is westerly, we may look in that direction for their origin, and with very good reason suggest the intimate relationship of cause and effect.

The fourth characteristic, viz., the effect produced on these whirls by coming in contact with external objects, requires more than passing notice. Obstructions in the track of these whirls will sometimes cause them to collapse and be dispersed, while at other times whirls may be seen passing through trees, bushes, fences, and even coming in contact with houses without being in any way affected. By observing these effects I was assisted in arriving at the cause of these whirls as mentioned in section two, viz., whether caused by ascending or opposing currents. Those eddies caused by opposing currents of air are easily dispersed either by standing in them or by coming in contact with bushes etc., but a whirl produced by an ascending current is more violent in its rotatory motion, and on meeting with any temporary obstruction, and being broken, this violent up-current is very likely to restore the form of the whirl by reuniting with its upper part.

Hence those whirls produced by ascending currents are not, as a rule, much affected by coming in contact with obstructions, for as soon as the axis of rotation has passed the object, the up-current is restored as suggested. As an example of each I may mention that I saw one large whirl pass through a two rail fence, but on coming in contact with a paling fence about ten yards further on it completely collapsed. On the other hand I saw one, apparently no larger or different to the general species, come in contact with the Walbundrie Hotel (February 1892), and instead of being dispersed, it carried away two of the verandah posts and sent the sheets of iron flying. I have only seen one instance of whirls coming in contact with one another, viz., that mentioned on my list for March 15, 1893. In that instance, five small whirls (left handed), were chasing each other round in a circle about seven feet in diameter. They eventually conjoined, and proceeded as one whirl, still revolving in a left handed direction (as in Fig. 2). I watched it travel about fifty yards through the bush, when I lost sight of it.

Sometimes these whirls are seen under circumstances that make them very striking. For example, on Saturday March 19, 1892, (no barometrical record) wind south—I was walking through a stubble paddock that had been burnt off during the day, but was still smouldering in places. Hearing an unusual noise, I looked around, and perceived a large whirlwind that had settled over a floor, about one hundred yards away. I must explain that a "floor" is a place (in the paddock), where the farmer stands his winnower to clean the grain as it is brought in by the stripping machines. The chaff is left on the ground, and forms a floor of about a foot in depth. On this floor the chaff was damp underneath and therefore only smouldering, The whirlwind sucked up the smoke, forming a greenish-black column about three feet in diameter and fifty feet in height. As there was very little wind at the time, the whirl remained over the "floor" for the space of a few minutes, and it was accompanied by a roar audible from the place where I first noticed the whirl, a distance of one hundred yards. I did not attribute the roar to the whirl alone; in this case it was doubtless caused by the combined action of the smouldering fire and the whirl, thus producing a huge natural draught. After passing the floor, the whirl proceeded as a comparatively small specimen of its class, as the ground it then passed over had very little loose material left on it to make the column visible at any distance. Even from this example it will be seen that a large percentage of these phenomena must necessarily pass unnoticed, as the greater part of the surface furnishes none of the material required to make their presence perceptible. This fact alone will help to account for the paucity of the observations recorded, as I only noted down those I could ascertain some definite result from.

I am informed that dust whirls occur with greater frequency and violence in the northern and western parts of New South Wales than in this district, a fact which may be partly accounted for as the soil is in parts more sandy. Their violence being greater would indicate them to be caused by ascending air currents, the outcome of the westerly wind and low barometer as previously advanced or suggested as the origin of these whirls.

Thus the more prominent characteristics of these whirls have been detailed from observation. It would doubtless be easy to build up a theory with regard to their origin, by assuming the differences of temperature and pressure in the Western Districts to produce currents both at the surface and high in the air, and to assume that the currents may be descending as well as ascending in order to produce a whirl. But without facts I take it that theory goes for nothing.

These whirls are looked upon here as portents of a dry season, but then our summer is generally dry, as is well known. In conclusion, I can only add that their insignificance and brief existence makes these phenomena difficult to observe, and if this paper will aid in building up the system of our Australian "weatherology," the labour spent thereon will be amply rewarded.

THE LANGUAGES OF THE NEW HEBRIDES.

By Sidney H. Ray, London; revised by Dr. John Fraser, Sydney.

[With Plate IX.]

[*Read before the Royal Society of N. S. Wales, July 5, 1893.*]

Contents :—

I. Introduction.

The New Hebrides consist of about thirty inhabited and many uninhabited islands in the south-western part of the Pacific Ocean, and are situated between 14° 29′ and 20° 4′ S. latitude, and 166° 41′ and 170° 21′ E. longitude. The most southerly island, Aneityum, is distant from Sydney, New South Wales, about fifteen hundred miles, and from Auckland, New Zealand, about twelve hundred miles.*

* For a general account of the productions of the New Hebrides, the reader is referred to the following works :—"The New Hebrides," by the Rev. Robert Steel: London, 1880; "Islands of Melanesia," by the Rev. R. H. Codrington, in *Scottish Geographical Magazine*, 1889; "The Western Pacific," by Walter Coote: London, 1883; "Missions in Western Polynesia," by the Rev. A. W. Murray: London, 1863.

There is a considerable amount of variation in the languages of the New Hebrides, and this corresponds to differences which have been noted in the physical characteristics of the islanders. All accounts, though these are very few, agree in describing the natives of the southern islands of the group as darker in colour and inferior in culture to those of the north. An examination of the languages shows that the inhabitants must be regarded as sprung from not one, but several sources. The languages of Tanna and Eromanga, though agreeing in some instances with those of the Central and Northern districts, contain much that is different. This is especially seen in the long and complicated verbal forms they have, and in various points of grammatical detail. In the nouns, for example, we are told that the removal of what in the northern tongues would be a separable particle, will destroy the meaning of the word. In Tanna, *nigi* is 'tree,' and *nigum* is 'fire.' In Efate, these words appear as *nekau* and *nakabu*; in Malekula, *nice*, *nokambu*. But *na*, *ne*, *no* are separable, being forms of the article, leaving *kau*, *ce* (the Fiji *kau*, Araga *cai*), and *kabu*, *kambu* as the roots. But in Tannese, "if the *n* be taken away, there would be no longer any sense in these words, *gi* and *gum*."* Other points of divergence in the details of grammar and vocabulary render the languages of Aneityum, Tanna, and Eromanga distinct from those further north, while they are equally distinct from the languages of the Loyalty Islands and New Caledonia. Whether the southern languages of the New Hebrides represent an archaic form of the primitive Melanesian speech, or show traces of admixture with some other linguistic stock, is a subject well worthy of investigation, but it is beyond the scope of the present paper, which deals with facts rather than with speculations.

The languages of the Central portion of the group—those of Efate and the neighbouring islands—are much simpler in structure than those found north and south of them. Their vocabularies contain a large number of Polynesian words, and in their

* Rev. W. Gray, in Macdonald's "South Sea Languages," p. 134.

general character these languages are very similar to those of the Solomon Islands. The Epi and Malekula dialects, though locally not far removed from those of Efate, contain notable differences, especially in the verbal forms.

In Espiritu Santo, Whitsuntide Island, Lepers' Island and Aurora, the languages though distinct are not very dissimilar. The Santo dialects, to some extent, form a connecting link between these and the Efatese.

The language of Ambrym alone among those of the northern islands is difficult to connect, but, as it is the least known of all, many of its difficulties may disappear upon closer knowledge.

Polynesian languages are spoken on the islands of Futuna and Aniwa in the south of the New Hebrides group, and at Mae or Three Hills, Mele, and Fila in the Central district. Aniwa and Futuna, though purely Polynesian in vocabulary, are strangely different in grammar. Their complex and numerous forms, though showing no community of origin, appear to be imitations of Tanna expressions. The languages of Mae and Mele, are very nearly pure Maori.

The following classification is founded upon the grammatical structure of the languages and not upon the vocabulary alone, though the latter has necessarily been considered in the distinction of dialects. It will be advisable here to point out the leading features of grammar in each part of the group, reserving details for separate treatment.

1. Nouns:—All the languages agree in the distinction of nouns by means of demonstrative particles which may be called articles. In the Southern division, the article often coalesces with the noun, and in Tanna it is said to be inseparable, without destroying the meaning. With common nouns the article is some form of the syllable *na (ne, ni, in, no, nu, n).* In the north, *a* is sometimes found as an article used with common nouns. A personal article *i* is also found in the north and south, but does not appear in Epi and Efate.

Two classes of nouns are everywhere distinguished. One of these is used with suffixed possessive pronouns, the other without. The class taking suffixes is usually restricted to nouns denoting parts of a whole, but includes much more in Espiritu Santo than in the other islands. For the forms of the suffixed pronouns, see the Vocabulary.

2. Pronouns :—These are all from the same roots, as are also the words used as possessives. The forms found will be seen in the Comparative Vocabulary.

3. Verbs :—Particles are used with common words which are thus made verbs as to their grammatical form. The commonest particle is, in all the languages (except Espiritu Santo and Efate), some form of the syllable *mo*.

The future tense usually is clearly distinguished, but the past and the present require definition by an adverb. Person and number are defined by particles, which appear usually as abbreviated forms of the pronouns. The use of the particles in the several languages may be summarized as follows :—

a. Aneityum:—Distinct words for each tense, number, and person.

b. Tanna and Eromanga:—Combinations of pronominal forms with particles expressing the condition of the action (in progress, completed, continuous, customary, &c.).

c. Efate and Espiritu Santo:—Verbal particles appear to be simply abbreviated pronouns and indicate only person and number. Tense is shown by adverbs.

d. Epi:—Particles expressing person and number as in Efate, but with prefix *m* (or modification of initial consonant), to mark actual action (present or past), the verb without a particle being future.

e. Malekula:—Variation of number made by change of vowel, the tense sign being invariable. This is the verbal use in the Solomon Islands.

f. Arag, Omba, Maewo:—Particles as in Tanna and Eromanga. Also invariable particles denoting tense, used with pronouns.

g. Ambrym:—Same as in *(f.)*

The singular present (or past) and future of the verb 'to go,' will illustrate the use of the particles, which is here made the chief basis of classification.

	Indefinite Tense.	Future Tense.
Aneityum		
	1. ek apan ainyak *(pres.)*	1. ekpu apan ainyak
	2. na apan aiek *(pres.)*	2. napu apan aiek
	3. et um apan aien *(pres.)*	3. etpu apon aien
Tanna		
	1. iau yak-even	1. iau tak-even
	2. ik ik-even	2. ik tik-even
	3. in r-even	3. in tir-even
Eromanga		
	1. iau yakam-ampe	1. iau yak-ampe
	2. kik kikem-ampe	2. kik kik-ampe
	3. iyi kem-ampe	3. iyi k-ampe
Efate		
	1. (kinau)* a ba	1. (kinau) aga wo ba
	2. (nago) ku ba	2. (nago) kuga wo ba
	3. (nai) i ba	3. (nai) iga wo ba
Espiritu Santo (Tangoa dialect).		
	1. na thano	1. na pa thano
	2. ko thano	2. ko po thano
	3. mo thano	3. i pa thano
Epi (Baki dialect).		
	1. (kiniu)* na mbano	1. (kiniu) na vano
	2. (jau) ko mbano	2. (jau) ka vano
	3. (nai) mbano	3. (nai) ni vano.
Malekula (Pangkumu dialect).		
	1. me jo	1. be jo
	2. mu jo	2. bu jo
	3. mi jo	3. bi jo

* The pronouns may be omitted.

Indefinite Tense.	Future Tense.
Malekula (Aulua dialect).	
1. anu ne pen	1. anu ne pen bagcea
2. egco u pen	2. egco u pen bagcea
3. ‘ena ti pen	3. ‘ena ti pen bagcea
Arag	
1. nam ban	1. nav ban
2. gom ban	2. gov ban
3. ma ban	3. vi ban
Omba	
1. nom van	1. nain van
2. gom van	2. gon van
3. mo van	3. no van
Maewo	
1. nau u ras	1. nan ras *or* nau ni ras
2. niko u ras	2. gon ras *or* go ni ras
3. ia u ras	3. in ras *or* ia ni ras

4. Prepositions:—These are common in the Northern languages and are often plainly seen to be nouns and verbs. They are very few in number in the South, where their place is usually supplied by verbal suffixes. These verbal suffixes are most extensively used in Efate.

The following Table shows all the known languages and dialects of the New Hebrides. To it I add a Comparative Vocabulary with notes; for comparison the Vocabulary has corresponding words from the nearest Melanesian and Polynesian tongues. Throughout the Vocabulary, I have used the following *Alphabet*, and have transcribed all the words into it.*

* [It is a pity that so many different systems of phonology have been used by the missionaries in writing the dialects of the New Hebrides. But, as the Scriptures in part have now been printed in many of these dialects, the evil is, I fear, past remedy. Hence, Mr. Ray's labour here in transcribing his examples according to a uniform system is a service to philology.—J. F.]

Vowels: *a*, *e*, *i*, *o*, *u*, all as in Italian. *Consonants*: *b*, *d*, *f*, *h*, *j*, *k*, *l*, *m*, *n*, *p*, *r*, *s*, *t*, *v*, *w*, *y*, as in English.

c as English *g* in *go*	*dh* as English *th* in *the*
g ,, *ng* ,, *sing*	*th* ,, *th* ,, *thin*
gc ,, *ng* ,, *finger*	*gm* as a nasal *m*, nearly equal to *mw*.

The Melanesian *q* is written at length according to its sounds as *kw*, *pw*, *kpw*, *kmbw*, *gembw*, &c. The Melanesian *g*, a guttural trilled consonant, is written *g*‘. The nasal *d* is written *nd;* nasal *b*, *mb;* *z* as English *dz* in *adze*. *Diphthongs:* *ai* as in *aisle;* *au* as English *ou* in *house;* *ei* as *a* in *day*.

This method of transcription is also applied to the Mota, Fiji, Lifu, Samoan, and Maori words which are added for comparison.

II. Table of the known Languages and Dialects used in the Islands of the New Hebrides.

Southern Division.

I. Aneityum ; (1*) the most southerly island of the group.

II. Tanna ; dialects—1. *Kwamera*† (2), at the south end of the island, in the neighbourhood of Port Resolution ; 2. . . . . . , on the south-west coast, between Kwamera and Naviliang ; 3. *Naviliang*, on the west coast, south of Metautu or Black-beach ; 4. *Weasisi* (3), on the east coast, from Sulphur Bay to within a short distance of the north end of the island ; 5. *Iteing*, on the north coast.

III. Eromanga ; dialects—1. *Yoku* (4), at Dillon's Bay ; 2. *Ura* (5), on the north coast ; 3. *Sie* or *Sorung*, 4. *Utaha* (6), 5. *Novul-Amleng*.

Central Division.

I. Epi ; dialects—1. *Tasiko* or *Lemaroro* (7), at the south-east end of the island ; 2. *Maluba*, on the east coast ; 3. *Lamenu*,

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* The numerals in brackets are the reference numbers used in the first column of the Vocabulary that follows, to indicate the dialects.

† These are the names of the localities where the dialects are used.

on the north coast; 4. *Mari*, the inland districts; 5. *Bieri* (8), on the south coast; 6. *Baki* (9), on the west coast; 7. *Bierebo*, on the north-west coast; 8. *Paama*, the island of Paama, north of Epi.

II. Ambrym (10); dialects—1. *Embululi*, a bay on the east coast of the island; 2. *Limbol* or *Loliwari*, on the north-west coast, opposite Whitsuntide island.

III. Malekula; dialects—1. *Port Sandwich* (11), at Sandwich Harbour, on the east coast; 2. *Aulua* (12), on the east coast, north of Sandwich Harbour; 3. *Pangkumu* (13), on the east coast, north of Aulua; 4. *Rukumbu*, north of Pangkumu; 5. . . . . , at Port Stanley, on the north-east coast; 6. *Lamangkau* (14), at South-west Bay.

IV. Efate circuit; dialects—1. *Efate* (15), at Havannah Harbour; 2. . . . . . , on the east coast; 3. . . . . . , inland; 4. *Erakor* (16), at Erakor and Pango, on the south coast; 5. *Nguna* and *Tongoa* (17), Montague Island and the neighbouring islets of Pele and Emau with part of Tôngoa; 6. *Sesake* (18), at the east end of Emae or 'Three Hills' island; 7. *Livara* or *Liara* (19), in two villages of the *Tasiko* district of Epi; 8. *Makura* (20), on the island of Makura and part of Tongoa, with Tongariki, Buninga, Ewose and Mataso.

Northern Division.

I. Espiritu Santo; dialects—*Savan*, St. Bartholomew island, on the south coast of Espiritu Santo; 2. *Malo* (21), on the west side of Malo island, south coast of Espiritu Santo; 3. *Eralado* (22), at Cape Lisburn, south coast of Espiritu Santo; 4. *Tangoa* (23), the central district of the south coast; 5. *Nogogu* (24), 6. *Valpay*, 7. *Wulua*, all on the west coast; 8. *Marina* (25), Bay of SS. Philip and James, on the north coast.

II. Omba (26); dialects—I. *Walurigi*, 2. *Tavalavola*, 3. *Lobaha*, 4. *Longana*, all on the north coast.

III. Arag; dialects—1. *Qatvenua* (27), at the north end of the island; *Vunmarama* and *Loltavola* (28), at the north end of the island; 3. . . . . . . , at the south of the island.

IV. Maewo (29); dialects—1. *Tanoriki*, 2. *Qaranggave*, 3. *Tasmouri*, to the north; 4. . . . . . , to the south.

Other Melanesian dialects in the Vocabulary are:—(34) *Mota*, in 'Banks' islands'; (35) *Fiji*; (36) *Lifu*, in the Loyalty Islands, off New Caledonia.

POLYNESIAN DIALECTS IN THE NEW HEBRIDES.

I. FUTUNA island (30), to the east of Tanna; ANIWA island (31) to the north-east of Tanna.

II. EMAE island (32) (Central district) or 'Three Hills' island, to the north of Efate.

III. MELE island (33) and FILA island, in 'South-west Bay' (Efate).

Other Polynesian dialects in the Vocabulary are:—(37) *Samoan*, (38) *Maori*.

COMPARATIVE VOCABULARY OF THIRTY-THREE DIALECTS OF THE NEW HEBRIDES, COMPILED BY SIDNEY H. RAY.

[To Mr. Ray's list I have added a few lines, numbered 39, 40, 41, 42, drawn from personal sources* which are not available in London, but which may be useful to philologists in tracing the connection of the Ebudan† dialects with others. These are examples of the:—(39) *Taian* dialect of *Uvéa* (Loyalty Islands), the *Nengonese* of (40) *Maré Is.* (Loyalty Islands), (41) the language of NEW BRITAIN Is., to the east of New Guinea, and (42) of DUKE OF YORK ISLAND, a small island which lies in the narrow strait between New Britain and New Ireland; as an example of the dialects spoken on the south coast of New Guinea, I add (43) the *Motu* dialect of PORT MORESBY, the best known on that coast.

These examples I have written in Mr. Ray's alphabet. In the Taian dialect, most of the personal nouns are here given with the suffix consonant of the third person, as kame*n*, '*his* father'; the *ö* is very broad, something like *or* in sound, and *û* is like *ĕu*; *g* is only *g* hard in this dialect, and *ng* represents the nasal *g*; the inverted comma, as in '*veto*, marks a nasal sound. In Lifuan, *ë* is a subdued nasal, like the last sound in the French *bi-en*, and *ö* is nearly the German *ö*.—J.F.]

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* See list of authorities at the end of this paper.

† It is awkward to have to use New Hebrides as an adjective. I therefore substitute *Ebudan* and *Ebudans* formed from *Ebudes*, the classical name for the old Hebrides.—J.F.]

Ref. No.†	1. *Sun.*	2. *Daylight.*	3. *Moon.*	4. *Star.*	5. *Stone.*
1.	nagesega, nethig	apnyin[1]*	mohoc	moijeuv	hat
2.	meri	eran	mokwa	ku-mahau	kapir
3.	muti-gar	lenyan	mauug	mahau	kabil
4.	nipmi-nen	mran, dan	itais	mosi	vat
5.	nihmi-umugkum	lin	umova	umse	...
6.	nimnim-ugkum	lin	iriis	umse	...
7.	ndae	...	kubario[2]	erue	kilavaru
8.	meti-ki-au	lani	ka-mbatiau	a-mahoi	vatu
9.	mare-gi-o	ligian	si-mberio	mari-bitano	veru
10.	yial	...	ola	moho	...
11.	...	...	...	...	var
12.	iel	uta-nrien	a-mbisia	mose	vit
13.	ar	ute-rin	bur	majo	vit
14.	ual	...	vul	mosei	vet
15.	elu	aliati	atu-lagi	masei	fatu
16.	al	aliat	at-lag	masei	fat
17.	elo	aleati[3]	ate-lagi	gmasoe	vatu
18.	elo	aleati	masina	masoe	vatu
19.	elo	aleati	ate-lagi	masoe	vatu
20.	ale	maram	ki-mbati	gmahe	vata
21.	alo	rane	vitu	vitu-sarasara	takase
22.	alo	...	wulu	...	suli
23.	alo	rani	vitu	vitu-sarasara	thatu
24.	meta-ni-alo[4]	roni	wula	matsoi	sule
25.	maso	...	vula	vitui	sule
26.	aho	ran	vule	visiu	vetu
27.	alo	maran	vula	visiu	vatu
28.	mata-ni-al	maran	vula	...	...
29.	aloa	marani	wula	vitiu	vatu
30.	ra	ao	mrama	fatu	fatu
31.	ra	au	mrama	fatu	fatu
32.	mata-ra	aso	masina	fetu	...
33.	ra	ao	marama	masoi	fatu
34.	loa	maran	vula	vitu	vat
35.	mata-ni-siga[5]	siga	vula	kalokalo	vatu
36.	dhö	drai, lai	meleme, teu	wëtesidh	etë
37.	lā	ao, aso	masina	fetu	fatu
38.	ra	ra	mărama	whetu	ko-whatu
39.	seuno	hauolan, lan	tehi	okhû	‘veto
40.	du	ran	chekol	wadhekol	ete
41.	lapap	bug, keake	kwai	takwul	wat, lika
42.	make	kapa	kalag	nagnag	wat
43.	dina	diari	hua	hisiu	nadi

* *Also*—[1]natbiat; [2]variu; [3]marama; [4]meta-n-maso; [5]siga. † *See* p. 107.

Ref. No.	6. *Night.*	7. *Darkness.*	8. *Wind.*	9. *Sky.*	10. *Rain.*
1.	pig	apat, mehcim	nimtinjap	nohatag	incoptha
2.	napen	nepitevien	nematagi	neai	nesan
3.	laben	nabinabu	nemtagi	neai	nu'wun
4.	pumrok	nelebokevat	nemetagi	neiai, pokop	noisap, nebip
5.	...	...	wavelau	naiyai	nebip
6.	...	...	...	pokup	...
7.	gbwog	maliko	lagi	peni	yuwa
8.	mbogi	...	lagi	...	...
9.	bogian	mbombogio	jegi	iogobu-mabi	yuo
10.	...	...	leg	...	o
11.	...	...	ag	mon	us
12.	uta-meligco	meligco	lag	mao	usa
13.	ambug	uta-mi-bug	rig	mamarin	us
14.	...	meligk	leg	...	ue
15.	bog	maligo	lagi	*elagi*	us
16.	bog	malko	lag	elagsau	us
17.	pwogia[1]*	maligo	lagi	koroatelagi	usa
18.	bogi	maligco	lagi	koroatelagi	usa
19.	bogi	...	lagi	...	usa
20.	ecbwog	malig	lag	rikitilagi	ih
21.	dodo	dodoca	lage	tukaelagi	kiri
22.	...	...	...	...	...
23.	bogi	...	lagi	tug'a[2]	usa
24.	pon, *poni*	...	loni, *lani*	toloni, *rontro*	usa
25.	pog'i	po	...	...	usa
26.	bogi	ndondo	lagi	mawe	uhe
27.	kpwog	maligco	lag	mare	uhe
28.	bog	bog	lag	...	...
29.	kmbwog	...	lago	wogana	reu, usa
30.	po, pugi	pauri	mtagi	ragi	ua
31.	po, pogi	pouri	mtagi	ragi	owa
32.	...	...	...	ragi	...
33.	...	po	matagi	ragi	ua
34.	kpwog	silig'a	lag	tuka	wena
35.	bogi	buto	dhagi	lagi[4]	udha
36.	dhint	melöhlem	enyi	hnegodrai	mani
37.	po	pogisā[3]	matagi	lagi	ua
38.	po	pouri	hau	kikoragi	ua
39.	lit, nigheit	meneholem[5]	ag	dran	we
40.	rid	nashin	yego	awe	ele
41.	marum	kokodo	vuvu, ubar	bakut, lagit	bata
42.	marum	boboto, *adj.*	dadaip	lagit, maua	polo, *adj.*
43.	hanua-boi	dibura, *adj.*	lai	guba	medu

* *Also*—[1]cbwogi; [2]tug'akeza; [3]pouliuli; [4]lomalagi; [5]lit.

Ref. No.	11. *Water.*	12. *Sea.*	13. *Land.*†	14. *Earth, soil.*	15. *Fire.*
1.	wai	jap	pece	nobo-tan	cap
2.	nui	tasi	tana	tuprana	nap
3.	nahu	nitahi	tani	nafu-tani	nigum
4.	nu	tok	nuru	nemap	nom
5.	ne	de	...	dena	nampevag
6.	uyu	novonau	...	yumup	...
7.	wi	si	buru-vanua	tono	kabi
8.	uai	sahi	fiko, vanua	san	kam
9.	ue	tei	venuo	tano	sembi
10.	we	tie	vir, viri	tan	av, marum
11.	we	ras	...	ran	cambr
12.	bui	tis	batic-venua	tan	g'amp
13.	ui	tis, aror	batin-fenu	tan	kambu
14.	uei	tis	...	tan	amp
15.	oai	*tasi*	fanua	*tano*	kabu
16.	āi	tas	fanu	tan	kab
17.	oai	tasi	vanua, *ure*	tano	kapu
18.	oai	tasi	vanua	tano	kapu
19.	oai	tasi	vanua	tano	kapu
20.	ran	tah	ure	...	kam
21.	reu	tas[1]*	mbatui-nsara	tano	g'ambu
22.	ai	tas	vanua	...	ambrr
23.	wai	tas	thanua	...	g'abu
24.	pe-ra, *rei*	tosi[2]	...	lepa, *ono*, tano	...
25.	pei, tei	g'etja	vanua	...	g'apu
26.	wai	wawa, tahi	vanue	tano	avi
27.	wai	tahi	vanua	tano	g'api
28.	...	taihi	vanu	...	...
29.	mbei	tas, lama	vanua	tano	avi
30.	vai	tai	fenua	kele	afi
31.	vai	tai	fanua	kere	afi
32.	vai	moana	fenua	...	...
33.	vai	tai	fenua	...	afi
34.	pei	lama	vanua	tano	avi
35.	wai	tadhi	vanua	gcele	mbuka[3]
36.	tim	hnacedhë	nödhe	hnadro	eë
37.	vai	tai	fanua	'ele'ele	afi
38.	wai	moana	whenua	oneone	ahi
39.	koianam[4]	koia	'nei	konha	meich
40.	tin	chele	nod	rawa	iei
41.	tava, polo	tā	wanua	pia	yap
42.	polo, pala	waga, tai	wanua	pia	ugan
43.	ranu	davara	tano	tano	lahi

* *Also*—[1]tarusa; [2]tarusa; [3]wagca; [4]koia. † That is, *Country*.

Ref. No.	16. *Smoke.*	17. *Shade.*†	18. *Pig.*	19. *Dog.*	20. *Rat.*
1.	nathran-cap	naii, nalmu	picath	kuri	cetho
2.	nese-nap	nanumu	puka	kuri	asuk
3.	naha	narumun	puka'	kuri	kahau
4.	...	...	pekase	kuri	lakis
5.	...	...	...	...	...
6.	...	...	...	...	...
7.	yopua	molu	...	lekoli	...
8.	iahau	fo-melu	bukahi	kuliu	...
9.	iou	va-melu	bue	kuli	souo
10.	wa-lehi	...	bue	kuli	tomo
11.	...	...	baramban	lipaeh	...
12.	g'amp-basua	...	mbui	kuli	goba
13.	esi-gkumbu	mor	bue	kuri	g'asup
14.	ritu-la-amp	molemol	mbele, bue	ambur	...
15.	asu	*melu*	wago	koria	*kusue*
16.	*asu*	...	wak	kuri	kusu
17.	asua	*melu*	wago	koria	*kusue*
18.	asua	meelu	wagco	koria	kusuwe
19.	...	...	wagco	koria	kusue
20.	ah	mela	...	...	kahow
21.	asu	mala	mboi	vuria	arivi
22.	...	...	puaka	...	...
23.	asu-habu	...	boi	viriu	g'aribi
24.	osun-ovi	nuniu	poi	wuri	keriu
25.	asu	...	poe	owoi	carivi
26.	ahu	malu	mboe	...	g'arivi
27.	aho	...	kpwoe	...	g'arivi
28.	...	...	boe	...	...
29.	asu	malumalu	kmbwoe	...	g'ariv
30.	aus-afi	marumaru	pakasi	kuli	kimoa
31.	...	...	pakas	kuli	kimoa
32.	...	...	poaka	kuri	...
33.	...	...	...	...	kimoa
34.	asu	malu	kpwoe	kurut	g'asuwe
35.	kumbou, kumb	malumalu	vuaka	koli	kalavo[1]*
36.	hadh	ahnuen	puaka	kuli[2]	adhi
37.	asu	malu	pua'a	uli	imoa, isumu
38.	au-ahi	marumaru	poaka	kuri	kiore
39.	hau	menon, hanu	buaka	kuri	tēp
40.	kale	wahae	puaka	pailai	g'ele
41.	pitmur, mi	maluru	boro	pap	gculag
42.	mi	ma-daudau	boroi	pap	kaupa
43.	kwalahu	kerukeru	boroma	sisia	bita

* *Also*—[1]cadho; [2]nailai. † That is, *Shadow*.

Ref. No.	21. *Bird.*	22. *Fowl.*	23. *Snake.*	24. *Fish.*	25. *Shark.*
1.	man	man, jaa	nimyiv	numu	nipciv, pai
2.	manu	manu	gata	namu	...
3.	manug	manug	gata	namu	pauwun
4.	menok	tuo	neskil	nomu	...
5.	...	...	...	nomu	...
6.	...	...	...	numu	...
7.	manu, *menu*	to	le-mwara[1]*	ika	*pia*
8.	manu	so	mata	ika	bekeu
9.	menu	tu	maro	niadro	biauo
10.	behel	to	mar	ika, malo	bi
11.	...	...	...	...	...
12.	min	to	mat	ika	...
13.	min	to	mat	ig‘	bace
14.	...	tau	...	...	...
15.	manu	toa	mata	ika	*bako*
16.	man	tū	māt	ik	...
17.	manu	toa	gmat	ika	...
18.	manu	toa	mata	ika	...
19.	manu	toa	mata	ika	pakoa
20.	man	...	...	ik	...
21.	mansi-auau	toa	moata	mansi	bacio
22.	karai	toa	...	...	...
23.	nazi-abuabu	toa	mata	nazi-ki-tas	...
24.	...	toa	...	iga, *mats*	kumiru
25.	nanu	toa	...	natj	...
26.	manu	toa	mata	ig‘e	mbag‘eo
27.	manu	toa	...	ig‘e	...
28.	...	...	...	...	...
29.	manu	kur	...	masi	...
30.	manu	moa	gata	eika	mago
31.	manu	moa	gata	ika	...
32.	manu	...	...	ika	...
33.	...	...	...	ika	...
34.	manu	toa	gmata	ig‘a	pag‘oa
35.	manu	toa	gata	ika	gcio
36.	wacho	cutu	une	ie	eöt
37.	manu	moa	gata	i‘a	tanifa[3]
38.	manu	manu	nakahi[2]	ika	magō
39.	‘meno[4]	khoto	ön	woa	ohaich
40.	ia meded	titewe	une	waie	yoch
41.	beo	kakaruk	ui	ian	mog
42.	pika	kereke	ui	en	bia
43.	mānu	kokorogu	...	kwarume	kwalah

* *Also*—[1]minya; [2]neke; [3]malie; [4](*sc.* ni dran, ‘of the sky’).

Ref. No.	26. *Fly.*	27. *Mosquito*	28. *Butterfly.*	29. *Louse.*	30. *Tree.*
1.	lag	inyum	mokemoke[1]*	necet	cai
2.	...	...	...	...	nei
3.	kiug	kumug	paubauuk	kiget	nigi
4.	lag	...	...	...	nei
5.	...	...	...	...	nyi
6.	...	...	...	...	nokuwai
7.	lago	namu	pepepe	kuru	laki, *jeki*
8.	alago	dia	...	...	lakai
9.	jago	iomo	bĕmbe	suru	bur-iesi
10.	...	...	...	...	liye
11.	...	...	...	...	...
12.	lag	tongas	care	g'ut	ki
13.	rag	num	ceri-kakas	cut	ce
14.	lig	...	...	...	...
15.	lago	namu	bebe	kutu	kasu
16.	lago	namu	bebe	kutu	kas
17.	lago	namu	pepe	kutu	kau
18.	...	...	...	...	kau
19.	...	...	...	...	kau
20.	lag	mamamam	tambembe	kit	keh
21.	lago	mohe	vebe	utu	wucai
22.	...	...	...	...	...
23.	lago	mŏke	mpwempwe	utu	bita-g'ai
24.	lano	...	...	...	kau
25.	lago	namugi	...	cut	cau
26.	lago	g'ag'asi	mbembe	wutu	g'ai
27.	lago	namu	pepe	g'utu	g'ae
28.	...	...	...	...	...
29.	lago	namu	mbembe	wutu	g'eig'a
30.	rago	namo	pepe	kutu	rakau
31.	...	...	...	...	rakau
32.	...	...	...	...	rakau
33.	...	...	...	...	rakau
34.	lago	namu	rupe	wutu	tang'ae
35.	lago	namu	mbembe	kutu	kau, kadhu
36.	neg	tesit	fenifen[2]	ötë	sinöe
37.	lago	namu	pepe	'utu	la'au
38.	rago	waeroa	pepepe	kutu	rakau
39.	lago	minâ	walalaba	utu	uto, uo
40.	nego	nine	...[3]	ote	sereie
41.	lag	gatigat	...	ut	dawai
42.	lag	...	...	nanut	diwai
43.	lao	namo	kaubebe	utu	au

* *Also*—[1]teijig; [[2]a species; [2], [3]no generic name—J.F.].

Ref. No.	31. *Leaf.*	32. *Root.*	33. *Fruit.*	34. *Cocoanut*	35. *Banana.*
1.	rin	neucvan[2]	nohwan	neaig	nohos
2.	numai-nei	nuku-ne-nei	nukwan	...	...
3.	numalin[1]*	nakin	nowan	nien	nipin
4.	nugkelin	noatnin	novuan	noki	...
5.	...	...	nimil	...	...
6.	...	...	...	novau	...
7.	lova-ri, gma	pia	raki, ndaki	meru, niu	paravi[3]
8.	lu-te	kabwate	masakte	...	vihi
9.	mati	mbati	marati	marou	barabi
10.	...	...	...	ol	vi
11.	...	...	...	maru	...
12.	ra'te	bulukte	vana'te	kula	ves
13.	raun	rambuin	fanan	ni	vij
14.	...	...	...	metu	igcut
15.	*uli*	koa	ua	*niu*	*atse*
16.	uli	kō	uā	niu	anr
17.	ulu	lake, koa	wa-na-kau	*niu*	*andi*
18.	lau, li	lake	wa	niu	andi
19.	...	...	wa	niu	andi
20.	mitiau	kili	witi-na-ke	niw	vih
21.	rau	oro	vira	niu	vetai
22.	...	...	...	niu	...
23.	rau	kwari	bua	niu	biatali
24.	rurua	keri	pegini, tou	*kolo*, metui	...
25.	rau	g'oe	va	matui	vetali
26.	raug'i	g'oarig'i	wai	matui	votali
27.	rau	g'aro	wai	niu	ihi
28.	...	...	...	niu	...
29.	ndoui	g'oarii	oi	matua	undi
30.	rau	koga, kai	fua	niu	fuji
31.	...	...	hua	niu	...
32.	...	...	...	niu	...
33.	...	...	...	ono	...
34.	naui	g'ariu	woai	matig'	vetal
35.	drau	waka, vu[4]	vua	niu	vundi
36.	drö, dön	iwan	wen	ono	wahnawa[5]
37.	lau	a'a, pogai	fua	niu	fa'i, mo'e
38.	rau	pakiaka	hua	...	...
39.	len, le	wechin	whau	nu†, whanu	hovich
40.	rune	iewēn	wawen	wanu	hnamacho
41.	pil ?	okorina	vuaina	lama *(tree)*	vudu
42.	...	akara	...	lama *(tree)*	wundu
43.	rau	ramuna	huahua	niu, ǵaru	diu†, bigu

**Also*—[1]numa; [2]nicvan; [3]pirai; [4]gcasika; [[5]*the tree is* meteun; †*tree*—J.F.]

Ref. No.	*Breadfruit.*	37. *Yam.*	38. *Taro.*	*Sugarcane.*	40. *House.*
1.	inma	nuh	tal	to	eom, im
2.	nemar	nuk	nērē	ruk	imwa
3.	nime	nu'	nitei	tu	imwa
4.	mara	nup	tal	poria	nimo
5.	nimal	...	...	...	nima
6.	...	...	...	...	...
7.	pirevi[1]*	yuwi, ui	piaga	potovi	yugma
8.	mbatai	iobu	biagka	sob	iuma
9.	berebi	yubi	biako	botobi	yimo
10.	peta	dim, rem	bwe	su	ima, hale
11.	arab	ram	buag	...	im
12.	...	tim	buagk	tif	imwa
13.	betiv	rum	buagk	tuv	im
14.	bataf	...	biagk	...	ium
15.	bitam[2]	ui	tal	parai	suma
16.	ptum	uī	tal	porai	sum
17.	mbatau	uwi	...	...	sugma
18.	mbatau	wui	tale	mbarai	kopu
19.	batau	uvi	tale	mbarai	suma
20.	mbatava	nao	...	...	igma
21.	baico	dam, ram	bueta	tou	vanua
22.	...	ram	...	...	...
23.	...	ram	peta	tovu	ima
24.	*lewu*	...	*pera*	tov	ima, venua
25.	...	sinara	...	tovu	ima
26.	...	ndamu	kmbweta	...	vale
27.	pata	damu	...	...	igma
28.	...	dam	...	...	...
29.	...	ndamu	...	...	vale
30.	kuru	ufi	taro	toro	fare
31.	ulu	ufi	taro	toro	fare
32.	...	ufi	taro	...	hare
33.	kuru	uf	taro	toro	fare
34.	patau	nam	kpweta	tou	igma
35.	uto	uvi, ndam	ndalo	ndovu	vale
36.	ön[3]	koko	inacath	wia	uma
37.	'ulu	ufi	talo	tolo	fale
38.	...	uhi	taro	...	whare
39.	oûn	hu	konyin	'aku	uma
40.	on	wakoko	waani	waea	'ma
41.	kapiaka[3]	up	pa	tup	pal
42.	bere	up	pa	tup	ruma
43.	ûnu	maho	talo	tohu	ruma

* *Also*—[1]parai; [2]bitau; [[3]that is *the tree*—J.F.].

Ref. No.	41. *Road.*	42. *Bow.*	43. *Arrow.*	44. *Spear.*	45. *Club.*
1.	nefalaig	fana	nithjan[1]	iraklup[2]	nelop
2.	swatuk	faga	kuankuan	tei	neap
3.	swaru	...	...	...	...
4.	selat	fane	gasau	sau	nirum
5.	..	...	...	...	...
6.	...	levenahan	...	iso	...
7.	rapa[3]	viyu, viu	ndai	kwila-mira	pulaki
8.	hamau	...	...	...	...
9.	mara-mbo	...	...	...	...
10.	...	yu	wu	meta	bor
11.	...	rus	wu	...	buts
12.	‘avila	evsa	netu-n-bal	sare	mbor
13.	sar	vus	ui	metas	hemaramar
14.	...	...	tu-n-bal	...	...
15.	bua	āsu	tipwa, usu	ola; soka(*v*)	...
16.	bu	as	us	olā	mbat
17.	sala, mbua	asu	ticbwa	io	cbwe, tiko
18.	mbua	asu	tipwa	io	mbwe, gcue
19.	mbua	...	...	...	...
20.	hale	vih	e	toke	ogm
21.	sala	baka	ivini	sare	mansa
22.	...	...	...	...	...
23.	nalele	baka	evina	zari	maza
24.	...	vini, toô	wusu, vina	meur, soki	watsa
25.	rio	vus	tinana	cole, sari	maja, tig‘o[6]
26.	mata-hala	vuhu	liwai	sari	rogcmbwi
27.	hala	ihu	...	sari	irukpwe
28.	halo	...	lio	...	...
29.	tur-sala	usu	rage	mataso	kere
30.	retu	...	...	foitao	foiraka
31.	retu	fana	gasao	tao	rakao
32.	ara	...	...	...	mbatu
33.	...	fana	gasau	tao	lakau
34.	mate-sala	us	kpwatia	isar	kere
35.	salatu, sala	vudhu[4]	luveluve[5]	moto	malumu[7]
36.	codhen	tane-pehna	pehna	dho	dhia
37.	ala	āu-fana	u	tao	uatogi
38.	huarahi, ara	kopere	pere	tao	patu
39.	gethen	chafana	fana	dö	utamhu, bōn
40.	len	toa-pehna	pehna	chaach	hmu
41.	ga	panak	rumu	...	ram, palau[8]
42.	akapi	...	...	...	...
43.	dara	peva	diba	io	gahi *(stone)*

* *Also*—[1]nefana; [2]mopul; [3]mira-vandapa; [4]ndakai; [5]gasau; [6]sol; [7]ivau; [8]bior.

Ref. No.	46. *Boat.*	47. *Paddle.*	48 *Outrigger*	49. *Basket.*	50. *Food.*
1.	(alav)elcau	hev	nijmaig[1]*	cat	haig
2.	entata	...	...	tanarup	vegenien
3.	gau	vea	rimel	numahan	nuge
4.	lo	...	...	veiyu	vag
5.	lai	...	...	...	ven
6.	lo	...	...	...	vug
7.	wa, wagca	velua	...	...	kinaniena[2]
8.	oagca	voho	ihama	atinbo	vagana
9.	uako	babeluo	iame	basaro	senanien
10.	bulbul	...	...	...	ye, be
11.	uagca	...	...	...	...
12.	aki	pos	...	gonta	vagan
13.	ce, matarah	bos	jam	cat	tincan[3]
14.	uagk	obo	...	...	...
15.	rarua	wos	semen	bolo, ala[4]	finaga
16.	raru	wos	semen	ala	finag
17.	rarua	...	...	lasa	vinaga
18.	rarua	wose	...	vigira[5]	vinaga
19.	rarua	vose	...	...	vinaga
20.	raru	...	...	..	...
21.	aka	iwose	isama	cete	sinaca
22.	aka	...	...	...	...
23.	aka	ebose	...	taga	kanikani[6]
24.	ovo	...	...	...	...
25.	ovo	*lua*	...	...	sinag'a[7]
26.	agca	...	...	...	hinag'a
27.	wagca	...	...	tag	g'inag'a
28.	...	...	...	...	...
29.	aka	...	...	...	sinag'a
30.	boruku, vaka	foi	iama	kato	akai
31.	vaka	foi	...	kato	kai
32.	vaka	...	...	...	...
33.	paci, pogi	...	...	...	...
34.	aka	wose	sama	g'ete, taga	sinag'a
35.	wagca	ivodhe	dhama	kato	kakana
36.	he *(canoe)*	calu	(hn)epan	(wa)teg	g'en-i
37.	va'a	foe	ama	'ato, taga	mea-e-'ai
38.	waka	hoe	ama	kete	kai
39.	hu	wasadro	...	tag	jeu, nahan
40.	he *(canoe)*	g'aru	eden	cucheg	kaka
41.	mon	wo	aman	rat	makwit
42.	mon, tampag	wo	aman	ka	utna, nian
43.	vanagi, asi	bara	...	bosea	ani, mala

**Also*—[1]nikmeij; [2]vevana; [3]henan; [4]taga; [5]ndaga; [6]sinaka; [7]kani.

Ref. No.	51. *Father.*	52. *Man.*	53. *Male.*	54. *Husband*	55. *Child.*
1.	etman	natimi	atamaig	atmehgan[1]*	halav
2.	rema, tara	nermama	neruman	yeruman	nate
3.	timi	yetamimi	yeruman	au'wa'li	netin
4.	itemen, nate	neteme	temen	asuon	nalau, nitu
5.	rimen, dera	yirema	...	auin	nehni
6.	timen, timo	...	...	...	...
7.	arima, ata	aririna, yeru	erumŭne	oa	nucariki[2]
8.	tama	atatu	atamani	ohoa	nati
9.	ka-rama, teta	toro	sumano	koa	ki-neri
10.	...	ta, vantin	...	...	terera
11.	...	...	...	...	...
12.	temen, teta	asamagk	asamagk	asunu	neti
13.	ta, tata	haris	fe-mokoman	teuan	netin
14.	...	murut	...	...	...
15.	tema, mama	ta, tamole	nanoi	wota	nani
16.	tema	tamol	nanui	nanui	nani
17.	tama, mama[3]	ta, tagmoli	nanoai	wota	ka-ririki[4]
18.	tama	ta, tamoli	...	...	natu
19.	tama, mama	tamoli	...	wota	natu
20.	ke-tama[5]	ata	...	...	natu-ruseh
21.	tama	tamaloci	muera	tamanatu	natu
22.	...	olo (?)	...	...	...
23.	tama, tata	tamloci	lamani	tua	natu
24.	tama, tata	leman	leman	kuaworesi	notu
25.	tama, tetai	tatsua	...	...	paule
26.	tama, mama	tagaloe	mera	...	natug'i
27.	tama, tata	atatu	ataman	...	nitui
28.	...	ata, atatu	...	...	natu
29.	tama, tata	tatua	tatua	...	natui
30.	tama, tata	tagata	tane	nuane	tama
31.	tama, tata	tagata	tane	nunwane	tariki
32.	tama	tagala	...	...	tama-titi
33.	ma	tagata	tagata	...	tama
34.	tama, mama	tanun	gmereata	rasoai	natui
35.	tama, tata	tamata	atagane	wati	gone, luve
36.	kem, kaka[6]	ate, trahman	trahmanyi	trahmanyi	nekön
37.	tamā	tagata	tane	tane	tama
38.	matuatane, pa	tagata	tane	tane	tama-iti[7]
39.	kamen	at; tavat (*pl.*)	bŭca	aian	nokon[8]
40.	chechen	ngome	chahman	chahman	tenen
41.	tamana	tutana	tutana	tau	bul
42.	tamana	muana	muana	...	nat
43.	tamana	tauna	maruane	adavana	natuna

**Also*—[1]atamnyu; [2]sisiwa; [3]popo; [4]natu; [5]ke-popo; [6]tetetro; [7]tama-riki; [8]wanakat.

Ref. No.	56. *Mother.*	57. *Female.*	58. *Wife.*	59. *Chief.*	60. *Head.*
1.	risin	takata, tahig	ehgan	natemarith	pek, ithjinin
2.	ri'na	bran	rukwei	yerumanu	nukwane
3.	iti	petan	nuwei	yerumanug	kaba
4.	dineme, name	asiven	retepon	natemonok	numpug
5.	ihnin	ariareven	livan	yarumne	...
6.	...	...	...	yatumu	...
7.	ane, awia	sira	oa	supwe	pwa, cbwa
8.	la	fafine	ohoa	sumba	bati
9.	ka-ine	tira, bŭvino	k-oa	tumbo	baru
10.	...	vihin	...	yafu	botu
11.	...	...	...	sum	...
12.	gansen, nina	tambaluk	asunu	namal	bati
13.	are	fe-nevseven[1]	g'ason	namar	karu
14.	...	momo	...	...	bati
15.	bwile	garuni	garuni	wot	bau
16.	rait	matu	matu	ot	pau
17.	pwila, tete	goroi	goroi	wota	pwau
18.	bwila, tete	g'oroi	g'oroi	wota	mbau, cbwau
19.	bwila, tete	koroi	koroi	wota	bau
20.	ke-pila, anu	vavine	...	...	cbwai
21.	tina	vavini	tabaloci	teriki	batu
22.	...	vavine	...	...	...
23.	tina, nana	g'arai	narău	moli, supe	patu
24.	tina, meme	geai, levina	kan-mena	mul, mulisa	potu
25.	tina, tiai	g'ajae, wahine	...	varese	re
26.	g'aruweg'i[2]	vaivine	g'aihora	ratahigi	gcmbwatug'i
27.	ratahi	vavine	tasala	...	kpwatu
28.	...	vaivine	...	turaga	...
29.	veve	tawone	taima	nagonago	kmbwatu
30.	jina, moma	fine	nofune	teriki	uru
31.	tina, nana	fine	inahune	teriki	uru
32.	...	...	...	...	...
33.	shina	fafīne	...	riki	noa
34.	veve	tavine, vavine	rasoai	tavusmele	kpwatui
35.	tina, nana	lewa	wati	turaga	ulu
36.	thin, nena	föe	ifenekön[3]	dhog'u	he
37.	tinā	fafine	avā	ali'i	ulu
38.	matuawahine	wahine	wahine	ragatira	upoko
39.	hinyen	momo	aian-momo	than	ban, bo
40.	hmaien	föe	hmenue	doku	hawo
41.	tinana	vavina	taulai	luluai[4]	uluna, lor
42.	nana	tebuan	...	tadaru	lorina
43.	sinana	haine	adavana	lohia bada	kwara

* *Also*—[1]nevseven; [2]inde; [3]föe, *if barren;* [4]uviana.

Ref. No.	61. *Eye.*	62. *Ear.*	63. *Tooth.*	64. *Nose.*	65. *Tongue.*
1.	nesganimtan	tikgan	neijin	githjin	man
2.	nanimen	nakwaregen	reven	peseg	ta'ru
3.	nuganemtin	numa-teligen	ne'lu	noamige	min
4.	nipmi	telugon	nugon, nis	worokolag	lua-men
5.	...	...	...	...	...
6.	...	...	...	...	...
7.	ko-mara[1]*	kiliga	jua	kuna, *konu*	pu-mene
8.	mata	seligo	livo	kinihu	mena
9.	mira	tiline	mari-juvo	sunu	buru-mina
10.	meta	rigi	lowo	cuhu	meen
11.	mera	taliga	libu	nusu	meme
12.	meti	arsi	elfa	gunse	leme
13.	meta	ririga	ribo	honsi	nori-me
14.	mata	taliga	elfo	gunse	melambuga
15.	mita	taliga	bati	gusu	mena
16.	met	talge	mbati	gurin	mne
17.	mata	raliga[2]	pati	gisu	mena
18.	mata	daliga	mbati	gisu	mena
19.	mata	daliga	bati	gisu	mena
20.	mata	tiliga	...	kinihi	mena
21.	mata	boro	udu	bona	meme
22.	mata	...	...	malesu	...
23.	mata	pero	oru, pati	galisu	meme
24.	meta	anla	peti	nono, mansun	meme
25.	nata	salig'a	uju, utsu	g'og'o	meme
26.	mata	gcmbwerog'i	livog'i	gcmbwanog'i	meag'i
27.	mata	kpwero	liwo	kpwerigano	mea
28.	...	...	...	...	...
29.	mata	kmbworoi	liwoi	lisui	lue-mei
30.	foimata	tariga	nifo	isu	rero
31.	foimata	tariga	...	isu	rero
32.	...	...	niho	...	...
33.	mata	teriga	nifo	tus	li-mona
34.	matai	kpworoi	liwoi	manui	g'ara-meai
35.	mata	ndaliga	bati	udhu	ya-me
36.	(ala-)mek	hnagenyë	nyö	(hna-)fidh	thinem
37.	mata	taliga	nifo	isu	arero
38.	kanohi	tariga	niho	iho	arero
39.	emakan	nikonyen	nyion	bahoin	bomen
40.	waecoco	wabaiwa	ce	cupied	cutinen
41.	mata-na	taliga-na	palagie-na	bilauna	karamea-na
42.	mata-na	...	loko-no	gigiro-no	karamenawa
43.	mata	taia	hise	udu	mala

* *Also*—[1]meri; [2]ndaliga.

Ref. No.	66. *Belly.*	67. *Hand.*	68. *Foot, leg.*	69. *Blood.*	70. *Bone.*
1.	etgan[1]*	ikman[2]	ethuon	ja	ethuon
2.	tubu	raga	nesu	ta	nekakarin
3.	ner'fu, nisiga	nel'limi	nel'ki	ra	nikikili
4.	netnin	koben	nowon	de	novian
5.	...	...	...	...	..
6.	...	...	...	unde	...
7.	togmocbwo[3]	lima, jima	la	ta	cbwuri-yu
8.	bembe, tne	ma	le	ta	hio
9.	mambo, tinie	juma	ja	ja	bur-iu
10.	...	vera	le	...	...
11.	...	...	...	...	...
12.	tamba	ver	lua	ri	bolo-gkont
13.	damba, jini	fera	bura-gco	re	bura-gco
14.	veti	vari	mbulu	...	...
15.	kwela	ru	tuo, mwele	tra	fatu
16.	marte	ru	tu	ra	fatu
17.	pwele, cbwele	ru	tua	ra, nda	vatu
18.	mbwele	ru	mwele	nda	vatu-na-ta
19.	mbwele	ru	tua, mweli	nda	...
20	mbwele, tia	...	lao	ndah	su
21.	bage, tine	lima	karu	dai	sui
22	...	lina	sari	...	...
23.	page	lima	balo	rai	sui
24.	page, tia	lima	seri	...	sui
25.	...	g'ave	para	tsae	sui
26.	tagcmbagig'i	limeg'i	g'arug'i	ndai	huig'i
27.	sikpwegi	lima	kpwalag'i	dag'a	hui
28.	...	...	...	...	...
29.	takmbwagii	lima	rogo	ndai	surii
30.	jinai	rima	vae	toto	eivi
31.	...	rima	vai	toto	ivi
32.	...	...	...	...	...
33.	sinae	lima	vae	toto	...
34.	tokpwe, tinae	panei, lima	ragoi	nara	suriu
35.	kete	liga	yava	ndra	sui
36.	hni, oe	ime[4]	(wa-)cha	madra	dhun
37.	manāva	lima	vae	toto	ivi
38.	kopu	riga	wae	toto	wheua
39.	nyeakon	benyin	chan	dra	jeien, jo
40.	ore	wanin	wata	dra	dun
41.	bala-na	lima-na	kake-na	cap	ur, ura-na
42.	bala-na	lima-na	kaki-na	gcap	uri-na
43.	boka	ima	ae	rara	turia

* *Also*—[1]auwintin; [2]ijman; [3]sine; [4]iwanakoim.

Ref. No.	71. *Skin.*	72. *Flesh.*	73. *Name.*	74. *Good.*	75. *Bad.*
1.	narasin	nemihtan	nithan	imrihin, upene[1]	has
2.	teki	nupra	na'gen	amasan	reraha
3.	nosi	nuvahege	narige	amasan, tauwer	tera, ra
4.	nokolistan	fan	nin	aremai	ur
5.	...	...	nivana	aremai	wat
6.	...	...	nin	aramai	rat
7.	iobou	...	ki, ci	cbwo, wo, o[2]*	pioroa[3]
8.	kul, kuku	vioko	kia	mbohi	msa
9.	kulu	buru-moi	sia	mbo	boba
10.	...	...	sa	bua	hacavi
11.	...	...	...	navoi	...
12.	kalukte	rambanta	ag'se	embu	esamp
13.	firarembi	vusico	cis	bu	jij
14.	aulse	...	ia	...	...
15.	*uili*	bwakas	agie	wia	sa
16.	bulei	fsik	agi	ui	sa
17.	wili	pokasi	gisa	wia, cbwia	sa
18.	wele	bokasi	gisa	kwia	sa
19.	weli	bokasi	gisa	wia	sa
20.	...	...	kiha	woh, cbwoh	taha, aha
21.	uri	visico	cisa, isa	ducu	sat
22.	...	...	...	...	...
23.	kwuri	visiko	kiza	ruku	sati
24.	kuri	visgo	...	mertai, leli	ovun
25.	tinina	visig'o	...	pei	oso
26.	vinug'i	vihig'og'i	hena	rea	esi
27.	vinui	visog'i	ihan	tavuha	hantai
28.	...	...	ihan	tavuha	hantai
29.	vinui	visig'oi	sasai	wia	seseta
30.	kiri	nohkano	igoa	rufie	sa
31.	...	konouri	igo	erefia	sa
32.	...	...	igoa	...	...
33.	...	...	...	..	...
34.	viniu	visog'oi	sasai	wia	tatas
35.	kuli	lewe	yadha	vinaka	dha
36.	kupein	idhön	atesi, ëdhe	loi	gazo
37.	pa'u, iliola	'a'ano	igoa	lelei	leaga
38.	kiri	kiko	igoa	pai	kino
39.	unyin	utio	ien	e so	e kog
40.	nenun	iaile	ielen	roi	nia
41.	palina	viono	ya-na	boina	akaina
42.	pànina	kamanog	ya-na	auakak, koina	aka
43.	kopi	anina	ladana	namo	di-ka

* *Also*—[1]esjilid; [2]sumara; [3]pecbwerua.

Ref. No.	76. *Great.*	77. *Small.*	78. *Red.*	79. *White.*	80. *Black.*
1.	alupas	haklin, tintin	cap, tanana	ahi	apig
2.	asori	auar, auhi	rerverev	pusan	piter
3.	asoli, teabut	akaku	ervarev	...	aben
4.	tamas	virok, urekis	navilara	nesebo	nakomsu
5.	lamapa	...	...	...	...
6.	...	...	...	...	...
7.	taura, kevin, keu	otakisi	bilili	miyuwowo	mekoliko
8.	sombi	biliki	bilbil	arara	...
9.	toru	teliki, kiri	bilibili	miubu	...
10.	tlam, kon	rakakre[1]*	...	...	...
11.	...	...	...	...	...
12.	lumbon	kakas	miel	embusa	miet
13.	pareh, bimbut	kakas, keril	parpar	visvis	metamet
14.	mbau	vare	miel	mevus	metimet
15.	kwila	giki	miel	tare	maeta[2]
16.	tōb	ses	miel	tar	got
17.	warua, tauwata[3]	kiki, kirikiri	miela, miala	tare, ndare	gogota[4]
18.	mbula	gciki, kiki, riki	miala	ndautau	gogota
19.	mbula	gciki, riki	miela	dare, tau	...
20.	lam	susugm	lulu	pilavili	maete
21.	tauera, lewu	uoruore	dai-ca	lulu	urica
22.	...	...	...	...	...
23.	tabera	rikiriki	kakara	lulu	berika
24.	tuga-lav, pulpa	tage-rigi	kgara	wuo, lovu	metu
25.	tag'a-suei	tag'a-piu	g'ag'ara	voke	naeto
26.	lawua	mbiti	memea	mavuti[5]	maeto
27.	g'ai-vua	tirig'i	memea	maita	meto
28.	kai-vua	itirici	...	...	...
29.	lata	riki	memea	sigara	osooso
30.	sore	sisi	mea	kego	uriuri
31.	sore	sisi	emea	kego	uri
32.	lasi	titi	...	...	...
33.	...	...	kalukalu	te	kelekele
34.	poa	mantag'ai	nemea	akpwag'a	silsilig'a
35.	levu	lailai	ndamundamu	vulavula	loaloa
36.	tru, atrawhat	cho	palulu[6]	wië	wetewet
37.	tele, latele	laitiiti	ulaula, mumu	sinasina[7]	uliuli
38.	nui	iti, ririki	whero	ma	magu
39.	e can	inukog	e dra	e hau	e lit
40.	hmaiai	waiam	dera-dera	cada	diwe-diwe
41.	cala, cir	a-ikilik[8]	meme, tara	kabag	marut[9]
42.	cala	knialik	tara	kabag	marut
43.	bada	maragi	kaka-kaka	kuro-kuro	korema

* *Also*—[1]kakerega; [2]gota; [3]lapalapa; [4]loa; [5]pita; [6]totototo; [7]pa'e-pa'e; [8]marakan; [9]korog.

Ref. No.	81. *Holy.*	82. *See.*	83. *Hear.*	84. *Speak.*	85. *Know.*
1.	itap	ecet, almoi	ahgei	asaig, tas, ika	ato
2.	amasan	ata	aregi	ani	urkuren
3.	asim	asal, eru	atetelig	ani, agahadi[1]	ahovein
4.	tumpora	kesi	rigi	nuwi	kili
5.	uvuhnumu	...	...	...	ocori
6.	etura	...	...	...	ocori
7.	ki-e-ki-wa	malia, luali	logo, loge	pisa, visa, luc	gkilia, cili
8.	hambo	mhove, mleo	mlogo	mhou, mbetin	mkile
9.	lu	miali	mjogi	mili, mbere	mjiki
10.	...	lehe	rogta	fie	kelea
11.	...	...	...	...	...
12.	bembui	lise	enrogo	sur	lise-mbose
13.	ukon	risi, coro[2]	mire, irir	rij, forei[3]	refasai[4]
14.	...	...	...	...	rogurve
15.	tab	libi, *lo*	rogi	bisa	atai
16.	tab	lek, lims	nrog	fsa, til	tae
17.	tapu	leo, vunusi	rogo, ndog	vasa, noaki	atae
18.	...	punusi	dogo	pasa, noa	atai
19.	tabu, ducu	punusi	dogo	pasa, noa	atai
20.	...	loh	ndog	mbetog[5]	ata
21.	...	leo, sori	rogo	viti, sora	mata-uosae
22.	...	...	...	...	...
23.	tabu, ruku	lukilau, kite	rogo	reti	rogo-bosaki
24.	...	varuo, vi	ronoa	veti	pisia
25.	...	reni, kile	...	veti, aso	...
26.	g'og'ona	lehe	rorogtag'i	veve[6]	iloilo
27.	sapug'a	g'ita	rogo	vev, avo	iloilo
28.	...	...	rogo	veve, vosa	ilo
29.	rogorogo	ete	rogo	veti, lakmbwa	g'ig'ilea
30.	tapu	sira, safe	rogo	visau, tukua	iro
31.	tapu	citi	rogo	fasao, utucua	ilo, fakarogo
32.	tapu	kute	...	muna	...
33.	...	...	rorogo	...	tae
34.	rogo, tapu	ilo	rogo	vet, vava	g'ilala
35.	tabu	rai, sarasara	rogo	vosa, muna	kila
36.	hmitöt	coeëne, wag	deg	hape, ewekë	ate
37.	sa, pa'ia	va'ai, iloa	logo	gagana, fai	iloa
38.	tapu	kite	rogo	ki, korero	mātau, taea
39.	kap	ûă	leg	ha, fuj	hana, hata
40.	hmijoch	ule	taedegi	negoche	ule-kachen
41.	tabu	na, kwire	wa-logore	tata, biti	nukure
42.	tabu	bobo, wako	vatorome	piri	numere
43.	...	itaia	kamonai	koau	diba

**Also*—[1]anus; [2]mbunsi; [3]simbwe; [4]rukere; [5]calakala; [6]lagcmbwa.

Ref. No.	86. *Barter.*	87. *Eat.*	88. *Drink.*	89. *Dig.*	90. *Bury.*
1.	auanimtam	caig, hag	umnyi	irar	ati, atelmoi
2.	avahi-namri	sani	sanumi	eri	enumi
3.	os-emti	un	amanum	il	anum
4.	va-sigi	eni	moneki	kol	tenumi
5.	...	...	...	...	...
6.	...	...	...	...	...
7.	ligani	kani, kinana	muni	kili	sini
8	mbuli	kani	muni	mkili	msivini
9.	mbuli	jenano	muni	mkili	jivini
10.	...	cene, drog[1]*	...	cali	fo
11.	...	...	...	...	...
12.	gcole	gani	min	...	durse
13.	fuiri	hani, roi	min, minige	kiri	teven
14.	...	...	min	...	...
15.	fa-gkota	bami, fami	muni	gili	ofaki
16.	bā-kot	fam	min	kil	tanumia
17.	vaga-tovi[2]	ganikani	munugi	kili, *cili*	ovaki
18.	vaga-koto	kani	munugi	gili	guatuni
19.	...	kani	sorovi[4]	...	...
20.	sori	cinikan	munum	cili	...
21.	uolia	cancan	inu	cele	tanomia
22.	wolwol, woli	...	...	...	...
23.	volvoli	kani	enu, inu	...	tabuni
24.	...	gongoni[3]	oomi, un	keli	...
25.	voli	kani	oo	...	...
26.	voli	g'ani	...	g'eli	tuleg'inie
27.	vol	g'ani	...	...	taua
28.	vul	gangan	...	...	...
29.	tunu	...	...	gili	taua
30.	fa-mata	kai	einu	vere	tanumi[6]
31.	faka-mata	kei	inu	...	tanumea
32.	...	...	...	...	tanomi
33.	...	...	...	...	...
34.	wol	g'anag'ana	ima	g'il	saloa
35.	voli	kana	gunu, unuma	kelia	buluta[5]
36.	itö	g'en	idh	sin	kelem
37.	fa'a-tau	'ai	inu	'eli	tanu
38.	hoko	kai	inu	keri	tanumia[6]
39.	uchoa	han	ij	hĭn	khonom
40.	itich	kaka	kua	kin	cherigid
41.	bua	an, yan	mome	kalia	punag
42.	kuli	an	inim	kili	punag
43.	hoi-hoi	ania	inua	geia	guria

* *Also*—[1]yen; [2]sori; [3]genia; [4]munugi; [5]lovona; [6]tanu.

Ref. No.	91. *Weep.*	92. *Fear.*	93. *Live.*	94. *Die.*	95. *Sleep.*
1.	taig	imtac, imtitaig	umoh	mas	umjeg
2.	abi	ehekeru	umuru	e'ma	apuri
3.	asuk	agen	umyuga	imis	buli
4.	tugi	metet	murep	amas	aleiepo
5.	...	...	...	...	naleimpa
6.	...	...	...	...	nahlumrag
7.	tagi	metaku, marau	mali	marè	momalio
8.	mkai	mataku	mauli	mate	mionomban
9.	jegi	merou	meouli	maro	monomelio
10.	mdurig	meteha', tine	...	mar	fwer
11.	...	...	...	mat	...
12.	ntag	metoh	maur	emis	ien
13.	teg	metoh	maur	mej	metur
14.	...	...	...	mes	metur
15.	gei, tagi	mitaku	moli	mate	maturu
16.	kai, tagi	metak	mōl	mat	matur
17.	*cae*, tagi	mataku	mauri	mate	maturu
18.	gcai	mataku	mauri	mate	maturu
19.	gcai	...	...	...	...
20.	are	...	...	...	matiri
21.	tagtage	matacu	mauru	mate	maturu
22.	...	...	...	mat	...
23.	tagi	nataku	nauru	nate	zuruve
24.	toni	wotoa	mēuri	mati	manoro
25.	...	...	...	mate	surubi
26.	tagi, gara	matag'u	masoi	mate	maturu
27.	...	matag'u	rahu	mate	maturu
28.	...	mataca	dro	mate	matura
29.	...	matawu	aowe[1]*	mate	maturu
30.	tagi	mataku	mauri	mate	moroa
31.	tagi	mtacu	mouri	mate	mero
32.	...	mataku	...	mate	...
33.	...	...	mauri	mate	...
34.	tagi	matawu	esu	mate	matur
35.	tagi	rere-vaka	mbula	mate	modhe
36.	teidh	whou	mele	mechi	meköl
37.	tagi	mata'u	ola	mate	moe
38.	tagi	wahi, mataku	ola	mate	moe
39.	tegi	oten	moat	mokut	mokut
40.	mane	pareu	chiroi-ko	tago	thaet
41.	tagi	burut	nilaun	mat, inul[2]	wa, diop
42.	tagi	burut	laloun	mat[3]	inep
43.	tai	gari	mauri	mate	mahuta

**Also*—[1]mauri; [2]wirua; [3]wirua.

Ref. No.	96. *Stand.*	97. *Stay.*	98. *Sit.*	99. *Go.*	100. *Come.*
1.	aiji	atapanes[2]	ateuc	apan, han	ham, apam
2.	arer[1]*	amaro	akure	even	uvehe
3.	utul	aharug[3]	aharug	uven	uva
4.	tur	tendowi	tesep	ampe, ve	ve-lum
5.	...	amenda	...	...	enim
6.	...	...	...	...	enim
7.	su, su-malu	to	totono	peno	pimi, viru-mi
8.	mtu-mau	mtoko	mtoko-san	mbene, mlobo	mbei-ma
9.	ju-molu	jo	jo-a-tano	mbano	mbini-me
10.	...	ru, ro, to[4]	ro, to	va, mul	mai, lo
11.	...	...	...	van	vani-mai
12.	ndu	tok	sagcali[5]	mben	bene
13.	tu	tok	non, sagcer	jo	vine
14.	...	...	...	...	...
15.	tu	*toko*	to-a-tan	bano	bana-mai
16.	tu-leg	tok	tok-e-tan	fan	mai
17.	tu, tuleana	toko	ta-sake[6]	va, pano	umai, rumai
18.	ndu-leana	toko, tuna	to-na-tano	va, pwa	ve, pwa
19.	do	...	...	va, pa	vei
20.	batok	...	arah	ndow	dah
21.	turu	ovi	ate	vano	mai
22.	...	...	...	maimai	mai
23.	turu	toko	sa-kele	thano, mule	nai
24.	tup-toko	...	toko-siwo[7]	va, mule[8]	vanai, si-mai[9]
25.	turi	tog‘	...	van, mule	mai, so-mai
26.	tu	tog‘a	tog‘a	van	humei
27.	tu	...	dog‘o	vano	mai
28.	...	togo	tono	vai, vano	ba
29.	tu	tog‘a	tog‘a	vano, rasu	vano-mai[10]
30.	tu	nofo	puku	fano	hmai
31.	tu	nofo	nofo	fano, roro	mai
32.	to	nofo, noho	noho	saere	mai
33.	...	...	...	...	...
34.	tira	tog‘a	pute	vano, mule	van-ma[11]
35.	tu, toka	tiko	tiko	lako, mbau	lako-mai
36.	chil	lapa-pe	lapa	tro-tha	tro-he-mi
37.	tu, tula‘i	nofo	nofo	aga, alu	sau
38.	tu	noho	noho	haere	haere-mai
39.	toat	laba	laba	he-but	o-thö, he-jem
40.	ser	hnedi	meneg	hue	hue-bot
41.	turu	ki	ki	wan	uti
42.	turu	ki	ki	wan	urin
43.	gini	noho	hela	lao	mai, aoma

**Also*—[1]esekamter; [2]amen; [3]a‘nin; [4]mobo; [5]ambalok; [6]ndoko-na-tano; [7]soko; [8]lako, noa; [9]sa-mi; [10]su-mai; [11]mule-ma.

Ref. No.	101. *One.*	102. *Two.*	103. *Three.*	104. *Four.*	105. *Five.*
1.	ethi	ero, ohwat	eseij	emanowan	ikman
2.	iti, kwati	ka-ru	ka-har	ke-fa	kari-rum
3.	kadi	kai-yu	ki-sil	ku-vert	kari-lum
a.	kilik, kerik	ki-lalu	ki-sisel	ku-vas	kilkilep
b.	ke-ri	ki-yu	ki-sel	ku-ver	kadi-lum
4.	sai	du-ru	de-sel	de-vat	suk-rim
5.	sai	ce-lu	ce-heli	lemelu	suo-rem
6.	sokei	ka-lu	kĭ-hĭli	lemelu	suk-rim
7.	tai, taga	lua	tolu	vaeri	lima
8.	sakai	i-lua	i-tou	i-vase	i-lima
9.	tai, takuramo	juo	tolu	veri	jimo
10.	hu, *hu*	ru, *ru*	sul, *sul*	vir, *it*	lim
d.	tai	e-lua	e-tolu	e-hati	e-lime
11.	sikai	eru, eyu	e-rei	e-vads	e-rim
12.	bokol	e-nrua	e-ntil	e-mbis	e-lima
13.	soko	‘e-ru	e-tir	‘e-vej	e-rim
14.	i-se	e-ru	e-til	e-ves	e-lim
15.	iskei	rua	tolu	bate	lima
16.	sikei	nru	tun	pat	lim
17.	sikai	rua, ndua	tolu, *ndolu*	pati	lima
18.	sikai	ndua	ndolu	pati	lima*
20.	iti, sikitik	i-ru	i-tole	i-vati	i-lime
21.	a-tea	a-rua	a-tolu	a-vate	a-lima
22.	es	e-rua	e-tolu	e-vate	e-lim
23.	ma-tea	mo-rua	ma-tolu	mo-thati	mo-lina
24.	tewa, ke-tea	rua, ke-rua	tulu, ki-tulu	vate	ki-lima
25.	mo-tea	mo-rua	mo-tol	mo-vati	mo-lina
26.	g‘a-tuwale	g‘ai-rue	g‘ei-tolu	g‘ei-vesi	...
27.	g‘ai-tuwa	g‘ai-rua	g‘ai-tolu	g‘ai-vasi	g‘ai-lima —28
29.	tewa	irua	tolu	ivat	tava-ligma
30.	tasi	rua	toru	fa	rima
31.	tasi	e-rua	e-toru	e-fa	e-rima
32.	tasi	rua	toru	...	...
33.	tasi	rua	toru	fa	rima
34.	tuwale	ni-rua	ni-tol	ni-vat	tave-ligma
35.	e-ndua	e-rua	e-tolu	e-va	e-lima
36.	chasi, chas	lue-te	könit	eke-te	tripi
37.	e-tasi	e-lua	e-tolu	e-fā	e-lima
38.	ka-tahi	ka-rua	ka-toru	ka-wha	ka-rima
39.	khacha	lo	kun	‘vak	thabun
40.	sa	rewe	tini	eche	se-dongo
41.	tikai	a-ura	a-utul	a-iwat	a-ilima
42.	ra	ruadi	tuldi	watdi	limadi
43.	tamona	rua	toi	hani	ima

* No. 19—No information.

Ref. No.	106. *Six.*	107. *Seven.*	108. *Eight.*	109. *Nine.*
1.	ikman-melidet-eti	ikman et ero	ikman et eseij	...
2.	karirum-riti	...	...	...
3.	karilum-hadi	karilum-kaiyu	karilum-kisil	karilum-kuvert
4.	sukrim-mĕ-sekai	sukrim-na-ru	sukrim-de-sel	sukrim-minde-vat
5.	mi-sai	si-mhe-lu	si-m-heli	sĭ-ni-vat
6.	sĭ-m-sokei	si-mna-lu	si-mni-heli	si-mni-vat
7.	o-rai	o-lua	o-rolu	o-væri
8.	log-tagkai	lok-ua	loku-tou	loku-vase
9.	a-ri	a-luo	a-rolu	ko-veri
10.	lise, *lisa*	luru, *luru*	lusul, *lisul*	liaver, *iafer*
d.	a-hitai	o-lu	o-tolu	a-hati
11.	sukai	wu-ii	wu-rei	wu-bats
12.	ro-bokol	ro-ku-rua	ro-k-til	ro-k-bis
13.	rub-tis	rub-ru	rub-tur	rup-e
14.	sau-se	sau-ru	sau-til	sau-vei
15.	la-tesa	la-rua	la-tolu	la-fiti
16.	la-tis	la-ru	la-tul	le-fut
17.	la-tesa	la-rua	la-tolu	lo-veti
18.	...	...	...	... —19
20.	la-ti	la-ru	la-tole	lu-vite
21.	a-iono	a-bitu	a-ualu	a-sua
22.	ars	a-rua	a-rolu	a-thare
23.	mo-linarave	mo-linarabi-rua	mo-linarabi-tolu	mo-linarabi-thati
24.	ono, kai-oni	pitu, kai-pitu	olu, kai-alu	diwo, kai-sua
25.	arave	ve-rua	ve-tou	ratati
26.	g'ai-ono	g'ai-mbitu	...	...
27.	g'ai-ono	g'ai-vitu	g'ai-welu	g'ai-siwo
28.	g'ai-ono	g'ai-vitu	g'ai-welu	g'ai-siwo
29.	lava-tea	lava-rua	lava-tol	la-vat
30.	ono	fitu	varu	iva
31.	e-oano	e-fitu	e-varu	e-iva
32.	...	...	...	...
33.	ono	vitu	varu	siva
34.	lavea-tea	lavea-rua	lavea-tol	lavea-vat
35.	e-ono	e-vitu	e-walu	e-dhiwa
36.	cha-ge-men	lue-ge-men	köni-ge-men	eke-ge-men
37.	e-ono	e-fitu	e-valu	e-iva
38.	ka-ono	ka-whitu	ka-wharu	ka-iwa
39.	thabun ke nua khacha	thabun ke nua lo	thabun ka nua kun	thabun ka nua 'vak
40.	sare-che-men	rewere-che-men	tinire-che-men	echere-che-men
41.	lep-tikai	levurua	levutul	levuwat
42.	nomdi	limadimaruadi	limadi ma tuldi	limadi ma watdi
43.	tauratoi	hitu	taurahani	taurahani ta

Ref. No.	110. *Ten.*	111. *I, my.*	112. *Thou, thy.*
1.	ikman ero	ainyak; -k; ek, kis	aiek; -m; na, as*
2.	karirum-karirum	iau; -k; yak	ik; -m; ik, tik
3.	karilum-karilum	iau; -k; yak	ik; -m; nuk
a.	...	iau; -k; ...	ik; -m; ...
b.	...	iya‘; -k; ...	yik; -m; ...
c.	..	io; -k; ...	ik; m; ...
4.	na-ro-lem	iau; -g	kik; -m, -mu, -mi
5.	lu-rem	iau; ...; n-	ca; ...; ken-
6.	na-ro-lem	yo; -ko; ĭmn-	ko; -m; kumn-
7.	lua-lima	nu; -u; ne	ko; gma; o
8.	lua-lima	nagku; -ku; ne, na	aiko; -ma; ku
9.	duŭ-limo	kiniu; -ku; na	jau; -mo; ko, ka
10.	sagaul, ahu	na, ino; -g; na-	neg; -m; o-
d.	ha-lua-lim	inau; -k; na	keiko; -m; ko, ki
11.	sigiab	...	...
12.	sagabul	anu; -k, gk; ne	egco; -m; u
13.	sagabur	g‘ina; -g; ma, me	g‘au; -m; mo, mu
14.	gabul	kinagk; ...; ...	egk; ...; ...
15.	re-lima	kinu; -gcu; a, te	nagco; -ma; ku
16.	ra-lim	kenu; -k; *a*	ag; -m; *ku*
17.	rualima	kinau; -gu; a	nigo; -gma; ku
18.	ndua-lima	kinau; -gcu; a, ta	niigco; ma; ko, ku, tu
19.	...	kinau; -gcu; a	...; ...; ku
20.	ndua-lima	keino; -g; ni	kaig; -gma; ko
21.	sagavulu	iau; -ku; ku	nico; -m; o
22.	senavul	...	...
23.	ma-sagavulu	enau; -ku; na, a	egco, enico; -m; ko, o
24.	sunuvulu	nau; -u, -u; †	nigo; -m; †
25.	sogovul	inau; -ku, -k; †	inig‘o; -mu, -m; †
26.	hagavulu	inew; -gcu; no-	inigco; mu, m; ‘o-
27.	hagvulu	inau;-gcu, -ku, -k; na-	ig‘igco; -gma; ‘o-
28.	hagwul	inau; -gu, -ku, -k; na-	g‘igco; -ma; kho-
29.	sagwulu, sawul	inau; -ku, -k; †	iniko; -ga; †
30.	tamtagafuru	avau; -ku; †	akoi; -u; †
31.	imtagahuru	avau; -ku; †	akoi; -u; †
32.	...	aku; -ku; ku	koe; -u; ke
33.	nofuru	avau	akoe
34.	sagavul	inau; -k; †	iniko; -gma, -gm; †
35.	e tini, sagavulu	au; gcu; †	iko; -mu; †
36.	lue-pi	ini; -nge; †	eö; †; †
37.	e-sefulu	a‘a, ‘ou; -‘u; †	‘oe; -u; †
38.	ka-tekau, ngahuru	ahau, au; -ku; †	koe; -u; †

* This table of PRONOUNS is explained at the end of the Notes on the Vocabularies. On pages 130, 131 and here, *a* means the South-west, *b* Naviliang, *c* Iteing—all of Tanna, and *d* is the island of Paama.

Ref. No.	113. *He, his.*	114. *Thou* and *I, etc.*
1.	aien; -n; et, is	akaijau; -ijau; intau, intis
2.	in; -n; r, k	krau; -rau; krau
3.	in; -n; t, k	ki'lau; -'lau; kw, ku, ki
a.	in; -n; ...	kelau; ...; ...
b.	yin; -n; ...	...; ...; ...
c.	in; -n; ...	ka'lau; ...; ...
4.	iyi; -n, -ni	kosenduru; -nt
5.	iyi; -ni; k-	...; ...; ...
6.	iyi; -ni; umn-	...; ...; ...
7.	naga; -na; †	ita; ...; te
8.	nigana; -na; †, (ti)	airavelua; ...; to
9.	nai, naiu; -no; †,(ri)	...; ...; ...
10.	g'e, ge; -na, -n; †	kenrog; -gkenro; ...
d.	kei; -n; e	...; ...; ...
11.	...	...
12.	g'ena; -n, na; ti	anturua; -ntarua; tur
13.	g'ini; -n; mi; †	raru; -raru; ruma
14.	amatag; ...; e	...; ...; ...
15.	nai; -na; e, te	nigita; -gita; *ta*
16.	ga; -n; *i*	nigita; -gita; *ta*
17.	nae; -na; e	nigita; -gita; toro
18.	nae; -na; e, u, te	...; ...; ...
19.	...; ...; e	...; ...; toru, toro
20.	kinini; -n; i	keigcite; ...; taandu
21.	nia; -na; mo	g'idacarua; ...; ...
22.	...	...; ...; ...
23.	enia; -na, -n; ma, mo, me, mu, i	endra-rua; ...; ...
24.	nigina; -na; †	urua; -rua; †
25.	itug'a, ken; na, -n; †	g'ijerua; -jerua; †
26.	ige; na, ne, n; †	g'inderu; -nderu; nderu
27.	kea; -na, n; †	g'itaru; -ndaru; ...
28.	g'eko, keko; -na; †	g'idaru; -ndaru; taru
29.	ia; -na; †	...; ...; ...
30.	eia; -na; †	akitaua; -taua; †
31.	aia; -na; †	acitawa; ...; †
32.	ia; -na; e	taua; ...; ta
33.	eia	taua
34.	ineia; -na, -n; †	inarua; -nara; †
35.	kokoya; -na; †	endaru; -ndaru; †
36.	nyëne; -n; †	eësho; †; †
37.	ia; -na; †	i tāua; -taua; †
38.	ia; -na; †	taua; -taua; †

Ref. No.	115. *He and I (etc.).*	116. *You two.*
1.	aijumrau; -mrau; ecrau, ecrus	aijaurau; -mirau; ekau, akis
2.	kimrau; ...; yarau	kimirau; ...; irau
3.	iti'mlau; -ti'mlau; yakwa, ku, ki	itu'lau; -tu'lau; nukwa, ku, ki
a.	kimilu; ...; ...	kimilu; ...; ...
b.	ku'mlau; ...; ...	ku'milau; ...; ...
c.	...; ...; ...	ilu'lau; ...; ...
4.	kamenduru; -mam	kimenduru; -me
5.	...; ...; ...	...; ...; ...
6.	...; ...; ...	...; ...; ...
7.	memi; ...; me	amiu; ...; a
8.	amaivelua; ...; mo	amunuvelua; ...; ko
9.	...; ...; ...	...; ...; ...
10.	g'emaro; -maro; ...	g'omoro; -mro; ...
d.	...; ...; ...	...; ...; ...
11.	...	...
12.	amarua; -marua; mar	amurua; -muru; mur
13.	nemuru; -nemuru; duma	g'amuru; -muru; ruma
14.	...; ...; ...	...; ...; ...
15.	...; ...; ara	...; ...; kora, koro
16.	komam-ra; ...; ara	akam-ra; ...; kora, koro
17.	kinami; -gami; aro	nimu; -mu; koro
18.	...; ...; ...	...; ...; turu
19.	...; ...; aru, aro	...; ...; koru, koro
20.	keigcem; ...; gmoandu	kami; ...; kia
21.	kamamcarua; ...; ...	kamimcarua; ...; ...
22.	...; ...; ...	...; ...; ...
23.	...; ...; ...	...; ...; ...
24.	umurua; -murua; †	umrua; -mrua; †
25.	kanamirua; ...; †	kanirua; ...; †
26.	g'amaru; -meru; maru	g'imiru; -miru; miru
27.	kamairu; -maru; ...	kimiru; -miru; ...
28.	kamaru; -maru; karu	kimiru; -miru; kiru
29.	...; ...; ...	...; ...; ...
30.	akimaua; -maua; †	akorua; -rua; †
31.	acimawa; -omawa; †	akorua; -orua; †
32.	maua; ...; ma	korua; ...; kore
33.	maua	korua
34.	ikarua; -nkara; †	ikamurua; -murua; †
35.	keirau; -irau; †	kemundrau; -mundrau; †
36.	nyiho; †; †	nyipo; †; †
37.	i māua; -māua; †	'oulua; -'oulua; †
38.	maua; -maua; †	korua; -korua; †

Ref. No.	117. *They two.*	118. *You and I* (plur.)
1.	arau; -rau; erau, erus	akaija; -ija; inta, intis
2.	irau; -nrau; krau	kitaha‘; -taha; sa
3.	ilau; -lau; kw	kita‘; -ta‘; kot
a.	iliu; ...; ...	kitawa‘; ...; ...
b.	...; ...; ...	katar; ...; ...
c.	...; ...; ...	ketat; ...; ...
4.	iroranduru; -ndi	kos; -nt
5.	...; ...; ...	gis; -kis; n-
6.	...; ...; ...	cis; -gkis; lemn-
7.	nagala; ...; a	ita; -ta; te
8.	nigavelua; ...; lo	aira; -ra, -re; te
9.	...; ...; ...	kito; -dro; ra, ro, re
10.	neero; -raro; ...	ken; -gken; yi-
d.	...; ...; ...	...; ...; ...
11.	...	...
12.	oronrua; -rua; or	antil; -ntil; til
13.	raru; -raru; ruma	riti; -riti; rama
14.	...; ...; ...	...; ...; ...
15.	ratrua; ...; ra	gcita; -gcita; tu
16.	ra-nru; ...; ra	akit; -kit; *tu*
17.	rara; -ra; ero	nigita; -gita; tu
18.	rarua; ...; eru	niginda; -ginda; tu
19.	...; ..; eru, ero	...; ...; tu
20.	keniare; ...; ria	keigcite; -igcite; ti
21.	niracarua; ...; ...	g‘ida; -da; ka
22.	...; ...; ...	...; ...; ...
23.	...; ...; ...	endra; -ra; ra
24.	rurua; -rurua; †	rie; -rie; †
25.	g‘irerua; ...; †	ig‘ije; -ja; †
26.	aru; ...; aru	ig‘inde; -nda, -nde; nda-
27.	...; -raru; ...	ig‘ita; -nda; ta-
28.	kerag‘airua; -nira; ramura	g‘ida; -nda; ta-
29.	...; ...; ...	iginda; -nda; †
30.	akiraua; -raua; †	akitea; -tea; †
31.	acrawa; -rawa; †	acitia; -oteia; †
32.	raua; ...; kire	tatou; ...; tu
33.	raua	tatou
34.	irarua; -rara; -nrara; †	inina; -nina; †
35.	erau; -drau; †	eda; -da
36.	nyido; †; †	eëshe; †; †
37.	i lāua; -lāua; †	itātou; -tatou; †
38.	raua; -raua; †	tatou; -tatou; †

Ref. No.	119. *They and I* (plur.).	120. *You* (plur.).
1.	aijama; -ma; ecra, ecris	aijaua; -mia; eka, akis
2.	kimaha‘; -maha; yah	kimyaha‘; -myaha; hi
3.	iti‘ma; -ti‘ma‘; yakot	itu‘ma; -tu‘ma; nukot
a.	kimawa‘; ...; ...	kimia; ...; ...
b.	ku‘mar; ...; ...	ku‘miar; ...; ...
c.	iti‘mat; ...; ...	itu‘mat; ...; ...
4.	kam; -mam	kimi; -mi
5.	gim; -kim; uhn-	gimi; -nimi; kĭhn-
6.	kum; -gkum; lemn-	kimi; -gkimi; kimen
7.	memi; -memi; me	amiu; -miu; a
8.	amai; -mai; me	amunu; -munu; ke
9.	kumemi; -memi; ni	kamiu; -miu; ku
10.	g‘ema; -ma; ma-	g‘imi; -m; mi-
d.	komei; ...; mo, me	kami; ...; mi
11.	...	...
12.	amintil; -mintil; mil	amuntul; -muntul; mul
13.	nemdi; -nemdi; dama	g‘amdi; -mdi; tama
14.	...; ...; ...	...; ...; ...
15.	gcami; -gcami; u, tu	kumu; -mu; ku
16.	komam; -nami, -gami; au	akam; -mus; *ku*
17.	kinami; -gami. -ginami; au	nimu; -mu; ku
18.	nigcami; -gcami; a, u	nimui; -mui; ko, ku
19.	...; ...; au	...; ...; ku, ko
20.	keigcem; -igcem; gmo	kami; -igcam; ki
21.	kamam; -mam; ka	kanim; -mim; no
22.	...; ...; ...	...
23.	kanam; -nam; kana, ana	kanim; -nim; ka, a
24.	emam; -maman; †	emiu; -miu; †
25.	ikanam; -nam; †	ikaniu; -niu; †
26.	ig‘amai; -mai, -mei; g‘a-	ig‘imiu; -miu; mi-
27.	ikamai; -mai; g‘a-	ikimiu; -miu; g‘i-
28.	kama; -mai; ka-	kimi; -miu; ki
29.	kami; -mami, mi; †	ikamu; -mu; †
30.	akimea; -mea; †	akaua; -ua; †
31.	acime; -ome; †	acowa; -owa; -†
32.	matou; ...; matu	kotou; ...; kote
33.	matou	koutou
34.	ikamam; -mam; †	ikamiu; -miu; †
35.	keimami; -imami; †	kemuni; -muni; †
36.	eëhun; †; †	nyipunie; †; †
37.	i mātou; -matou; †	‘outou; -‘outou; †
38.	matou; matou; †	koutou; -koutou; †

Ref. No.	121. *They* (plur.)	122. *Sign of Plural.*
1.	ara; -ra; era, ecris	*Prefix* ilpu *or* ra, r
2.	iraha'; -nraha; h	*Suffix* mĭ
3.	ila'; -la; kot	*Suffix* min, *Prefix* n
a.	ilia, iria; ...; ...	
b.	ilar; ...; ...	
c.	ilat; ...; ...	
4.	irora; -nda	ovun *preceding*
5.	lel; -nil; kihn-	
6.	yoril; -kor, -ra; lemn-	
7.	nagala; -la; a	lala *(plur. pron.) following*
8.	niga; -la; le	*Adjective following*
9.	nalo; -lo; a	*By plur. pron. following or adj.*
10.	geira; -ra, -r†	
d.	kaila; ...; u, i	
11.	...	
12.	g'era; -ra; ar	*By adjective or numeral*
13.	g'iniri; -r; rama	*By plural pronoun following*
14.	...; ...; ra	
15.	nara, kita; -ra; ra, ru	mau, laba *following*
16.	nigar; -r; *ru*	mera wan *follow. (combin. dial).*
17.	nara; -ra; eu	maga, mamau, lapa *following*
18.	nara; -nda; e, u	mau, mamau, maga *following*
19.	...; ...; e, u, eu	
20.	keniare; -niare; ri	emag, abau *following*
21.	nira; -ra; na	*Prefixes* va, vei, ra. *Adj. foll.*
22.	...	
23.	enira; -ra; la, ila	*Adjective following*
24.	rire; -rire; †	*Prefix* ro *or adjective*
25.	ig'ire; -ra; †	naure *or* vao *following*
26.	gere; -ra, -re; ra-	teri
27.	ikera; -ra; ra-	g'aha *following*
28.	kera, nira; -ra; ra-	...
29.	ira, iri; -ra; †	gmaraga *following, or* ririki
30.	akiria; -rea; †	*Prefix* a *or* aga
31.	acre; -ore; †	a *prefixed*
32.	ratou; ...; kite	nga *prefixed*
33.	latou	
34.	ineira; -ra, r; †	gag *following; prefix* ra, re
35.	era; -ndra; †	*Prefix* vei, *or adjectives*
36.	angate; †; †	*Prefix* o *or* i. *Plur. pron. or adj.*
37.	ilātou; -latou; †	*By particles or lengthened vowel*
38.	ratou; -ratou; †	*By particles or lengthened vowel*

IV. Notes on the Vocabularies.

In the languages of Aneityum, Tanna, and Eromanga, the words in this Vocabulary are often given in the form in which they appear in the lists of the missionaries, and the reader should keep it in mind that an initial *n* or *in* represents a demonstrative, the article, and a final *n* the possessive suffix, third person singular.

The relationship of many of the following words to those found in Malaysia and other parts of Oceania is commented upon in the work of the Rev. Dr. Codrington on "The Melanesian Languages." Reference is accordingly made to the pages of that work for fuller evidence of the connection of the languages of the New Hebrides with those of Oceania generally. What is intended in this list is chiefly to show the relations of the New Hebrides dialects to one another.

[As it may be of interest to some readers of this Journal to trace the origin of the words used in these dialects, I have supplemented Mr. Ray's notes by some notes of my own, which are offered to assist in determining the origin of the races in Oceania. Apart from language, the traditions and history of these races give us no sure evidence on that point. My notes are enclosed in square brackets.—J.F.]

1. *Sun*—The word common is some form of *alo*. In *muti-gar*, *nipmi-nen*, *nihmi-umugkum*, *nimnim-ugkum*, *meti-ki-au*, *mare-gi-o*, *meta-ni-alo*, *mera-i-ali*, the first member of the compound is *mata*, the common word for 'eye or face,' and the expression is a parallel one to the Malay *mata-ari*. The Aneityum *thigo*, Fiji *siga* are forms of *sina*, a common Polynesian word for 'shine,' 'white,' seen also in the Sesake *masina*, 'moon,' Efate *sin*, 'to burn splendidly' as a great fire. The Marina *maso* is the usual New Hebrides word for 'star.' Cf. *Mel. Lang.* p. 93.

[Words for 'sun' come from roots meaning (1) 'to shine,' 'to burn'; cognate ideas are :—(2) 'bright, clear, manifest'; (3) 'red, red-hot, scarlet, blood'; (4) 'white, a sail, splendid, beautiful'; (5) 'heat, passion, love'; (6) 'sharp, acrid, sour,to cut.'

The simple roots which express these ideas are:—*ka*, by metathesis *ak; ba; da; di;* and, by change of consonant, *la, ra;* by the addition of formative syllables, chiefly suffixes, these roots produce a great variety of words which are spread all over Oceania. All these roots exist in Sanskrit and other Aryan languages; thus:—

KA:—Sk.* *kam*, 'to burn,' *kâma*, 'love, desire,' Gr. *ka-io.*

AK:—Sk. *agni*, 'fire, Lat. *ignis*, 'fire,' *acer*, 'sharp,' *oculus*, 'eye.'

BA:—Sk. *bhâ*, 'to shine,' *bhâlu*, 'sun,' *maha*, 'light,' Lat. *(b)uro*, 'burn.'

DA:—Sk. *dâha*, 'burning,' Gr. *daio*, 'burn,' *dais*, 'torch,' *daēlos*, *dēlos*, 'clear, manifest.'

DI:—Sk. *dîp*, 'to shine,' *div* (dya), 'day.'

RA:—This form has many representatives in Sanskrit, and as these forms illustrate the process by which variations in the meaning of the original root are acquired, several of them may be given here; as:—

Sk. *ranj*, *raja*, 'to colour, to glow'; *rakta*, 'red, agitated by passion, fond, pure, blood, vermilion, copper, saffron.'

rajata, 'white, silver, gold, ivory, blood.'

râj, 'to shine'; *râga*, 'red colour, love, wrath, passion, envy.'

râma, 'beautiful, black, white'; *ravana*, 'sharp, hot'; *ravi* 'the sun.'

ruch, 'to shine, to please, to desire, to like'; *ruchita*, 'bright, sweet'; *rukma*, 'clear, bright, gold'; *ruch*, 'light, lightning, beauty, desire'; *ruch-aka*, 'agreeable, sharp, a tooth, salt.'

rudhira, 'blood, saffron'; Gr. *eruthros*, 'red.'

roka, 'light'; *rochana*, 'irradiating, splendid, sharpening'; *rochanî*, 'red arsenic; the aether'; *rochis*, 'light, flame.'

roshana, 'angry,' quicksilver, a touchstone'; *rohita*, 'red'; *rohini*, 'blood.'

raudra, 'irrascible, acute, heat'; *rupya*, 'silver.'

Examples of most of these meanings are to be found in the Oceanic languages.

* Abbreviations:—*Dr.* for Dravidian; *Gr.* Greek; *Lat.* Latin; *Sam.* Samoan; *Sk.* Sanskrit; *Tukiok* is the native pronunciation of Duke of York (island); *A.-S.* Anglo-Saxon; *rt.* root.

In the Dravidian languages of Southern India, the root KA is represented by *kay*, 'to burn' (Telugu dialect, *kâ-lu*, *kâ-gu*, Tamil *kanyei*), *kân*, 'to see,' *kan*, 'the eye,' *kadu*, 'to be sharp, pungent, fierce, swift, to be hot, to ache,' *kadi*, 'to bite,' *kavi*, 'red ochre,' *kaveri*, 'turmeric,' *chem*, *ke-n*, *se*, 'to be hot,' *sembu*, 'red,' *ti*, 'fire,' *avâ* (for kava), 'desire.'

Now, in Mr. Ray's list of words for 'sun' and 'daylight,' the most common is some form of *alo*, and the nearest approach to that is the Dravidian *kâlu*, 'to burn, to shine.' The loss of an initial *k* is no uncommon thing in Oceania, but the *k* still remains in the Samoan *'alo-'alo*, 'a sunbeam'; it remains also in several words used in the Indian Archipelago to mean 'sun,' as *kaliha*, *kluh*, and *kai*, *kila*, *gawak*, 'daylight,' *kalap*, *chaleret*, 'lightning.' Even the negrito Samangs of Malacca say *kael* for 'sky,' and Fiji has *kalo-kalo*, 'a star.' And *'ula* (kula), 'red,' is another word in Samoa which I trace to the Dr. *kâlu*, for metathesis is common there. Brightness is the original idea in all these words.

In the list, *la*, *ra* is the common Polynesian word for 'sun.' It is immaterial whether we take this from the root KA or the root DA, for both changes of sound are legitimate; I prefer to take it from KA, for that is the form which appears to have spread most to the East, the *k* often changing into *l*. The connection of *la*, 'sun,' with words for 'blood' (*q.v.*) is manifest, and the reason why is shown by the Sanskrit meanings under the root RA, as above. But in Samoan, *la* also means a 'sail'; here again you may see the reason why in the Sk. *rajata* and *râma;* the Sk. *ruch* also, when written in Greek, is *leukos*, 'white,' and the Greek *lampros*, 'bright,' if written *lamb-ara*, might pass as a pure Oceanic word. The Maori *ko-ma*, 'whitish,' and *ko-maru*, 'sun,' 'sail' (from the root BA, MA) illustrate the Samoan double meaning of *la*.

From this root MA come other words for 'sun' in Mr. Ray's list, *ma-so*, *ma-re*, *me-ri*. In some parts of Oceania this root also means 'to see'; whence the *ma-ta*, 'eye,' of our lists, and that corresponds with the Dravidian *kan*, 'eye,' from the verb *kân*, 'to see,' and the root KA. Under this head also come *ma*, 'white' (*q.v.*), *masi* (Fiji) 'native cloth' made from the 'white' fibre of the mulberry tree, the Samoan words *masi-na*, 'the moon,' and *masoa*, 'arrowroot.'

The root DA gives *dhö*, *du*, *ndae*, *dan*, *drai*, in our list, nnd DI gives *di-na*, *di-ari*, *ne-thig*, *na-diat*, with which compare the Latin *di-es*, 'day,' sub *di-o*, 'in the open air,' *di-vus*, 'a god,' and the Sk. *deva*, 'a god,' *Dyauspater*, Lat. *Jupiter*. Compare also the Fijian *diva*, *dia*, 'to look.' The *gar* of line 3 I take to be for *kar*, whence the Malay *ari* in *mata-ari*, 'the sun.' This connection is supported by the Motu *gara-gara*, 'hot,' Efate, *giri-giri*, 'bright,' Tukiok, *garo*, 'to desire earnestly,' (*cf.* Sk. *ruch*, and Sam. *alo-fa*, 'love'), *kwire*, 'to see, look,' Maori, *koro-tu*, 'desirous,' *koro-pupu*, 'to boil,' (*cf.* Malay, *goring*, 'broil'), New Britain, *karat*, 'to bite,' *kara-gap*, 'rage,' Motu, *koria*, 'to bite' (*cf.* Dr. *kadi*, Sk. *ruchaka*). With *gar* compare also the Ebudan words for 'red,' No. 78, lines 23 – 25. Consult also Curtius ("Greek Etymology") on the roots *ghar*, *bha*, *bharg*, *rag*, *arg*, *lamp*, 'to shine.' The Sk. has *ghr-ansas*, 'heat of of the sun,' and the Keltic has *gr-ian*, 'the sun.'

I now wish to show how widely the root KA has spread in Oceania. Thus the Malay *chaya* is 'bright, clear,' and *garam* is 'anger'; the Motu *kaka-kaka* is 'scarlet,' *halaka* is 'scorch'; New Britain has *kolot*, *kan-kan*, 'anger,' *ka-ka*, 'bright red,' *ka-pa*, 'to shine'; Tukiok has *kal-kalawap*, 'to burn,' *kup*, 'to blaze,' *kum-ala* 'to shine, and *wa-kupi*, 'to light'; Maori has *kan-apa*, 'bright' and the words with *koro* as given above. A longer form of *ka-ka* is the Samoan *'a'asa* (kakasa), 'to be red hot,' and *to-'asā*, a chief's 'anger,' from the same root *ka*. The Aneityumese, which delights in dethroning an initial root-consonant so that the word may begin with a vowel, says *ef-ehcas* (for *kakas*), 'bright, shining,' *ehli* (for *kali*), 'to singe'; it also has *aces*, 'to bite,' *acas*, *cas*, 'burning, hot, pungent, sour,' *acas*, 'to burn,' *acen*, 'sour, angry.' This *acas*, *cas* or *kasa* (*cf.* Samoan 'a'asa) is the Fijian *ngesa*, 'to burn' in cooking, and seems to me to be the body of the word *nagesega* (line 1), 'the sun,' as if 'the burning one,' for it may be resolved into *na-agese-ga* of which *na* and *ga* are formatives. Again, if, following the analogy of the Sk. derivatives of *raj* (supra) and the meaning of the English expression '*brand* new,' we take the Samoan *kakasa* in the sense of 'bright,' it brings us close to *hakoso*, 'the sky' in the ancient language of Java, and *angkasa*, 'sky' in the neighbouring island of Bali.

The root TI also has a place in Oceania. In Maori, *ti-aho* and *ti-ti* mean 'to shine,' while *tio-tio* is 'sharp'; in Samoan *tio* is 'sharp,' said of the eyes, *ti-ga* is 'pain,' *ti-ti'e* is 'to be angry,' *'i'ila* (ki-kila) or *'ila-'ila* is 'to shine, to glisten,' said of the eyes; in Fiji *dhila* is 'to shine'; in Motu, *kia-ma* is 'bright.' The Malay has *kilu*, *gīlang*, 'to shine,' *ñgilu*, 'to ache'; the Pâli of India has *tikkho*, *tino*, 'sharp, acrid,' and the Dravidian has *tindu*, 'to kindle,' *tîdu*, 'to whet,' and *ti*, 'fire.' Another Oceanic form of TI is SI, whence the Samoan *si-sila*, 'to look, to see, to know,' *si-na*, 'white,' *sisifo* (as if sisi-ifo, 'to look down'), 'the west,' *si-sili*, said of 'shooting pains.' From the same root come the Fijian *siga-sigau*, 'white,' the Fijian name for 'sun,' *mata-ni-siga*, and the Malay *sigi*, 'torch.' Still another root form is SE, but this corresponds more with the Dr. *s'e*, 'to be red' where the *s'*, as in Sanskrit *s'ona*, 'to be red, represents an original *k*. From *s'e* the Samoan has *se-ga*, 'the crimson parroquet,' *se-gi*, 'to burn a scar,' *sega-vale*, 'to shine dimly' (said of the sun), *sega-sega*, 'yellowish' (*cf.* Sk. *rudhira*, 'saffron'), *sege-segi*, 'twilight,' *se-sega*, 'to dazzle.' The Dr. *se-mbu* is 'red' and the Malay *sĕ-rah* is 'red.' At Baki (New Hebrides) *se-mbi* is 'fire.' From the same monosyllabic roots as above come many Oceanic words for 'fire,' 'smoke,' 'eye' (*qq.v.*), as *ka-p*, *ka-pi*, *ka-bu*, *ma-ta*, *la-hi*, and, dropping the *k*, *afi*, *ahu*, *asu;* also words for 'burn,' 'ashes,' 'oven,' and the like. In Aneityum, *cap*, *cop* is 'hot, red, beloved; *cf.* Sam. *'alofa*, 'love.'

I have thus examined at considerable length the words in Mr. Ray's first column, for the purpose of showing how intimate is the connection between the Oceanic languages and root-words which may be found in India; for my belief is that the races of Oceania, both black and brown, came thither from their original homes in India. The ancient literature of the Javanese shows that Kalinga of the Madras coast (Dravidian) was well known to them, and that they had intercourse with the people of that country. Similar results could be obtained by a careful survey of the words in other columns of these lists; but the labour would be a long one and this is not the place for it. In the rest of these notes I shall merely indicate the direction in which inquiries might be carried to ascertain the sources from which the words have come.]

2. *Daylight*—The proper word is *ran*, *maran*. In Malekula, it it is combined with *uta*, 'place,' so that *uta-n-rien*, *ute-rin* is 'place-light,' just as in Motu (New Guinea), *hanua-boi*, 'land-dark,' is night. The word *ran* is seen in the Efate *ran melu*, 'daylight shadowed,' 'evening.'

[For *ra-n* see 'blood,' and my notes on No. 1. *La*, *ra* in Polynesian is 'sun,' *ra-ngi*, *la-ngi* is 'sky.' In New Britain *rag* is 'scorch,' and *ro*, *rau* is 'dazzle.']

3. *Moon*—The widely spread Oceanic word *vula* is found in the Northern languages and in Ambrym. A common word for 'star,' *vitu*, which is *betuch*, 'sun,' in Dayak, is 'moon' in Malo and Tangoa. The Eromangan *itais*, *iriis* is probably the same word. The Tasiko *variu* suggests that in *ku-bario*, Bieri *ka-mbatiau*, Aulua *a-mbisia* and (by regular change of *k* to *s*) the Baki *si-mberio*, we have *vitiu* with a prefix, which is found in Kwamera with the word for 'star.' In the three Southern languages *mohoc*, *mokwa*, *mauug* may be the *mag'ag'a* of Torres and Banks' Islands. Cf. *Mel. Lang.* p. 82.

[For *vula* see 'white,' line 35. In Samoa *pu-pula* is 'shine.' In Duke of York Island *pua* is 'sun, moon, lamp.' The Sanskrit root is *bhâ*, 'to shine.' With *mohoc* compare (Ambrym) *moho*, 'star,' (Sesake) *masoe*, 'star,' Samoan *ma*, 'clear, pure,' Epi *ma*, 'see,' New Britain *bo-bo*, 'see.']

4. *Star*—Some form of *masoe* is the usual word in the Southern and Central languages. *Vitu* is found in the North, in Tasiko *erue*, and, with adjective *sarasara*, in Malo and Tongoa. Cf. *Mel. Lang.* p. 92.

[The same root word in different languages may mean 'sun,' 'moon,' 'star,' the idea common to all being 'shine'; words for 'lightning' also come from such a root, *Fa-tu* is the original form, from root *bhâ*, 'to shine'; from *fa-tu* come *fetu* and *vitu*, with which compare Malay *bintang*, 'star,' the body of that word being *bita.*]

5. *Stone*—The Polynesian *fatu* is seen everywhere, except in Tanna, where, however, *kabil* (properly 'limestone') seems to be New Britain *bil*, a verb, 'to cast stones,' with an instrumental prefix *ka*. The same prefix is seen in the Tanna *ka 'kil*, 'a digging stick,' from *il* 'to dig.' This prefix, as *ga*, is common in the Banks' Islands. [See notes on 'bone,' No. 70.]

6. *Night:* 7. *Darkness*—The common word is *bog* in various forms. This word also means 'black,' in Aneityum *apig*, Tanna dialect *arabug*. In Tanna *nûpug* is a 'cave.' In the Malekulan *uta-meligco*, *uta mi bug*, *uta* is the Malay *utan*, common in Melanesia for 'land, bush, etc.,' (see words for daylight). The Efate and Malekula *meligko* is in Baki *meliju*, 'cloud.' Malo *dodo*, Omba *ndondo* is also 'cloud,' and in Florida (Solomon Is.) *rorodo*, 'blind.' Cf. *Mel. Lang*. p. 85.

[*Bog* should be 'day'—from Sk. rt. *bhâ*, 'to shine,' Dr. *pag*-al, 'day'—but *bug*, 'night,' from Sk. rt. *mu*, 'to bind,' hence 'to cover, to close,' as in Maori *puni*, 'to cover,' Malay *buni*, 'to conceal'; *cf.* "surely the darkness shall *cover* me."]

8. *Wind*—The Polynesian *matagi* is found in the three Southern languages. All others have a form of *lagi* which in Polynesia is 'sky.'

[The rt. idea in 'sky' here is 'brightness,' from *da*, *ma*, as in No. 1; *da-gi* gives *ta-gi*, *la-gi*. *Ma-tagi*, 'wind,' probably equals 'from sky.' But three Pâli words mean both 'air' and 'sky.']

9. *Sky*—The Malo, Tangoa *tug'a*, *tuka* is the Mota *tuka*, properly meaning the 'firmament.' Aulua *mao* is Omba *mawe*, Baki *mabi*, 'above,' Duke of York Is., *maua*.

10. *Rain*—A form of *usa* is common. The Maewo *reu* is 'water' in Malo and Nogogu. Eromanga *bip* may be the Lamangkau verb 'to rain,' in *na ue i bop*, 'it is raining,' the rain falls. Cf. *Mel. Lang*. p. 86.

11. *Water*—The common word is *wai*. *Reu*, *rau*, *ra* are the Maewo *reu*, 'rain,' and probably also the Santa Cruz *luwe*. Cf. *Mel. Lang.* p. 97.

[Sk. rts. are *ap*, *am*, *ma*, and *su; cf.* Hebrew *ma*(i), *mo*, 'water,' Indian *pa-ni*, 'water,' *su-mas*, 'milk,' 'water,' Samoan *sua*, 'juice,' 'liquid.']

12. *Sea*—The usual word is *tasi* or *tahi*. Pangkumu *aror* is the sea breaking on the beach, 'waves'; in Ponape (Caroline Islands), *oror* is 'the shore,' the water's edge. Omba *wa-wa* is 'the open sea.' Maewo *lama* is local in the Banks' Is., but as *laman* it is found also at Nusa on the Northern extremity of New Ireland. Marina *g'etja* is Lifu *cedha*. Cf. *Mel. Lang.* p. 89.

['Sea, salt, bitter, sharp' are cognate ideas, and 'sharp' is cognate to 'shine, 'burn'; hence Aneityumese *acen* is 'salt' and *acas* is 'burn'; so *ta-si*, 'sea,' may come from rt. *da*, *ka*, as in Note 1. The Sk. has *tad*, 'to shine,' *tij*, 'to be sharp,' *tikta*, 'bitter.' Cf. Gr. *tha-l-assa*, Lat. *ma-re*, *sa-l.*]

13. *Land*—All except the Southern tongues have some form of *vanua*. In Tasiko *buru-anua*, *buru* is 'mass,' 'lump.' The Malekula *batic-venua*, *batin-venua*, which is also in Malo, is properly 'the country belonging to a chief.' Tanna *tano* is the common word for 'ground.'

[*Fanua* probably for *fau-na;* a Sk. rt. is *bhû* (bhav), 'to be,' whence *bhumis*, 'earth,' and Gothic *bau-an*, 'to dwell'; *cf.* Sam. *mau*, 'to dwell.']

14. *Earth, soil*—The common word is *tano*. Tanna *nafu-tani* is probably 'earth-dust'; *afu* being the Fiji *kuvu*, 'dust,' Efate *afu-afu* 'to be dusty.' In the Weasisi district there is a continual rain of black volcanic dust. The Aneityum *noboh-tan* is apparently the same word, *tan* being 'red earth.' Nogogu *lepa* is in Efate 'clay.' Futuna, Aniwa, Fiji and Samoa *kele*, *kere*, *gcele*, etc., is 'earth,' 'dirt.' Wulua *ono*, Maori *oneone*, is very common in Melanesia for 'sand, beach.'

15. *Fire*—The word *kabu* is in general use, except in the north, where *afi*, which is also Polynesian, takes its place. The Fiji *wagca*

in *mbuka-wagca* (Ura *vag* in *nampe-vag*) is 'burning.' 'The fire burns' is in Efate *nakabu i faga*, in Pangkumu *nokambu pagpag*, Baki *sembi-bo vago*. Cf. *Mel. Lang.* p. 67. [See Note 1.]

16. *Smoke*—The usual word is *asu*, with or without the word for fire. Cf. *Mel. Lang.* p. 90. [See Note 1.]

17. *Shade*—The list is very imperfect, but some form of *malu* is distributed over the whole region. In Epi *fo-melu*, *va-melu* are verbs 'to shade'; *fo* and *va* are the causative particles.

[The rt. idea of most is 'soft' (Tukiok *malu-a*, Efate *mul-mul*), that is, away from the burning rays of the sun. Others are 'leafy, shady.']

18. *Pig*—The original word was no doubt *poe*. *Puaka*, *puka* are probable introductions from Polynesia. The Efate, etc., *wagco*, *wak* may be forms of *puaka*, since *pu* or *pw* is there interchangeable with *w*. Cf. *Mel. Lang.* p. 86.

[The rt. idea is 'fat'; a Sk. rt. is *pa*, *pi-van*, 'fat.']

19. *Dog*—The origin of the common word *kuri* is obscure. It is probably of recent introduction in many of the islands, certainly so in Tanna, Eromanga, and Aneityum. In Mota the word *kurut*, says Dr. Codrington, was in the language when first known to white men, though the islanders had no dogs.

[In the Dravidian of India *kudi* is 'to leap, to run,' and *kuderei* is a 'horse'; the dog and the horse are 'leapers'; they leap in running.]

20. *Rat*—The word *kusuwe* appears in many forms as *hasup*, *goba*, *kaue*, *souo*, *kahau*, *asuk*, *cetho*, *adhi*. *Carivi* is found only in Santo, Omba, Arag and Maewo. Cf. *Mel. Lang.* p. 86.

21. *Bird*—The word *manu*, which is in general use, is in a few cases used indefinitely of any animal. In Malo and Tangoa, *man-si-auau*, *nazi-abuabu* is 'flying animal'; *cf.* Efate *kuvanguva*, 'to fly.' Tangoa 'fish' is *nazi-ki-tas*, 'animal of the sea.' Eralado *karai* is applied in Malekula to the 'flying fox,' and, in Aulua, the same word *care* is a 'butterfly.' Cf. *Mel. Lang.* p. 56.

[*Manu* = 'an animal' (hence the addition *ni dran*, line 39); the Indian root is *bhû*, 'to be,' *bhav-ati*, 'to exist,' Pâli *pani*, 'a creature.']

22. *Fowl*—The common term is *toa*. Of the three Southern languages Aneityum and Eromanga alone have *jaa*, *tuo*, = *toa;* the others have the general term *manu*, 'bird.' Cf. *Mel. Lang.* p. 70.

23. *Snake*—The word *mata* is very common, with variations to *gmata* and *gata*.

24. *Fish*—The distinctive word is *ika*. The Marina *natj* is the Tangoa *nazi*, and since *n* in those languages represents a common *m*, these are the Malo *mansi*, Maewo *masi*, Nogogu *mats*, and all are probably forms of *manu;* see notes on 'bird.' The three Southern languages have *numu* or *namu*. Cf. *Mel. Lang.* p. 68.

[New Guinea dialects show the rt. *ma* ('water'?), as *ma'a*, *wa-pi*, *ma-gam*; Admiralty Is., *uka* (for *v-uka*?), 'fish,' thence *ika*. An Australian dialect has *makoro*, 'fish,' and Sk. has *makaras*, 'a sea animal,' *matsya*, 'fish'; cf. *mansi*, *nazi;* and *nazi-ki-tas* in No. 21.]

25. *Shark*—An imperfect list shows *bako*, *bekeu*, *bace*, *bacio*, *pciv* as forms of Mota *pag'oa*. *Biauo*, *pia*, *bi*, *bai*, *pauwun* may possibly be the same word.

26. *Fly*—All the words found are forms of *lago*. The Tanna has a prefix *ki* which is also seen in the names for 'mosquito' and 'louse.' Cf. *Mel. Lang.* p. 69.

27. *Mosquito*—The common term is *namu*. The Tangoa *moke*, Malo *mohe*, is possible a general term for 'insect.' In Aneityum *moke-moke* is a 'butterfly.' Cf. *Mel. Lang.* p. 83. [Rt. *mu* is 'buzz.']

28. *Butterfly*—A form of *bebe* is found in the Northern and Central regions. In Malekula *ceri*, *care* are also applied to the 'flying-fox.' In *ceri-kakas*, *kakas* is the adjective 'little.' Cf. *Mel. Lang.* p. 62.

29. *Louse*—All the languages have the word *kutu*, with little variation. In Baki *k* becomes *s* by a change which is there common. Cf. *Mel. Lang.* p. 81.

[In the Pâli of India *khuddo* means 'small.' South Australian aborigines say *kutta*, 'louse.']

30. *Tree*—The common term is *kau* or *kai*. In Baki *bur-iesi*, *bur* is a prefix meaning 'body, mass,' and is seen also in *buru-jo*, 'neck,' *buru-suku*, 'mountain.' The Epi prefixes *la*, *je*, Polynesian *la*, *ra*; Ambrym *li* has a similar meaning. Another prefix is the Utaha *ku*, Malo *wu*. Cf. *Mel. Lang.* p. 95.

31. *Leaf*—The Northern and Central tongues have *rau*, of which the Aneityum *ri*, Maewo *ndoui*, Mota *naui* are extreme forms. The Nguna *ulu*, Efate *uli* are properly used of blades of grass, or as a verb 'to grow, sprout,' and are the words commonly used elsewhere for 'hair.' Cf. *Mel. Lang.* p. 89.

[One Australian tribe uses the same word for 'hair and grass'; *cf.* also the Latin *coma*.]

32. *Root*—Aneityum, Tanna, Efate and the Northern languages have *koa* in various forms, which may be Mota *g'ariu*, Malay *akar*, etc. Baki *mbati* is in Fiji and Nguna 'tooth,' the original meaning being 'spike.' Cf. *Mel. Lang.* p. 88.

33. *Fruit*—The word *vua* or *wa* is the usual term. Malo *vira* is 'flower,' the Tangoa *bira*, Nogogu *vira*, etc. Malo has also *wa-i-ca*, 'fruit of tree.' Cf. *Mel. Lang.* p. 71.

34. *Cocoanut*—The word *niu* is very widely spread throughout Oceania. The Aulua *kula*, Nogogu *kolo*, Ambrym *ol* suggest the name of the island Malekula, 'the place of cocoanuts.' *Malo* in Nguna is 'place,' and *male* in Florida of the Solomon Islands has the same meaning. It is a common custom to name places from their productions, *e.g.*, *Aniwa* is 'full of cocoanut'. Tanna and Futuna are called respectively in Aneityum, *Inpece ran ma*, 'land of breadfruit,' and *Inpece ran has*, 'land of badness.' (See also *Codrington*, *Mel. Lang.* p. 252). The words *matua*, *metui*, *metu*, *maru* may probably be the cocoanut when ripe. *Cf.* the Polynesian *matua*, 'ripe, mature, full-grown.' Cf. *Mel. Lang.* p. 64.

35. *Banana*—There being several species of bananas with distinct names, it is by no means certain that the words given all

represent the same thing. The word *vetal*, noted by Dr. Codrington as local in the Banks' Islands, is here found in Savan, Santo, and Malo. The Sesake *andi*, Maewo *undi*, is the Fiji *vundi*, the common word in the Solomon Islands, and found also in Malay. The Epi *barabi*, *paravi* is nearly the same word as that for breadfruit. Cf. *Mel. Lang.* p. 54. [For Sam. *futi*, 'banana,' see 'white,' No. 79.]

36. *Breadfruit*—Central and Northern languages have *patau*, the Southern have *mar*. The Savan and Malo *baico* is nearly the Epi and Malekula *biako*, *biagk*, 'taro.'

37. *Yam*—The Northern languages have *dam* in various forms. The Efate and Epi *ui*, Sesake *wui* are no doubt the Polynesian *ufi*.

38. *Taro*—The common Epi and Malekula words are forms of *buagk* or *biako*, to which the Malo *baico*, 'breadfruit,' may perhaps be also referred. The Malo and Santo *bueta*, and similar words in Omba and Mota, are connected with words for breadfruit, *bitau*, *batau*, by the Ambrym *peta*. The Southern languages have the Polynesian *taro*.

39. *Sugarcane*—*Tovu*, *tou*, *to* is the common word, except in the Efate dialects, where *porai* is found with the meaning of 'sweet.' In Fiji *vuravura* are the shoots of the sugarcane or of any kind of reed.

40. *House*—The common word is *ruma*, with which is found in Ambrym and Omba *hale* and *vale*, the Polynesian *fale*, *fare*. The Sesake *kopu* is 'inside,' in Maori *kopu*, 'belly.' Malo *vanua*, Nogogu *venua* is a 'dwelling place'; the Baki *vonua*. [See 'land,' No. 13.] Cf. *Mel. Lang.* p. 77.

[Indian rts. are *gam*, *fal*, 'to cover'; *gam*, travelling to the West, produced Lat. *dom-us*, 'a house,' to the East, *lum-a*, 'house.']

41. *Road*—A representative of the common word *sala* is found in the Centre and North of the group. *Bua* appears to be local in the Efate district. In Epi and Omba *mira*, *mara* or *mata*, also in Mota *mate-sala*, is the 'eye' or surface of the 'path,' and is the word common for 'eye' or face. Cf. *Mel. Lang.* p. 87.

42. *Bow;* 43. *Arrow*—The words for Bow, Arrow and Shoot cross one another. *Fana*, used for 'bow' in the three Southern languages, is 'arrow' in Tangoa and Lifu, 'bow and arrow' in Nogogu; 'shoot' in Pangkumu is *pen*, Aulua *binea*, Maewo *vene*, Malo *vini*. In the Efate dialects *fana* does not appear, but *talifaga* is 'bowstring.' In Aneityum *inceen-ne-fana*, 'the stock or tree of shooters' is bow and arrows, *nithjan-ne-fana*, 'point of shooters' is arrow. Samoan *āu-fana*, 'bow,' is of similar construction, from *'au*, 'tree.' Some form of *vusu* is used in the Northern languages and Malekula for 'bow' and is possibly the same as the *wusu, usu, us, wu*, used for 'arrow' in Nogogu and Efate. In the latter language and in Samoa, *usu, u* is a 'reed,' as is also the Eromangan, Fiji, Aniwa and Mele *gasau*. The Efate *tipwa* is in Banks' Island and in New Guinea (Motu) *dipa*, a verb 'to shoot.' The Tangoa and Malo *baka* is the *bag'e*, etc., of Florida and Isabel in the Solomon Islands. Omba and Arag *liwai, lio* is the common word *liwo*, 'tooth,' used in a general sense for 'spike.' Cf. *Mel. Lang*. p. 61.]

44. *Spear*—The word *sare*, found in Mota, Arag, Omba, Santo and Malekula, is properly 'pierce.' *As*, which is 'stab' in Mota, may explain *metas, mataso*. *Mat* may be 'point.' Cf. *Mel. Lang*. p. 91.

45. *Club*—The Efate *mbat* is probably the Maori word *patu*, Mota *kpwat*, and really means 'knob'; *cf*. words for 'head.' Nguna *tiko* is Marina *tig'o*. Otherwise there is little agreement.

46. *Boat*—Some form of *vaka*, 'a boat' built up with planks, is very common, except in the South, where canoes are merely hollowed out logs. Here the words *cau, gau* are those common for 'tree.' The Efate *rarua* is a local term, but may possibly be connected with the Fiji *rara*, 'a board,' deck of a canoe. The Futuna *boruku* is probably Samoan *fŏlau*, 'ship, voyage,' Efate *borau*, 'one carried on a ship,' the New Britain *parau*, 'a ship,' Malay *prau*. In Efate, *ibarau* is now applied to any mode of locomotion by horse, ship or carriage. The Marina *ovo* is probably in mistake for 'paddle.' Cf. *Mel. Lang*. p. 59. The Ambrym *bulbul* may be the Mota *welewele*, 'a dug-out.'

47. *Paddle*—The Aneityum and Tanna *hev*, *vea* may be the common *wose* which appears as *bose*, *vose*, *vos*, *vcho*, *obo*. The Baki verb *beluo*, 'to paddle,' Efate *balus* explain the Marina *lua*, Tasiko *velua*.

48. *Outrigger*—An imperfect list shows the word *sama* very widely distributed.

49. *Basket*—The Fiji and Polynesian *kato* appears as *cat*, *gouta*, *cete* in Aneityum, Malekula and Malo. The *tag* of Tangoa and Arag, the Efate *toga*, the *taga* of Mota and Samoa, the Loyalty Islands *teg*, is a widely spread word for 'a woven or plaited basket or bag.'

50. *Food*—A common word is *sinaca*, *hinag'a* or *vinaga*. Tangoa *kani-kani*, Lifu *g'en*, is the common verb 'to eat,' which may also be in Tasiko *vevana*, Bieri *va-gana*, Aulua *va-gan*, Kwamera *ve-genien*, with causative particle *va*. In Nguna *va-gani* is a verb 'to make eat,' 'to feed.'

[A Sk. rt. *ad* (by metathesis *ta*) is 'to eat,' Lat. *ed-o*; *ta* gives *ka*, whence many Oceanic words for 'eat' *(q.v.)* and 'food.']

51. *Father*—The common noun is *tama*, almost without exception. The vocative, used only in addressing is *tata*, rarely *mama*. Cf. *Mel. Lang.* p. 66.

52. *Man*—The word *ta* is very generally used, mostly in composition. Malekula *haris* is 'person,' male or female. Cf. *Mel. Lang.* p. 81.

53. *Male*—The word denoting male is no doubt *mane*, usually combined with *ta*.

['Father, man, male'—all from rt. *ta*, 'male'; hence Samoan *ta-ma* is either 'father' or 'boy'; the Polynesian *ta-ga-ta* (*ka-na-ka*) is 'men' in general. 'Male,' 'female' are often expressed by their physical peculiarities, as *trahman*, line 36.]

54. *Husband*—The Epi *hoa*, *koa*, *oa* is explained by the Maori *hoa*, 'a companion,' and is applied to both husband and wife. In origin and use, the Mota *soa* in *ra-soai*, Lifu *föe*, Futuna and Aniwa

wa, *ua* are the same. The Efate *wota* is also 'chief,' perhaps the Fiji *wati*.

[*Atmeh-gan* is from *ta-ma*, by metathesis common in Aneityum. For *soa*, 'companion,' *cf.* Sk. *sama*, 'together.' *Ta-ne* is from *ta*, (see 'male'), our mode of address to 'father' as 'the man.']

55. *Child*—The common word is *natu*. Tasiko *sisi*, Nguna *ririki*, the Aniwa *riki*, Mae *titi*, Maori *iti* (in *ka-ririki*, *ta-riki*, *tama-iti*) are adjectives 'little,' *ta* being man, and *tama* the relationship between father and child—a word also used for 'father.' Cf. *Mel. Lang.* p. 63.

56. *Mother*—There is apparently no common term. The words *tete*, *tiai*, *nina*, *nana*, *mama*, *inde* are vocatives. *Tina*, *ina*, which are in Solomon Islands and New Guinea, appear in Aneityum, Tanna, Malo and Santo, and with the Efate *bwile*, etc., may be connected with words for 'belly, bowels.' The plural prefix *ra* (upon which see Dr. Codrington, *Mel. Lang.* p. 83), appears in Aneityum, Tanna, Erakor, and Arag. Weasisi *iti* is also in Efate.* Cf. *Mel. Lang.* p. 83.

[*Tina*, *sina* are from 'belly *(q.v.)*, womb'; *cf.* Maori *tia*, 'abdomen,' Tasmanian *tiana*, 'faeces.' *Ve-ve*, *mo-ma*, and the *fe-*, *va-* of the next column, 'are the same as in Lat. *ma-ter*, 'the producer'; the Sk. rt. is *bhû* (bhav), 'to be, to come into being, to exist.' *Matua-wahine* is 'grown woman.']

57. *Woman, Female*—The common Oceanic word *vavine* or *fine* is found in the North and in Epi. Tangoa *g'arai* is Efate *goroi*. Pangkumu *navseven* is Eromanga *nasiven*. Cf. *Mel. Lang.* p. 98.

58. *Wife*—This word is frequently the same as that for husband (see note on 54). In other cases it is the word for 'woman.' Cf. *Mel. Lang.* p. 89.

59. *Chief*—The words are usually distinct. The Tangoa *supe*, Tasiko *supwe*, is Nguna *supwe*, a word used in translations for 'God.' The same word is in Banks' Island *sukpwe*, as the name of a club

* In one of the Efate dialects *eri* is 'mother'—Macdonald, "Oceania," p. 126.

or society which has a house in every village. To rise to a high position in this society requires a great deal of influence and expense, and, according to native ideas, some supernatural power. The members of the 'Sukpwe' exercise considerable control over affairs; hence the use of the word as equivalent to 'chief.' In Maewo, *Sukpwe-matua* is a being who spoilt things when *Tagar*, the legendary maker of various articles was doing them aright. In Arag and Omba the same opposing nature is ascribed to *Sukpwe.** The Omba *ra-tahiqi* is 'mother,' in Arag *ra-tasiu*, is 'brothers,' and in Mota *tasi* is a common word for 'brother.' The Ėfate, Nguna *wota, wot* may be connected with the Mota verb *wot*, 'to be prominent.

[Several of these words mean 'first, before,' as *ariki* (= Sam. ali'i) and lu-*luai.*]

60. *Head*—The usual word is some form of *kpwatu* or *batu*, literally meaning a 'knob' (see No. 45), and the Kwamera *kwa* is no doubt the same word; Weasisi *kaba* is also 'knob.' Cf. *Mel. Lang.* p. 76.

[Some of these words come from *ma*, 'a beginning,' 'top *or* end' (*cf.* the meaning of Hebrew *rôsh); 'ulu* may be a corruption from Sk. *kapala*, 'head.']

61. *Eye*—The word *mata* is seen everywhere. In Aneityum *nesgan-imtan*, *nesgan* is said to be the essence, the most important part, *i e.* the pupil. The Weasisi *nugan* may be of similar meaning to *nesgan.*

[I take *nesganimtan* to be *n-sega-ni-mata*, 'the *sheen* of the eye'; see Note 1.]

62. *Ear*—In various forms *taliga* is the common word. In the Northern languages *kpwero, boro, pero* and allied words are properly applied to the tip of the ear. Cf. *Mel. Lang.* p. 66.

[The Dr. rt. *kêl* means 'to hear,' hence Oceanic *tal-iga*, 'ear'; in Polynesian, *poro* means 'to end,' 'to be finished.']

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* Codrington, "Religious Beliefs in Melanesia"—Journ. Anth. Inst. Vol. x., p. 287, 292.

63. *Tooth*—The word *liwo* is found as *livo*, *libu*, *lowo*, *ribo*, *juvo*, *jua*, *elfo*, *reve*. The same has already been noticed in Arag and Omba as 'arrow.' In Efate, Santo, and Fiji *pati* is also 'spike.' *Udu* and *uju* of Malo and Santo are *udu*, 'nose,' in New Guinea (Motu), and may probably be referred to the common *gusu*, 'nose.' Cf. *Mel. Lang.* p. 94.

64. *Nose*—The three Southern Languages have different words. *Gusu* or *gisu* is the only word at all common elsewhere. In Fiji, *gusu* is 'mouth'; *gusu* is in Mota, 'lip.' Cf. *Mel. Lang.* p. 85. The Malo *bona* is probably 'his smeller,' *bo* being a common word for 'smell' and *na* the suffixed possessive pronoun. Omba *gcmbwanog'i* is 'nostril.'

65. *Tongue*—The Northern languages have *mea* or, reduplicated, *meme*, the others *mena*. The Baki prefix *buru* is 'lump.' A similar meaning may attach to other prefixes. The Eromanga *lua*, Maewo *lue*, Aulua *le* may be compared with Efate and Mota adverbs *lua*, *lue*, 'out.' Cf. *Mel. Lang.* p. 94.

66. *Belly*—There is little agreement in the words for 'belly,' though Malekula *tamba*, *damba*, which is probably the Mota word *tokpwe*, is found in three of the Northern languages. The word *tina*, 'bowels' is however in very general use. The Fiji *kete* is 'bag,' *i.e.*, 'stomach.' Maori *kopu* is used in Sesake for 'inside of house.' Efate *mbwele* is perhaps Duke of York Island (New Britain) *bala*, Santa Cruz *bole*. It is worth notice that *tina* and *pwile* (*i.e.*, *bele*) are also used for 'mother.' Cf. *Mel. Lang.* p. 55.

67. *Hand*—*Lima* is the usual Oceanic word. In Tanna *raga* and Aneityum *ikma* are probably the extreme forms. The Malekula *ver*, *fera*, *vari*, Ambrym *vera*, are the Mota *ta-verai*, 'the palm of the hand.' Eromanga *kobe*, Marina *g'ave*, is probably the 'hand' stretched out. In Mota *g'ave* is a kind of crab, Nogogu *kave* 'wing,' Efate *man kabe*, 'pigeon,' winged animal. Cf. *Mel. Lang.* p. 73.

['Finger' is from Ger. *fangen*, 'to seize hold,' and *hand* I take from A.-S. *hadd*, 'to hold'; a Sk. rt. *gam*, *gab*, is 'to hold,' usually hardened into *grabh;* we speak of a *grasp* of the hand'; the French say '*serrer* la main.' In Old Assyrian *khams-a*, *kham-iltu* is 'five,' and there *khams* is the root *gam.* In Java, *limo* and *gangsal*, 'five,' both come from the root *gam*, just as (Eromanga) no-*kob*-en and (Santo) *lima*-na, (Marina) *g'av-e*, all come from the rt. *gam*, *gab.*]

68. *Foot, Leg*—Little agreement appears in the words given, and there is probably some confusion between 'leg' and 'foot.' The Aneityum *ethuo*, Kwamera *esu* appears in the Efate dialects as *tuo, tu, tua*, which is Lifu *cha*, as the latter language substitutes a palatal for a more common dental. (*Cf.* father, die, stand, one.) The Weasisi *el'ki* may be the Omba *g'arug'i*, the Malo *karu.* Tangoa *balo*, Marina *para*, is the Arag *kpwalag'i*, *g'i* being in Arag and Omba a noun terminal. The Lamangkau *mbulu* suggests that the Efate, Sesake *mwele* may be the same as *balo*. In Livara, *na mweli na rugku* is 'my hand,' *na mweli na tuagku*, 'my foot,' a use which suggests comparison with the Efate, Nguna *pwele*, etc., 'belly,' and refers to the bulge. The Eromangan *nowon* is more exactly 'calf,' Aneityum *nohwanalek an nethuon*, 'calf of the leg.' Maewo *rogo* is Mota *raqoi.* In the neighbourhood of Epi, various forms of *la* are found. In Aneityum and Pangkumu, the word for 'foot' is the same as that for 'bone.'

69. *Blood*—All the words may be regarded as forms of the common root *ra*, except the Nogogu *megavina.* Cf. *Mel. Lang.* p. 58.

[See Note No. 2.]

70. *Bone*—There is no agreement among the Southern languages. The Northern have *suri.* The Efate *vatu* is 'stone,' Sesake *vatu ni ta*, 'stone of man.' In Epi and Malekula, *cbwuri*, *bur*, *bol* are forms of the prefix *buru* (See Tongue). Cf. *Mel. Lang.* p. 60.

[The original meaning of *fatu* is 'strong,' 'firm,' 'hard'; Sk. *bá-la*, 'strength,' Pâli *ba-li*, 'strong,' Malay *baligh*, 'mature,' New Brit. *pat-uan*, 'strong,' Sam. *matua*, 'strong,' 'mature.']

71. *Skin*—The Fiji *kuri* is in Santo, Efate, and Epi, and probably is Yoku *kolistan*. The *vinui* of the Northern languages, Mota *viniu*, is *pin* in Duke of York Island. Cf. *Mel. Lang.* p. 90.

72. *Flesh*—The word *visiko* is common in the North. The Erakor *fsik*, Pangkumu *vusiko*, Bieri *visiko* are the same word. The other words are strange. Cf. *Mel. Lang.* p. 69.

73. *Name*—The Efate has *gisa*, Malo and Tangoa *cisa*, *kiza*, Pangkumu *cis*, Aulua *ag'se*. The omission of the guttural gives Ambrym *sa*, Malo *isa*, Aneityum *itha*, Arag *iha*, Omba *hena*, Lamangkau *ia*, Fiji *yadha*. The Maewo and Mota may show *isa* reduplicated. The loss of the sibilant gives the Epi *kia*, Efate *agie*. The Baki *sia* is the Bieri *kia* by a regular change from *k* to *s*. See words for Moon, Fire, Nose.

74. *Good*—There is little agreement in the words found. The Mota *wia* is in Maewo and Efate. The Epi and Malekula agree in the use of some form of *bo*, which is also in the district of Raluana New Britain. Cf. *Mel. Lang.* p. 72.

[The Sydney aborigines of Australia said *bu-jari*, 'good'; Sk. is *bha-dra*, Pâli *pun-no*, Lat. *bon-us*, Malay *ba-ik*, Maori *pa-i.*]

75. *Bad*—The commonest word is some form of *sa*. Pangkumu *jij* is probably the Banks Island *tisi*. Cf. *Mel. Lang.* p. 53.

[Sk. rt. words for 'bad' are *ka* (prefix) and *kash-ta* (adj.); *cf.* Aneityumese *has* (for *kas*), 'bad,' *eh-ka*, 'very difficult,' and Efatese *sa*, 'bad.']

76. *Great*—There is a great variety of terms, with little agreement. The Savan *lewu* is Fiji *levu*, also found in Santa Cruz *levu* and Banks' Islands *luwo*. Omba *lawua*, and Mota *liwoa* may be forms of *lewu*. The Aulua *lumbo*, Ura *lamapa*, is in Efate, Nguna, *laba*, *lapa*, 'many.' Cf. *Mel. Lang.* p. 79.

77. *Small*—A form of *riki*, *giki* is very common. Cf. *Mel. Lang.* p. 81.

[Bengali *kichhi* is 'small,' Pâli *khuddo*, Malay *kechil.*]

78. *Red*—The Efate *miel* is found also in Malekula. The Omba, Arag, and Maewo *memea* is explained by Mota *mea*, 'red earth,'

reduplicated. The Malo *dai-ca* is 'blood,' *dai* with adjective termination, *ca*. The same word is in Baki *jie-ki*, a kind of purple. Eromanga *navilara* is from *vila*, 'lightning.' Aneityum *cap* is 'fire,' but there is also *tanana*, formed like *memea* from *tan*, 'red earth.' Tanna *ervarev* is the 'red glow of sunset,' which as *ravi-ravi*, *afiafi* is a common word in Oceania for 'evening.' Cf. *Mel. Lang.* p. 87. [See rts. *ma*, *me*, *ka*, *ra*, and *ravi*, in Note No. 1.]

79. *White*—*Vuti* or *vusi* is the common word, which is also in Malagasy and Malay Archipelago. With prefix *ma*, this is Omba *ma-vuti*, Malekula *me-vus*, *embusa*, Epi *mi-wowo*, *mi-ubu;* Efate *tare* is properly 'clean, pure,' Omba *ma-sara*, 'clean.' Malo *lulu* is Torres Island *lul*, 'white,' Mota 'fair.' Santo *voke* is Pangkumu *vogvog*, 'clean,' Mota *woke*, 'an albino.' The Maewo *sigara*, Samoa *sinasina*, is from a root meaning 'shine,' in Fiji, *siga* 'sun,' *sigasigau*, 'white,' Sesake *ma-sina*, 'moon.' Cf. *Mel. Lang.* p. 97.

[Sk. *valaksha*, 'white,' Dr. *vel*, Slavonic *veli*, Hungarian *vilag*, 'light'; another rt. is *pu* (ba), 'shine,' *q.v.*]

80. *Black*—The word *maeto*, seen in Arag, Santo, and Malekula, is very widely spread, and is also in Malagasy and Malay. In Efate, Sesake, *maeto* is 'angry.' The Fiji *loa* is in Nguna. Malo *urica* is 'skin colour' (*uri* 'skin,' *ca* the adjective termination). This suggests the Polynesian *uri* as 'skin,' but skins are not black in Polynesia. *Cf. po-uri*, 'dark.' Aneityum *apig* is also used for 'night,' as is the Mota *silsilig'a* for 'dark.' Mele *kele-kele* is 'dirty,' *kele*, 'earth.' Maewo *oso-oso* is *o-o*, 'cloud,' in Nogogu; *soso*, 'dirt,' in Fiji. Cf. *Mel. Lang.* p. 57.

['Black' is often 'burnt' (*cf.* the name Ham); hence *ma-eta*, *'uli*, &c. may come from rts. *ma*, *ka;* see Note 1; Sk. *kala*, 'black.']

81. *Holy*—The word *tapu*, which is also Polynesian properly, means 'prohibited, set apart,' and is found in Aneityum, Eromanga, Efate, Malo, and Tangoa, and also in the Arag *sa-pu* with adjective termination. The Pangkumu *ukon* may be Malo *ducu*, Santo *ruku*, Maewo *rogorogo*, Mota *rogo*, and the meaning is 'sacred.'

82. *See*—There is no doubt a great variety of terms for 'see,' and all may not have exactly the same meaning. An example

from Pangkumu may be given in illustration. *Coro* is 'to open the eyes and look for' (Nguna *leogoro*); *bunsi* (Nguna, etc., *punusi*, Florida of Solomon Is. *buguti*) is 'to look at,' *e.g.* a ship, a picture; *nunuri*, 'to stare, gaze at,' as in reading a book. The Mota is *ilo nurnur*, 'to look carefully.' *Rag'arag'*, 'to be present at' and therefore 'see', as a dance, a person's house. The word *kite*, which is Maori, is seen in Aneityum *ecet*, Tanna *ata*, *eru*, Tangoa *kite*, Arag *g'ita*, Maewo *ete*, Aniwa *citi*, Mae *kute*. Marina *kile* is the common word for 'know.'

[The Aneityumese *alum*, 'to look at,' and *ecet*, 'to see,' *ucni*, 'to burn,' show that the rts. in this column are the same as in *alo*, *kan*, *ma* of Notes 1 and 61 (*qq.v.*); see also 'know,' No. 85.]

83. *Hear*—The word *rogo* is very widely distributed in Oceania, and in its simplest form means 'to feel a sensation,' as pain or a noise. When meaning 'to hear,' it often takes a suffixed transitive termination, as in Ambrym *rog-ta*, Omba *rorog-tagi*, Mota *rogo-tag*, Samoa *logo-na*. The Aneityum *ahgei*, Tanna *aregi*, Eromanga *rigi*, Lifu *dege*, are all forms of *rogo*. In the Weasisi *ate-telig*, *telig* is the word common for 'ear,' and *ate*, no doubt, means 'to turn'; in Mota *ate* is 'to turn to,' *ate-nagoi*, 'to turn the face to.'

[See 'ear.' Malay is *dangar*, 'to hear,' cognate to *logo*, *rogo*.]

84. *Speak*, *Say*, *Tell*—It is by no means certain that all the words here given are exactly synonymous. The Fiji *vosa* is seen in Tasiwo, Efate, etc., and in Futuna and Aniwa *visa*, *fasa*, Lifu *whadha*, and Ambrym *fie*. *Vosa* is also in Malo the word for 'know.' We have *vet* in Mota, Maewo, Santo, Malo, and Epi, in Makura *mbetog*, and Tanna *ani* is Lifu *öni*, 'to say.' Malo *sora* is in Pangkumu *sur*, but is there only used in compounds, as *sori-menemen* 'speak kindly,' *sur-papagis*, 'speak angrily,' etc. Mai and Fiji *muna* is Samoan *muna*, 'to grumble.'

[Some of these words have an extraordinary resemblance to Sk. *vad*, 'speak,' Latin *fat-us*. *Cf.* also Malay *bhāsa*, Pâli *bhasa*, 'speech,' Dr. *pesu*, 'to speak,' Sk. *bhâsh*, 'to speak.']

85. *Know*—A representative of the Fiji *kila*, Mota *g'ilala*, is seen in Maewo *g'ig'ilea*, Ambrym *kelea*, Bieri *ki'i*, Eromanga *kili*. The Aulua *lise-mbosa* is 'see-speak,' Tangoa *rogo-bosa*, 'hear-speak.' The *atae* of Efate, etc., is in Mele *taea*, and in Lifu *ate*, and is also in South Cape (New Guinea) *ata*, and Ponape (Caroline Islands) *aja*. Arag *ilo*, Omba *iloilo* is 'see' in Mota, Efate, etc.

[*Cf.* 'See'; cognate is 'know'; *cf.* Lat. *vid-eo*, Gr. *oid-a.*]

86. *Barter*, *Buy*, *Sell*—The common Oceanic word is *voli*. This is seen in Epi and the Northern languages of the New Hebrides. There is an interesting correspondence of idiom in the word used in the Southern languages and Polynesia. In Aneityum and in Tanna, *aua* and *vahai* are causative prefixes, the same as *faka*, *fa'a* in Futuna, Aniwa and Samoa. The second part of the compound is the ordinary word in use for 'eye,' *nimtan*, *namri*, *mata*, but used as a verb. Hence *aua-nimtam*, *faka-mata*, etc., mean 'to cause any one to eye.' The same idiom is found in New Britain (Raluana district) *wa-mat*, 'to sell, offer for sale.' In the Duke of York Island *mata* is 'price,' in Florida (Solomon Islands) *mate*. In Efate, Nguna, Sesake, the first part of the compound is also the causative. Nguna *tovi* is 'distribute,' Futuna *tufa*, Aniwa *tufwa*, 'give out,' Samoan *tufa*.

[Some of these words mean 'to exchange'; *cf.* Tukiok *we-kelei.*]

87. *Eat*—All the dialects have some form of *kani* or *kai*. Pangkumu *hani* is restricted to the eating of cooked food, *roi* is 'to eat raw food.' Ambrym *drog* is perhaps the same as *roi*. [See 'food.']

88. *Drink*—The common word is *muni* in various forms, and often with the transitive suffix *gi*. *Inu* is also found.

[Rt. *ma*, *mi*, 'water,' *q.v.* *Cf.* Lat. *bi-bo*, Gr. *pi-no*. Oceanic *inu* (for *mi-nu*) perhaps gives *niu*, 'cocoanut,' by metathesis.]

89. *Dig*—All the words found are forms of *kili*, except Futuna *vere*, which is Fiji *were*, 'a garden,' *were-dha*, 'to garden,' dig up weeds, etc.

90. *Bury*—The Polynesian *tanu*, with transitive suffix, is seen in Tanna, Eromanga, Efate, and Malo. The original meaning is

'to cover with earth,' with Mota *tanu*, 'to cover'; *cf. tano*, 'earth.' In Tanna and Eromanga, the word is probably of recent introduction, as the heathen custom was to bury in the sea. The Fiji *bulu-ta*, from *bulubulu*, 'grave,' may be compared with Baki *bulu*, 'pit,' *bulu-si-maro*, 'pit of dead, grave.' Lifu *kelemi* may be an extreme form of *tanumi*, or be from *kele*, 'earth,' with transitive suffix.

91. *Weep*—The only departure from the common *tagi* are in Lifu and Tanna. *Kai*, *gcai*, *gei*, which are local in the Efate district, are also used for the buzzing of a fly, mosquito, etc. The same use is found in Pangkumu *keke*, 'to buzz,' *ke*, 'to shout,' *gceir*, 'to scream,' Malo *gara*, 'to scream.'

[The root idea is 'shrill, sharp, keen'; see rts. *gar*, *ka* in Note 1; *cf.* the Irish 'keen-ing.']

92. *Fear*—There are variations from the common Oceanic *mataku* in Tanna, Nogogu, Fiji, and Lifu.

93. *Life*—The word *mauri* is common, with a few exceptions.

[The rt. is *ma*, 'to live, to breathe'; *cf.* Sk. *bhû* (bhav), 'to be, to come into existence'; Pâli *pa-no*, 'life, vitality, a creature,' Sam. *ma-ṅava*, 'breathe.']

94. *Die*—Only one word *mate*, varying in form to *mar*, *mas*, and *mech*.

[The root is *ma*, 'fade away,' as in Gr. *ma-r-aino*. The old Assyrian is *ma-atu*, 'to die,' Hebrew *ma-veth*, 'death,' Australian *ba-lun*, 'dead,' Keltic *bas*, 'death.' The Aryans add *r*, as Sk. *mri* (mar), 'to die,' Lat. *mor-s*.]

95. *Sleep*—The Central and Northern tongues have *maturu*, which is Lifu *meköle*. There is no agreement among the Southern languages.

96. *Stand*—The usual word is *tu*, in most cases joined to a word meaning 'upright,' as in Sesake *ndu-leana*, Efate *tu-leq*, Epi *tu-mau*, *ju-moli*, *su-malu*.

['Stand, Stay, Sit' are allied ideas; *tu* is Sk. *s-thâ*, Lat. *s-to*.]

97. *Stay*—The word *toko* does not appear in Tanna and Eromanga, but is present in the Aneityum *ateuc*, 'to sit.'

98. *Sit*—This word is usually the same as that for 'stay,' often with the word for 'ground' added, as in *tok-e-tan*, *jo-a-tano*, *toko-san*, etc. The Malekula *sagcer*, *sagcali*, Tangoa *sakele*, mean 'to sit on something high,' Mota *sage*. Ambalok *non* means 'to sit on something low.' *Sake* is a very common directive, meaning 'upward; to ascend.'

99. *Go*—*Vano* and *va* in various forms are widely distributed. The notion is probably that of motion only. Pangkumu *jo* is Lifu *tro* in *tro-tha*, where *tha* denotes motion from the speaker.

100. *Come*—The word *mai* is probably never a verb, but rather an adverb 'hither.' It is commonly used with verbs of motion, as in Lifu *tro-mi*, Malekula and Maewo, *vani-mai*, *vano-mai*, etc.

['Go,' 'Come' are allied; *cf.* Dr. *pô*, 'to go,' *vâ*, 'to come,' Gr. *ba-o*, *ba-ino*,' 'I go,' Lat. *va-do.*]

Numerals.

These require little notice and many are fully discussed in Dr. Codrington's "Melanesian Languages." There are three methods of numeration in use. 1. Pure quinary.—"No word for ten is in use, except such a one as shows five to be the number really in view."* 2. Imperfect decimal.—"There is a word for ten; after five is reached there is no further mention of the five."† 3. Decimal.—"Each number is expressed by a different word."‡ The vigesimal system, which among the languages here shown is only found in Lifu, has no representatives in the New Hebrides.

Tabulated according to numeral systems, the New Hebrides Languages appear as follows:

1. Quinary: Distinct words from one to five; the remaining numbers expressed by addition. *Examples*:—Aneityum, Tanna, Eromanga. In Tanna, ten is 'five-five,' in Eromanga 'two-fives.'

2. Imperfect Decimal: (*a*) Distinct words from one to five; six, seven, eight, and nine are expressed by one, two, three, four,

* Codrington, Melanesian Languages, p. 222. † *Ibid* p. 223. ‡ *Ibid* p. 228.

with a prefix; ten is 'two-fives.' *Examples:*—Epi, Efate, Sesake, Paama, Nguna, Makura. (*b*) The same formation, but a distinct word for ten. *Examples:*—Ambrym, Malekula, Espiritu Santo (Eralado, Tangoa, Marina).

[There the *-ul*, *-bul*, *-vul* is the Polynesian *fulu;* see 'ten.']

3. DECIMAL: Distinct words for each number. *Examples:*—Malo, Espiritu Santo (Nogogu), Omba, Arag, Maewo, Fiji, and all the Polynesian dialects.

The numerals are generally used with a prefix, which is separated from the root in the vocabulary by a hyphen.

101. *One*—The words seem to be divided among three principal forms, *tasi*, *sikai*, and *tuwa*. In the New Hebrides *tasi* seems only to be found in Paama, Epi, Lifu, and perhaps the Southern Languages. The commonest New Hebrides word is a form of *sikai*, which is also in the Solomon Islands. The Arag *tuwa*, Maewo; Mota *tuwale*, *tewa*, is Fiji *ndua*.

[In *ta-si* and *si-ka-i*, the original root is *ka*, Sk. *êka*, 'one.']

102 – 104. *Two*, *Three*, *Four*—These are *rua*, *tolu*, and *vati*, in various forms. The chief variations are the Lifu *köni* for *tolu*, and the Lifu *eke*, and the Polynesian *fa (va)*, for *vati*.

[For *lua*, *tolu* (t'lu) *cf.* Sk. *dva* (Lat. *duo)* and *tri.*]

105. *Five*—*Lima* in various forms is found everywhere, and is the common word for 'hand.' Tanna *kari-lum* and the Eromangan *suk-rim* are 'one hand.'

[It has been shown (see note on the word 'hand'), that the old root-word *gab*, *gam*, 'to lay hold of' (*cf. Eng.* finger, *Ger.* fangen), is the source of *lima*, 'hand.' The nearest approach to this root are the Aneityumese *ikm-an* for *kim-an* and the Epi *jim-o*. The Irish *lam*, 'the hand,' and the Greek *e-lab-on*, 'I toók hold of,' are from the same root.]

106 – 109. *Six*, *Seven*, *Eight*, *Nine*—Where these numbers are distinct, there is an agreement in the use of the words *ono*, *fitu*, *walu*, *siwo*, or some form of them. When formed by prefix, a form

of *la* is commonly seen. In the Tangoa *linarave*, *linarabi*, *lina* is the word for 'hand.'

[The Aneityumese for 'six' is *(n)ikman um elid et ethi*, which means 'his-hand and added is one,' for the Oceanic numerals of the second hand are got by addition; the Motu 'eight,' *ta-ura-hani* is 'a two-fours.' The prefix *la* in some words is for *lima*, 'the (first) hand.']

110. *Ten*—The separate word for 'ten' is in all cases a form of *sagavalu*. In Mele it is *nofuru*, Samoan *se-fulu*.

[The Oceanic *fulu* is 'all,' *sc.* the fingers; Sk. pi-*par*-mi, 'I fill'; the Pâli *puro*, Malay *punnuh*, Efate *bura*, all mean 'full'; New Brit. *para*, *vuru*, 'all'; New Guinea (one dialect) *mura*, 'all.' The Maori has *poro*, 'to end *or* be finished,' with which *cf.* Pâli *puro*, 'full.' The Malay has also *bulah*, 'complete.' The prefixes are *sa*, 'one,' *nga* (ngo, go, ko), the article; so that *sa-nga-fulu* means 'once-the-whole,' *sc.* fingers. The Ebudan *lua-lima* is 'two hands,' and *kari-lum-kari-lum* is 'one-hand-one-hand.']

PRONOUNS:

In the Vocabulary three forms of pronoun are given, separated by semi-colons. Of these the first is the full form, the second is the possessive suffixed to nouns, the third is the shortened form used with verbs. Any form which I have not found to be now in use, is marked ...; when it does not exist it is marked †.

1. PERSONAL PRONOUNS: These show a general use of personal and demonstrative prefixes, *i*, *ki*, *ni*, *ke*, etc. The root-forms seem to be the following:

Sing.	1. au, nau	Plur.	1 (inclusive) kita, ita
	2. ko, o		1 (exclusive) ma, mi
	3. ia, e		2. mui, mu, mi
			3. ra, la

The dual forms may mostly be referred to the plural roots, with the numeral 'two' suffixed. In the same way, three or a few persons are often denoted by a suffixed numeral. In Aulua (Malekula) and in the Polynesian dialects, however, the suffixed *ntil*, *tou* used in the plural are the numeral *tolu*, 'three,' used indefinitely of any number more than two.

2. Possessive Pronouns: In the singular, these are all forms of *ku*, *ma*, *na*, and are suffixed to nouns denoting relationship or parts of a whole. The dual and plural forms do not appear to be distinct from those used as personal pronouns, but are in most cases abbreviated.

3. Verbal Pronouns: These are usually shortened forms of the personal pronouns, and are sometimes combined with the verbal particles. (See Introduction). In the third person, the word must often be regarded as a particle rather than a pronoun, especially in the consonantal forms *m*, *t*, *k*, etc.

Plural.

The methods of forming the plural are various. They may be tabulated as follows:—

1. By prefix *ra*, *ro*, *o*, *o*:—Malo, Santo, Futuna, Aniwa, Lifu.
   vei, *i*:—Malo, Fiji, Lifu.
2. By adjective following:—Commonly.
3. By plural pronoun following:—Epi and Malekula.
4. By noun preceding:—Eromanga.
5. By lengthened vowel:—Samoa and Maori.

Sources of the foregoing Vocabularies and Specimens.

1. *Aneityum*—Dictionary by Rev. J. Inglis.

2. *Tanna-Kwamera*— { Translations by Rev. W. Watt. 'Nineteen years in Polynesia' by Rev. G. Turner.

3. *Tanna-Weasisi*— { Grammar and Vocabulary by Rev. W. Gray in Rev. D. Macdonald's 'South Sea Languages.' Translations by Rev. W. Gray.

4. *Eromanga*— { Translations. 'Nineteen years in Polynesia' by Rev. G. Turner.

4. 5. 6. *Eromanga*—
24. *Santo-Nogogu*— { 'Three New Hebrides Languages' by Rev. D. Macdonald. (Nogogu words in Italic are Wulua dialect, words marked * are Valpay dialect).

7. *Epi, Tasiko*—
19. *Epi, Livara*— } MS. by Rev. R. M. Fraser. (Tasiko words in Italic from a slip printed by Bishop Patteson).

8. *Epi, Bieri*—
9. *Epi, Baki*— } MS. by Rev. R. M. Fraser
13. *Malekula-Pangkumu*—MS. Rev. A. Morton
21. *Malo*—MS. by Rev. J. D. Landels
23. *Tangoa*—MS. by Rev. J. Annand
} Also Grammars and Vocabularies by the same in the Rev. D. Macdonald's 'South Sea Languages.'

10. *Ambrym*— { 'Melanesian Languages' by Rev. Dr. Codrington. 'Die Melanesischen Sprachen' by H. C. von der Gabelentz.

11. *Port Sandwich*—
22. *Eralado*— } Journal of Commodore Goodenough.

20. *Makura*—
7. *Tasiko*— } MS. by Rev. O. Michelsen.

12. *Aulua*—MS. by Rev. T. W. Leggatt.

14. *Lamangku*—MS. by Rev. T. W. Leggatt and the Journal of Commodore Goodenough.

15, 16. *Efate*—Translations by Rev. D. Macdonald. (Words in Italic are from 'South Sea Languages.')

17. *Nguna*— { Translations by Rev. Milne. Tongoan in Italics by Rev. O. Michelsen, MS.

25. *Marina*—'Melanesian Languages' by Rev. Dr. Codrington.

28. *Vunmarama*—Bishop Patteson.

26. *Omba*—
27. *Qatvenua*—
29. *Maewo*— } 'Melanesian Languages' by Rev. Dr. Codrington Melanesian Prayerbooks and MS.

30. *Futuna*— { Translations by Rev. J. Copeland and Dr. Gunn. Grammar and Vocabulary by Dr. Gunn in Macdonald's 'South Sea Languages.'

31. *Aniwa*— { Translations by Rev. J. G. Paton. 'Nineteen Years in Polynesia' by Rev. G. Turner.

33. *Mele*—'Nineteen Years in Polynesia' by Rev. G. Turner.

32. *Mae*—MS. by Rev. Dr. Codrington.

34. *Mota*—MS. Rev. Dr. Codrington, and 'Melanesian Languages.'

35. *Fiji*—Dictionary by Rev. D. Hazlewood.

36. *Lifu*—MS. by Rev. J. Sleigh; now revised by Rev. S. M. Creagh, of Sydney.

37. *Samoa*—Dictionary by Rev. G. Pratt.

38. *Maori*—Dictionary by E. Tregear.

39. *Iai** or *Uvéa*—Communicated by Rev. S. Ella, Sydney.
40. *Maré*—Communicated by Rev. S. M. Creagh, Sydney.

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*[The native name of this island is Iai (not Tai as on page 109). The following account of the manner in which brown Polynesians came to settle on this island is worth preserving ; it is communicated by the Rev. S. Ella :—On the island of Uvéa (properly Iai), in the Loyalty group, some castaways, both from Tonga and Wallis' Island, have long been settled; one party, Uvéans (Wallis Is.), occupying the northern end of the island, to which they gave the name of Uvéa, and the other on the southern extremity, which they call Tonga. The original inhabitants (Iaians) occupy the central portion. The correct name of the island is *Iai*, but navigators, from first having had intercourse with the immigrants at the northern end, have misnamed the island from the introduced name of that district. The description given by some of the natives of the Union Group in a measure accounts for the manner in which these waifs get driven away to distant islands. They were accustomed to move from island to island, long distances apart, in times of scarcity of food or other emergencies; and the night time, when the sea is calmer and the wind lighter, was generally selected for voyaging. They steered by the stars; but if the night became cloudy, or a strong wind arose, they would simply lower their sails, entreat the protection of their gods, and then quietly resign themselves to drift whither sea and wind might bear them.

These Iaians were the original occupants of their island, but whence they came or when they settled there, I never could ascertain. They are Papuans, not negritoes, and resemble the peoples on the coast of New Guinea.

As on Iai, so in the New Hebrides; immigrants have been drifted thither from Eastern Polynesia. For instance, some forty years ago, missionaries from Samoa discovered a tribe of Samoans occupying a district on the island of Efaté (Sandwich Is.), with whom easy intercourse was held in their own language. The account of their emigration was to this effect :—In one of the sanguinary conflicts which took place in Samoa before Christianity was introduced into that group, a large canoe party effected their escape from their conquered district, and fled to seek refuge in Tonga. Owing to adverse winds they missed that group, and were carried to the New Hebrides, and made the island of Efaté. Here, after several conflicts with the natives, they were enabled to establish themselves. Many years afterwards they were visited by the *John Williams*, missionary ship, and some elected to return to their former home. The islands of Aniwa and Futuna, in the New Hebrides, are peopled by natives of Tonga and Futuna proper, westwards from Samoa, and also by emigrants from Tanna. Islands at the north of the New Hebrides also are inhabited by immigrants probably from the Eastern Pacific.]

41. *New Britain*— } Communicated by Rev. B. Danks, of
42. *Duke of York Is.*— } the New Britain Mission.

43. *Motu*—Grammar and Vocabulary of the Motu Language, New Guinea, by Rev. W. G. Lawes, second edition; Chas. Potter, Government Printer, Sydney.

☞ The Council of the Royal Society wishes here to acknowledge the courtesy of the Rev. Dr. Cosh, Sydney, Chairman of the Board of New Hebrides Missions, in granting the use of the Mission map (See *Plate* 9) to illustrate the localities mentioned in Mr. Ray's paper.

UNRECORDED GENERA OF THE OLDER TERTIARY FAUNA OF AUSTRALIA, INCLUDING DIAGNOSES OF SOME NEW GENERA AND SPECIES.

By Professor RALPH TATE, F.G.S., F.L.S., Hon. Memb.

[With Plates X. - XIII.]

[*Read before the Royal Society of N. S. Wales, July 5, 1893.*]

IT is now nearly five years ago that the Society published my "Census of the Fauna of the Older Tertiary of Australia." During that interval much additional material has been acquired, and observations in the field touching the stratigraphical phenomena have been recorded, and it now seems desirable to make known the new facts by way of a Supplement to the Census, including corrigenda as well as addenda.

The beds at the following sections, which had been tentatively included in the Miocene, are now transferred to the Eocene, viz., those at Cheltenham, Port Philip Bay; those in the Moorabool Valley, Geelong; the Turritella beds of Table Cape; and the marbles of the Great Australian Bight. These removals limit the Miocene to the oyster-beds of the Aldinga and River Murray

Cliffs, the upper beds of the Muddy Creek section and the low-level fossiliferous beds around the Gippsland lakes, which last repose against the escarpments of the Eocene-limestones, well-exposed in the cliffs of the Rivers Mitchell, Tambo, &c. A marine fauna of Pliocene Age has been discovered and recorded by me in Trans. Roy. Soc. S. Austr., Vol. XIII., p. 172, 1890.

An examination of the fossils of the Oamaru Series in New Zealand brings to light many previously unknown specific communities with our Older Tertiary; and in the case of the echinoderms, the generic grouping is absolutely identical, though the species are for the most part different, which leaves no room to doubt that the Oamaru Series is correlative with the Eocene of this continent, and is homotaxially related to the lowest members of the European Eocene, if it be not somewhat older.

The additions to the specific representatives of the various genera recorded in my Census are too numerous to record here, but I have described an exemplar species of each of the majority of the genera now added.

Class MAMMALIA.

The skeleton of a marsupial is recorded by Mr. R. M. Johnston from the "Turritella beds" at Table Cape, and by him referred to the living genus *Halmaturus* without specific name. At the time of writing my Census, I had thought it possible that the specimen might be of recent date, and had reached its position by way of a vertical fissure from the surface, and it was accordingly omitted. During the meeting of the Australasian Association for the Advancement of Science at Hobart, the slab containing the skeleton was carefully examined by Professors Hutton and Spencer and myself, and by us was unhesitatingly pronounced to be lying in the bedding plane of the rock. Subsequently Professor Spencer and myself visited Table Cape to study its stratigraphical features, with the result that this extensive vertical section represents one period of deposition, gradually passing from the basal conglomerates and coarse grits, rich in marine fossils, to the "Turritella-beds," in which the species have been greatly reduced in number, and to estuarine or fluviatile beds with plant-remains only. This discovery is of the highest interest, as hitherto no marsupial remains are known older than the age of the *Diprotodon* or Pliocene; and leads us to hope that other progenitors of the modern Marsupialia of this Continent may yet be found, and so help to solve the question of their geographic origin. Professor Spencer has promised to investigate the fossil with the view to determine the classifactory position of the oldest known Australian marsupial.

Class Pisces.

Genus *Strophodus.*

S. Eocenicus, *sp. nov.*, Pl. xiii., fig. 6.

I am not aware if representatives of this genus have been signalled in rocks younger than Upper Cretaceous, yet I have no hesitation in referring to it some fish-plates, which are not of uncommon occurrence at Cheltenham, Port Philip Bay, and also have been found by me in the Lower Murravian, and by Mr. Sweet from the limestones of the Moorabool River. The species is somewhat comparable with *S. magnus*, Agassiz, but is narrower with coarser reticulate rugosities and the inner margin is very finely reticulate-punctate; the outline is subtrapezoidal, about three times as long as wide, broader at one end, which is convexedly truncate and narrower at the other which is truncated; uniformly depressedly-convex above. Length 30 mm., width 8, increasing to 11 mm., thickness 7 mm.

Genus *Otodus.*

This genus is now merged in *Lamna.*

Genus ? of *Chimæridæ.*

Dental plates belonging to a Chimæroid fish have been collected at Grange Burn, Hamilton, by Mr. Sweet, but the material available is not sufficiently complete to permit of generic determination.

Class Cephalopoda.

Genus *Spirulirostra.*

S. CURTA, *sp. nov.*, Pl. x., fig. 1.

This genus was founded by D'Orbigny in 1841, and its type-species, *S. Bellardi*, from the Older Miocene of Turin has remained till now unique. A good figure of it is given in Fischer's Manuel de Conchyliologie, but is more fully illustrated in Nicholson's Manual of Palæontology.

Nicholson placed the genus in Sepiadæ, Fischer in Belopteridæ, Tryon in Belemnitidæ; this last location seems to me to be the best, as *Spirulirostra* may be viewed as a *Belemnite* with a sub-spiral phragmacone lying obliquely within the alveolar cavity.

An example of the present species was collected by me at Bird-rock Bluff, near Geelong, in January 1890, and I announced its discovery to the Royal Society of South Australia at its April meeting of that year; during the following summer I was successful in obtaining a second example at the same locality.

The rostrum of the Australian species is more robust, is shortly-pointed, and is less arched dorsally and ventrally, where it is more or less truncated. Lateral axis of rostrum 8, ventro-dorsal axis 12, length to apex of phragmacone 16; length of alveolar cavity above plane of apex of phragmacone 29 (incomplete).

Class GASTROPODA.

Genus *Murex.*

Subgenus *Muricidea.*

Of the described species of *Trophon*, only *T. icosiphyllus*, makes an approach to the characters of the genus, the rest belong as also do some species of *Ocinebra*, e.g. *O. biconicus*, to *Muricidea.*

Subgenus *Muricopsis.*

Murex (Ocinebra) alveolatus and *M. crassiliratus* belong here.

Genus *Clavilithes.*

This genus, so characteristically Eocene, is represented in the Eocene-beds of Australia by *F. incompositus*, *F. bulbodes*, and *F. Tateanus*, whose relations to the type-species of the genus, *Fusus longaevus*, Solander, I had already indicated.

Genus *Fusus*.

Subgenus *Tectifusus*, nov.

As suggested by M. Cossmann, I remove my *Fusus tholoides* and *F. Aldingensis* to form a new subgenus, *Tectifusus*, characterised by the tectiform and costulated pullus.

Genus *Latirofusus*.

This genus was founded by Cossmann in 1889 for the reception of *Fusus funiculosus*, Lk., and *F. decussatus*, Desh., of the Parisian Eocene; he refers to it the living *F. lancea*, Gmelin, placed by Tryon in *Latirus*. As suggested by Cossmann *F. aciformis*, mihi, proves to belong to *Latirofusus*. I have recently described a species inhabiting Southern Australian waters under the name of *Latirofusus nigrofuscus*. Species of this genus have a narrow elongate spire with a hemispheric embryo, the aperture is small and rounded, the canal straight and nearly closed, the columella obliquely plicated.

Genus *Concholepas*.

C. ANTIQUATA, *sp. nov.*, Pl. x., fig. 2.

This aberrant genus of Purpuridæ is represented by *C. Peruviana*, Lk., ranging from Peru to Patagonia, and *C. Deshayesi*, Rambur, of the Miocene of Touraine. The discovery of a third species by Mr. G. B. Pritchard in the clays at Mornington, Port Philip Bay, and in the calcareous sands at Muddy Creek, Hamilton, extends the stratigraphical range to the Eocene.

I am unacquainted with *C. Deshayesi*, either by description or figure; but compared with *C. Peruviana* our fossil presents the following differences:—The great variability of the ornament of the living species and the fact that the fossil species is known to me by only two examples make it difficult to select a character which may prove to be specific rather than individual. In respect of shape, the fossil is more tumid with a larger spire, the suture of which appears deeply impressed (arising from the steep slope intervening between the actual suture and the convex rib which ends at the posterior angle of the aperture). The prominence of the posterior angulation gives the posterior part of the aperture a truncated outline; the margin of the aperture is only feebly denticulated anteriorily. The anterior groove is broad and deep, and the columella-expansion is broadly concave and not horizontal. The ornament consists of linear grooves unequally placed, dividing-up the surface into flat ridges, which become somewhat angulated towards the front; the whole crossed by growth-lines, giving place to slight lamellae in the neighbourhood of the basal rib. There is a total absence of a fenestrate ornament as in most individuals of *C. Peruviana.* Length 26, breadth 22, height 14 mm.

Genus *Distortio.*

D. INTERPOSITA, *sp. nov.*, Pl. x., fig. 3.

This genus is represented in living creation by three species, one of which *D. anus*, Linn., of the Indian Ocean, is a familiar shell, remarkable for its ringent aperture. Among described species *D. septemdentata*, Gabb, from the Eocene of Texas is the most ancient; in the European Tertiary beds, it is represented by *D. tortuosa*, Borson, in the Piedmontese Miocene. Our Australian species is from the Eocene at Bird-rock Bluff near Geelong, whence a few examples have been obtained; it has the general aspect and latticed ornament of *D. cancellina*, Roissy, but has a very short canal, the spiral ribs are flat and alternate with riblets (there are about seven on the penultimate whorl, the third, fifth, and seventh more prominent), subgranose at the intersections of the primary spirals and costæ (most prominent in the early whorls). *D. septemdentata* has three spirals on the penultimate whorl. Length 25, breadth 15, length of aperture and canal 13·5 mm.

Genus *Argobuccinum.*

If this name is accorded generic rank, then it should replace *Ranella*, as the only species in the Australian Eocene, *R. Pratti*, Ten.-Woods, has the distinctive characters of *Argobuccinum* as already implied by me when redescribing the species.

Genus *Tritonidea.*

I here refer *Pisania obliquecostata* and *P. brevis*, Tate; whilst *P. rostrata* and *P. semicostata*, Tate, are better placed under

Cantharus, and *Pisania purpuroides* (Johnston), Tate, may be replaced in *Ricinula*. These transferences eliminate the genus *Pisania* from our list.

Genus *Harpa*.

HARPA PACHYCHEILA, *spec. nov.*, Pl. xi., fig. 5.

This species belongs to the Section *Eocithara*, Fischer, to the type of which *H. mutica*, Lamk., of the Parisian Eocene, it bears some resemblance, differing by its angulated whorls and the absence of the delicate clathrate ornament between the costae. It resembles also *H. abbreviata*, mihi, but has angulated whorls, acute not lamellate costae, intercostal spaces distantly cross-barred, pullus small, and outer lip excessively thickened (which ascends to near the keel of the penultimate whorl. Length 27, breadth 17 mm. Locality : Eocene, Spring Creek (common).

Genus *Pyrula*.

This genus is represented in the Eocene beds of Table Cape, Tasmania, by a large species, known to me by two examples in the collection of Mr. T. Atkinson ; it is undescribed.

Genus *Dolium*.

DOLIUM BIORNATUM, *spec. nov.*, Pl. x., fig. 5.

Shell thin, elliptic-oval ; spire elevated ; imperforate ; whorls six, ventricose, slightly flattened posteriorly, suture linear. Penultimate and body-whorl with narrow flatly rounded encircling ribs (six or seven on penultimate whorl), and a riblet or thread usually interposed, crossed by rather distant growth-lines. Posterior whorls ornamented with slender spiral ribs, alternating with threads, tessellated by raised striæ, which produce crenatures on the principal lirae. Outer lip narrowly expanded and slightly reflected, crenate-dentate. Columella simple, long and straight; beak short, narrow and slightly oblique and upturned. Length, 48 ; width, 45 ; length of aperture, 37. Localities—Eocene : Fyansford (Mulder), Muddy Creek (Pritchard).

In general appearance it resembles *D. Testardi*, Montrz.; but has somewhat tabulated whorls; whilst the apertural characters are so distinctive as almost to warrant generic separation.

Genus *Eburnopsis.*

This generic name was proposed by me in Trans. Roy. Soc. S. Austr., 1888, p. 117, for a fossil having certain affinities with *Eburna;* in addition to the type *E. aulacoëssa*, two other species have since become known, all are Eocene, one of which is here described.

EBURNOPSIS TESSELLATUS, *sp. nov.*, Pl. xi., fig. 10.

Shell like *E. aualcoëssa*, mihi, but very much smaller, base imperforate, suture narrowly excavate, spire-whorls ornamented with linear spiral and axial sulci, which divide up the surface into rhombic flat nodulations. A well-marked revolving sulcus on the body-whorl terminates on the outer lip, a little in front of the middle, in a small tooth-like projection. Length 8·5, breadth 5. Locality—Eocene: Spring Creek, near Geelong (common).

Genus *Cypræa.*

Subgenus *Cypræedia.*

CYPRÆDIA CLATHRATA, *Tate*, Tr. Roy. Soc. S. Austr., Vol. XIII., tab. 9, fig. 1, 1892,

The subgenera *Cypræedia* and *Cypræovula* include the cowries with raised ornamentation, the former is distinguished from the latter by the absence of a posterior notch in the aperture. Five species have been described from the European Eocene; and the Australian congener is most like *C. elegans*, Defrance, but it is not so regularly clathrate in its ornamentation.

Genus *Genotia.*

This genus forms part of the Pleurotomidæ, and includes the oval-fusiform species having a slightly twisted columella, a short canal, and the sinus at the peripheral keel. The genus is best represented in Eocene and Miocene strata. The Australian species of corresponding age, known to me, agree best with *Dolichotoma*, but I am not satisfied that it is clearly definable from *Genotia.*

All our species have a globulose pullus, its tip immersed and slightly lateral; three of the following are near alliances to *D. cataphracta*, Brocchi.

GENOTIA FONTINALIS, *spec. nov.*, Pl. x., fig. 4.

Fusiform, angulated at or a little behind the suture; the posterior area concave axially and ornamented with (about eight) slender liræ, tessellated by oblique threads, more or less granulose at the interstices; the keel is granose-crenate, compounded of three or four equal-sized threads. Body-whorl in front of periphery with subgranose ribs (twenty) with interposed threads. Length 23, width 10, height of last whorl 17. Eocene:—Spring Creek near Geelong (common).

The sutural position of the keel, its composite nature, and the tessellated ornament separate this species from *G. cataphracta.*

GENOTIA DECOMPOSITA, *spec. nov*, Pl. x., fig. 8.

This differs from *G. cataphracta* by its shorter and stouter snout, by its shorter spire, more ventricose and bluntly angulated whorls, and in the absence of nodose crenatures on the periphery and at the posterior suture. The transverse ornament consists of slender arched threads which are not confluent in small groups at the suture. In its ornament it approaches more to *G. engonia*, Watson, but that shell is slimmer and its whorls angulated. Length 28, width 12, length of aperture and canal 17·5. Localities—Eocene: Gellibrand River, and Fyansford near Geelong.

GENOTIA PRITCHARDI, *spec. nov.*, Pl. x., fig. 9.

Has a short stout snout and therein differs from *G. fontinalis;* it approximates to *G. cataphracta* in the position of the keel which is however composed of three threads. Length 27, width 18. Locality—Miocene, Gippsland Lakes.

Named in compliment to my young friend Mr. G. B. Pritchard, in whose company the species was collected.

GENOTIA ANGUSTIFRONS, *spec nov.*, Pl. x., fig. 7.

(*Dolichotoma atractoides*, Tate, M.S., non *G. atractoides*, Watson).

Biconic; keels two, elevated; the posterior keel overlapping the suture, sharply crenate on the edge; the peripheral keel is triplicate and granose-dentate, anterior to it on the body-whorl are largely elevated encircling ribs (about twelve) narrower than the sulci which are transversely wrinkled and produce crenatures as they pass over the ribs. Outer lip with a deepish and broad slit at the periphery, anterior to which it is very strongly arched in marginal outline and declivous towards the columella contracting the aperture to narrow-elliptical. Length 35, greatest width (at one-third of the whorl from the aperture) 17, height of last whorl 24·5 mm. Localities—Eocene: Muddy Creek, Gellibrand, Fyansford, Mornington.

G. angustifrons is a variable species, in respect of length and details of ornamentation, but my description applies to the more commonly prevailing form, which is fairly intermediate between the extremes of variability.

Family Cerithiidæ.

Genus *Diastoma*, Deshayes.

This name is in substitution for *Mesalia*, to which I referred our only species, *M. Provisi* (inedit.), because congeneric with *Mesalia melanoides*, Reeve, Icon. Conch., 1849. My valued correspondent M. Cossmann, to whom the fossil was sent under the above name, informs me that it is a *Diastoma;* from him I have received examples of several species of *Diastoma* and *Mesalia* from the Parisian Eocene. This material permits me to affirm that *M. Provisi*, mihi, and *M. melanoides*, Reeve, are congeneric with *D. costellatum*, Lamk.; whilst *Mesalia sulcata*, Lamk. (non *sulcata*, Gray, = *brevialis*, Lamk.), is of a totally different type. *Diastoma* simulates *Mesalia*, but the latter has a sinuated outer lip, whilst the spiral carination of the columella of *Diastoma* is quite a different feature from the slight twist of the columella-margin of *Mesalia;* moreover *Diastoma* is more or less variced. Reeve in his figure and description of *M. melanoides* omits the slight varices on the posterior whorls; at any rate the examples of this species obtained in South Australia, as well as *D. Provisi*, exhibit this character. *Mesalia* belongs to Turritellidæ; *Diastoma*, which has been located in at least two families, finds a resting place in Cerithiidæ, it may be viewed as a Melania-like *Cerithium*.

Until now the genus has been known only in a fossil state, in the Eocene and Oligocene of the Paris basin; *D. Provisi* occurs in the Australian Miocene and Older Pliocene, and *D. melanoides*, Reeve, is living in South Australian waters. The transference of *Mesalia melanoides*, Reeve, to *Diastoma* will avoid the dual employment of the species name in *Mesalia*, so that *M. melanoides*, Deshayes, may be retained.

The genus *Mesalia* will however stand, as a small species, previously overlooked, occurs in the Eocene marly clays of the Aldinga Cliffs.

DIASTOMA PROVISI, *spec. nov.*, Pl. x., fig. 6.

Test very thick (in adult body-whorl 1 mm.). Shell resembling *D. melanoides*, but the costæ are more slender and numerous, the spiral threads more neatly crenulating the costæ; the early spire-whorls subquadrate (not convex), whorls slightly over-lapping at the posterior suture (not lightly channelled), and the spiral ornament interrupted in the posterior four-fifths by a very narrow impressed track. In *D. melanoides*, the seventh spire-whorl has five equidistant liræ; in *D. Provisi*, the corresponding whorl has five anterior equal and equidistant liræ with an intervening thread-let, and posterior to the revolving impressed track there are about four slender liræ; whilst there are twenty costæ. The liræ and costæ increase in numbers with the revolution of the spire.

Aperture loop-shaped, somewhat angular and slightly depressed in front, not detached behind; outer lip thin; basal lip slightly incurved; columella thickened and obliquely bevelled on anterior and inner face, callously spreading behind the columella-ridge (which is more sharply defined than in the recent shell).

Dimensions:—Total length 46; width 14; length of aperture from posterior angle to base, 15; greatest transverse width of aperture 7 mm. The ratio of these measures are approximately the same in *D. Provisi* and *D. melanoides*, being for the former 100; 30·4; 32·6; 15; for the latter 100; 33·3; 33·3; 14·2.

Localities:—Miocene—Hallett's Cove, St. Vincent Gulf; Older Pliocene—Dry Creek bore near Adelaide (very abundant).

Named in compliment to Mr. Provis, the late Manager of the Dry Creek Smelting Works, to whom the writer is indebted for the extensive collection of fossils obtained from the bore-holes at that place.

Subgenus *Semivertagus*.

This name was established by Cossmann in 1889 (Annales de la Soc. Roy. Malac. de Belgique, Vol. XXIV., p. 28), for such species of Cerithiidæ resembling *Vertagus*, but which are distinguished by the absence of a plication on the columella, and by having a short canal; he includes in it six species from the Eocene of Paris. No species has as yet been met with by me from our Eocene beds, but the genus is represented by one species each in the Miocene and Older Pliocene strata in the neighbourhood of Adelaide. Both agree with the type species, *C. unisulcatum*, Lamk., from comparison of actual specimens, in the general outline and apertural characters, but their spires taper more rapidly, the body-whorls are rather more conspicuously contracted, and the sutures well-defined.

SEMIVERTAGUS SUBCALVATUS, *spec. nov.*, Pl. xi., fig. 3.

Shell pyramidally turreted, apex somewhat acuminate; whorls thirteen, slightly flatly rounded at the posterior suture, inconspicuously ornamented by seven spiral threads, with two to four threadlets in the interspaces. Length 21, breadth 6 mm.

Locality:—Miocene: Calciferous sandstones, Aldinga Cliffs.

SEMIVERTAGUS CAPILLATUS, *spec. nov.*, Pl. xi., fig. 1.

Shell pyramidally turreted, apex somewhat acuminate; whorls twelve, separated by a conspicuous suture; ornamented by twenty or more spiral graved lines, separated by wider intervals which increase in width towards the anterior suture, crossed by slightly arched striæ which are more distant than the revolving lines. Length 17, breadth 5 mm.

Locality:—Older Pliocene : Dry Creek bore, near Adelaide.

Genus *Ataxocerithium*, nov.

Type:—*Cerithium serotinum*, A. Adams in Sowerby's Thes. Conch. sp. 48. f. 102 ; id Reeve, Icon. Conch. f. 146.

Etymology:—*Ataxos* out of order, and *Cerithium.*

Shell like *Cerithium.* Columella lamellar and elevated, contiguous with the outer lip and forming a tubular canal of moderate length, shortly but abruptly bent to the left and backward at the tip. The peristome is almost complete posteriorly. There are no varices and there is no posterior canal. The outer lip is expanded anteriorly and laterally projecting as in *Cerithidea*, behind which the whorl is peculiarly contracted.

The aperture suggests *Terebralia*, e.g. *T. sulcata*, but its tubular canal is formed by the extension of the basal lip on to the columella; it has also varices, at any rate there is a large variceal thickening at the posterior-third of the body-whorl against which the recurved basal margin is fused. The resemblance is greater in the young, or even better with *Campanile*, the sudden twist in the columella simulates a plica at its base. It has some analogy with *Vertagus*, but the absence of a posterior canal and varix on last whorl forbid its association therewith. It differs from *Colina* by the short reverted canal, complete peritreme, and the absence of a variceal dilatation of the outer lip. The pullus is globulose of one-and-half turns, with a bulbous free tip.

Ataxocerithium concatenatum, *spec. nov.*, Pl. xi., fig. 6.

Shell triangular-oval, spire somewhat acuminate of seven flat whorls separated by a deeply furrowed suture ; apex apiculate of about three small rounded whorls, ornamented with arched transverse threads, tip a little excentric. Spire-whorls ornamented with oblique, broad, flatly-rounded, transverse ribs (about twenty-four on penultimate whorl), and about five similar but narrower lirae, the intersections of which produce oblong pits. Last whorl contracted, the fenestrated ornament gradually obliterated on the anterior-half. Length 11; diameter of penultimate whorl 4·5, of body-whorl 4 mm. Locality—Eocene: Adelaide-bore.

Genus *Colina.*

This genus founded by the Messrs. Adams in 1853, of which four living species are known, has been signalled in a fossil state by Cossmann in 1889, who refers to it eight species of the Parisian Eocene which had been described as Cerithiums by Deshayes. The characters bring it in near relation to *Lovenella* (as distinct from *Cerithiopsis)*, from which it is distinguished by its straighter canal, dilated aperture, and reflected peristome.

Some of our Eocene *Lovenellæ* may eventually prove to belong to *Colina.*

Colina apicilirata, *spec. nov.*, Pl. xii., fig. 7.

Shell slender, elongate; whorls slightly convex, with six slender liræ crossed by transverse threads of about equal strength, which produce square interspaces; aperture broadly dilated; columella-border thin and slightly reflected; canal rather long (about ·5 mm.), slightly upturned, and just perceptibly bent to the left. Apex obtuse of two-and-a-half lirate whorls. Length 7, width of penultimate whorl 2, of body-whorl 2·5 mm.

Eocene clays at Gellibrand River (Mr. Dennant).

This species closely resembles *C. Munieri*, Desh., but differs in its embryonic whorls, which in the Parisian fossil form an acute pyramid of four to five smooth and slowly decreasing whorls.

Colina fenestralis, *spec. nov.*, Pl. xii., fig. 11.

Shell pyramidal of eleven flat whorls separated by a canaliculate suture; apex of two small smooth inflated whorls; penultimate whorl with five flat spiral threads, crossed by perpendicular costæ, which are nearly equally stout as the liræ, thus dividing up the surface into square pits (six in a length of 2 mm.). Length 9·5; breadth 3 mm.

Locality:—Eocene: Gellibrand River. With it occur two other closely-allied species, and a fourth is in the Table Cape beds.

Genus *Ampullina.*

This name is in substitution for *Ampullaria*, conchologically I do not know how to separate the one from the other; but as our fossil is marine, the transference becomes necessary. Only one species occurs with us, *A. effusa*, mihi, which will be described in my forthcoming Part iv. of the "Gastropods of the Older Tertiary of Australia"; it is restricted to the Eocene at Adelaide.

Genus *Sigaretus.*

This genus, which commenced in the Chalk has a few Eocene species and about twenty in recent seas, is an addition to our Eocene Fauna through the discovery of two examples of an undescribed species by Mr. G. B. Pritchard in the Spring Creek beds near Geelong. The new species will be figured and described in my forthcoming Part iv. of the "Old Tertiary Gastropods" as *S. microstirus.*

Genus *Calyptropsis*, nov.

Examples:—*Trochita turbinata*, Ten.-Woods; Eocene, Muddy Creek. *Crepidula umbilicata*, Johnston; Eocene, Table Cape. *Calyptropsis arachnoideus*, Tate, (M.S.); Eocene, Adelaide.

Shell like *Calyptræa*, but umbilicated and with a columella-insinuosity at the umbilical border.

Family Pyramellidæ.

Genus *Actæopyramis*, Fischer, 1885.

This is in substitution for *Myonia* (Fam. Actæonidæ) in which the species was wrongly placed, the heterostrophe apex removes it from that family.

Actæopyramis olivellæformis, *spec. nov.*, Pl. xi., fig. 2.

Shell elongate-oval, body-whorl longer than spire; aperture a little less than half the total length. Whorls seven, shining; suture concealed by a slight thin imbrication from preceeding whorl. Surface sculptured with microscopic graved spiral lines; the basal-half of the body-whorl deeply sulcated, the width of the intervening bands decreases somewhat towards the base. Aperture elliptic; outer lip thin, arched medially; peritreme incomplete; columella with a fold-like twist, medially sulcated. Length 13, breadth 4·5 mm. Localities—Eocene: Muddy Creek; Spring Creek, Geelong (an uncertain identification.

Genus *Isapis*, H. and A. Adams.

The fossil which I refer to this genus has the general aspect of *Isapis fenestratus*, Carp., as illustrated in Tryon's Man. Conch., Vol. IX., p. 273, t. 52, f. 11, but it possesses a revolving plait on the columella; whereas that genus is described as having a small median tooth on the columella. Mayer says of *Raulinia alligata* in establishing the genus, "sa columelle non tordue, aplatie, et qui porte à l'intérieur, une dent tuberculeuse independante pour ainsi dire, et qui n'a absolutement rien à faire avec le pli des *Odontostoma*." Specimens of *Raulinia alligata*, Desh., from the Middle Oligocene of Pierrefitte, which I owe to the generosity of M. Cossmann, all exhibit a revolving plait on the columella, and if the so-called tooth of *Isapis* proves to be a plait, then the only distinction between the two genera is that *Isapis* is umbilicated and *Raulinia* imperforate. A second species, having the facies of the other, has a closed umbilicus; I cannot call one *Isapis* and the other *Raulinia*, as I think the presence or absence of an umbilicus is a character too unstable for generic distinction. If I am right in my conjecture as to the presence of a plait in *Isapis* as in *Raulinia*, then the latter must merge into the former; if I am wrong, then the two species here described must belong to *Raulinia* and its characters amended in respect of the umbilicus and embryo, as also by the substitution of a "revolving plait" for a "tooth" on the columella. The heterostrophe pullus of *Isapis eothinos*, mihi, places it in Pyramellidæ, whilst the slightly arched and concave columella brings it in the neighbourhood of *Fossarus; Lacunodon*, Cossmann, among Littorinidæ, is closely simulated by it.

Isapis eothinos, *spec. nov.*, Pl. x., fig. 11.

(*Raulinia eothinos*, Tate, MS.)

Shell oval-oblong, test thin, apex obtuse, embryo obtuse with a looped tip. Whorls five, rapidly increasing, convex though slightly flattened at the posterior suture, suture channelled; spirally flatly-sulcated, separated by narrower truncated elevated ribs, the sulci seven or eight on penultimate whorl (the posterior one double), with oblique distant threads; body-whorl with about fifteen spiral flat ribs, tessellated in the interspaces.

Aperture large, oval, posteriorly angulated, slightly effuse basally; peristome entire; collumella arcuate, somewhat flattened, slightly reflected over the umbilicus, with a revolving median plait which does not extend to the free margin of the columella; umbilicus moderate, conspicuous. Length 7·5, width 4·5, length of aperture 4·5 mm.

Locality:—Eocene: Spring Creek, near Geelong (several examples).

Isapis elatus, *spec. nov.*, Pl. x., fig. 10.
(*Raulinia elata*, Tate, MS.)

Differs from the foregoing in its elongate bulimoid shape, non-canaliculate suture and closed umbilicus; the ornamentation is the same; whorls five-and-a-half. Length 8·5, width 3·75.

Locality:—Eocene: Muddy Creek, near Hamilton, Victoria.

Family Litiopidæ.

Genus *Litiopa*.

Litiopa punctulifera, *spec. nov.*, Pl. xi., fig. 9.

Whorls four-and-a-half, of which the apical one-and-a-half are smooth; the rest of rapid increase, concave, ornamented by transverse arched and spiral threadlets of about equal strength, which produce the appearance of punctures in the narrower interspaces. Aperture obliquely oval; outer lip thin, nearly straight posteriorly, slightly expanding in front; peristome entire; columella arched, slightly reflected to form a false umbilical chink, terminated at a little in front of the middle by an acutely angular notch which runs on the free margin into a short acute tooth-like projection.

The species has the general outline of *L. bombyx*, but its punctate sculpture and sharp columella tooth separate it from the few known species. The genus is represented by one species in the Parisian Eocene.

Length 3·75, width 1·75, length of aperture 1·75 (vix).

Locality:—Eocene: Gellibrand River.

Family LITTORINIDÆ.

Genus *Risella.*

RISELLA ALTA, *spec. nov.*, Pl. xi., fig. 4.

Shell conical; whorls slightly concave; suture linear-impressed, margined on each side by a prominent spiral undulose rib, and presenting the appearance of being crossed by axially elongated nodulations; the intervening area is traversed by two to four slightly undulose rounded threadlets, rendered somewhat nodulose by the intersecting oblique folds of growth. Base flat, the periphery flatly and thinly extended; umbilicus minute; there are from three to four concentric folds on the base. Length 5·5, breadth 6 mm. Localities—Eocene: Spring Creek and Muddy Creek.

Family CYCLOSTREMIDÆ.

Genus *Tinostoma.*

The species in the Australian Eocene referred to under *Ethalia* belong to *Tinostoma* which is as well-represented in the European Eocene as in modern seas.

Genus *Adeorbis.*

This genus is represented by two or three species. *Adeorbis aster*, T.-Woods, is an *Astralium (Carinidea).*

Genus *Delphinula.*

This is represented by one if not two species in the Eocene at Muddy Creek, Gellibrand River, Fyansford and Mornington.

Family TROCHIDÆ.

Genus *Cantharidus.*

No species of *Trochus (sensu stricto)* are known to me from the Australian Tertiary, those referred thereto belong to *Cantharidus.*

Genus *Eumargarita*, Fischer, 1885.

To this genus must be referred the species included under *Minolia*, one of which *E. lucens*, mihi, from the Eocene of Spring Creek, belongs to the genus in its restricted definition, the others fall into the subgenus *Solariella*, S. Wood, 1842, they are *Margarita Keckwickii*, Ten.-Woods, Eocene, Table Cape, *Minolia strigata*, Ten.-Woods, Eocene, Muddy Creek, &c., and *S. rhysa*, mihi, Eocene, Adelaide.

Genus *Basilissa*, Watson, 1878.

Since the establishment of this genus, which originally included seven recent species, five have been signalled in the Parisian Eocene. It is especially distinguished by the sinus in the outer lip near its insertion. When describing *Sequenzia radialis*, Trans. Roy. Soc. S. Austr., 1890, p. 192, I referred to an undiagnosed species of *Basilissa*, obtained from the Eocene clayey sands in the Adelaide bore which simulated it; I add here a brief description of

Basilissa Cossmanni, *spec. nov.*, Pl. xi., fig. 8.

Shell broadly conical; whorls flat except a slight angulation at the posterior suture, ornamented with slender liræ (about seven on penultimate whorl) which increase in strength from behind forward latticed by slender oblique transverse threads, minutely granulated at the intersections. Base flat, ornamented with about nine depressed concentric ribs, the intervening sulci of about equal width to the ribs are traversed by radial threads; umbilicus moderate, its margin crenulated. Length and breadth 4 mm (vix.)

The species-name of this pretty shell of a very interesting genus is given in acknowledgment of valuable help in the elaboration of our Tertiary Mollusca rendered by the author of a "Catalogue Illustré des Coquilles Fossiles de l'Eocene de Paris."

Family Fissurellidæ.

Genus *Scutum*.

Scutum anatinum, *Donovan*.

Examples of this recent shell have been collected from the Eocene beds of the Moorabool Valley by Mr. Sweet; they are very little more than casts, but the comparative dimensions of the recent and fossil specimens are almost absolutely the same.

Family Actæonidæ.

Genus *Triploca*, nov.

Shell like *Actæon*, but with three revolving plaits on the columella.

Triploca ligata, *spec. nov.*, Pl. xi., fig. 7.

Shell oval, thick, spirally linear-sulcate. Sulci impunctate; whorls six and a-half, a little elevated at the suture and distinctly margined in front of it by an elevated band defined by an anterior impressed track; suture impressed. The linear sulci are close together, but vary in their prominence, and are sometimes almost obliterated. Outer lip thickened internally, but is bevelled to a sharp entire edge; columella triplicate, slightly reflected and producing a false umbilical fissure. Length 8, breadth 4. Locality—Eocene: Adelaide bore.

Class Lamellibranchiata.

Family Nuculidæ.

Genus *Poroleda*, nov.

Examples:—*Scaphula* (?) *elongata*, Hutton, Trans. N. Z. Inst., xvii., p. 332, 1885. *Poroleda lanceolata*, Tate.

Shell like *Leda*, having an oblique internal cartilage-pit and a small pallial sinus; the hinge-line (nearly straight) with a series of longitudinal imbricating teeth on each side.

Poroleda lanceolata, *spec. nov.*, Pl. xii., fig 6.

Shell depressed, pellucid, shining, transversely elongate, concentrically striate-ridged; posterior side much produced and narrowly roundly-truncated at the end; hinge-line straight; anterior side very short, rounded, rapidly sloping to about the middle of the ventral margin, thence sloping upwards but less rapidly to the posterior extremity. The post-dorsal area linear-lanceolate slightly flattened but not defined by a conspicuous angulation. Cartilage-pit linear with about seven teeth on each side.

Dimensions:—Antero-posterior diameter 11·25, anterior radius 2·5, posterior radius 8·75 ; ventro-dorsal diameter 3·75.

Locality:—Eocene, Gellibrand River.

Externally *Poroleda lanceolata* is exceedingly like *Leda Huttoni*, but the anterior side is shorter and not so acuminate, the posterior hinge-line is straight not incurved, and the post-dorsal area not defined by a keel. It differs from *P. elongata* by its attenuate posterior side and by its straight hinge-line, which is sensibly divergent in that species; and though about half as large again yet offers the same proportionate dimensions.

Family ARCIDÆ.

Genus *Plagiarca*, Conrad, 1875.

This is in substitution for *Macrodon*, so that our species will be quoted as *Plagiarca cainozoica*, Tate.

Genus *Arca*.

Subgenus *Fossularca*, Cossmann.

Arca equidens, Tate, and *Barbatia dissimilis*, Tate, belong to the group typified by *Arca quadrilatera*, Lamk., on the authority of M. Cossmann, the author of the subgeneric name.

Family UNGULINIDÆ.

The generic name *Scacchia* should be expunged, the species erroneously referred to it belong to the group *Felania* of the genus *Diplodonta* = *Mysia*.

Family ANATINIDÆ.

Genus *Pholadomya*.

PHOLADOMYA AUSTRALICA, *spec. nov.*, Pl. xii., fig. 2.

This is an important addition to our Eocene fauna, as though the species in the Older Tertiaries are few in number yet all the chief localities in Europe have a representative of the genus, the Oomaru formation in New Zealand contains *P. neozelanica*, Hutton. The present species occurs at Fyansford near Geelong, where it has been collected by Messrs. G. B. Pritchard and Mulder, and by the former also at Muddy Creek near Hamilton.

Shell oval-oblong, slightly inequilateral, moderately ventricose, the post-dorsal margin rapidly sloping to the somewhat narrowed, compressed, and roundly truncated posterior margin. Medial portion ornamented with slender simple ribs, eighteen in number, inclusive of five or six smaller interposed ones, crossed by a few slight concentric folds and coincident flat threads. Antero-posterior diameter 46—ant. side 20, post. 26,—dorso-ventral diameter 35, thickness 31 mm. Proportions:—length 1, height $\frac{7}{9}$, thickness $\frac{6}{9}$.

Among Tertiary species, *P. australica* comes nearest to *P. virgulosa*, Sow., and it seems to differ from *P. neozelanica* in its flat concentric folds, less inequilateral, and its simple (not beaded) ribs.

Genus *Anatina.*

A. DOLABRAEFORMIS, *spec. nov.*, Pl. xii., fig. 3.

The discovery of a species of this genus in the Eocene at Belmont is due to Mr. Mulder of Geelong, who has been instrumental in adding largely to our knowledge of the Eocene fauna of that part of Victoria in which he resides.

The species belongs to that section of the genus characterized by inequality of the valves, whilst its triangular-rotund shape and acute umbos separate it from all described species. The outline is rather equilaterally triangular, but shortly produced and truncated behind; the anterior dorsal margin is very sloping, the post-dorsal is incurved in front of the umbos, but is otherwise nearly straight, then sharply bent at an oblique angle to form a flat broadish triangular post-dorsal area; the ventral margin is gently curved upwards to the acutely rounded anterior margin. The umbos are about central and acute. Antero-posterior diameter 48 (less breadth of posterior area 38), ventro-dorsal diameter 36, sectional diameter 18.

Genus *Phragmorisma*,* nov.

Examples:—*Thracia Watsoni*, E. A. Smith, Challenger Lamell., p. 69, t. 6, figs. 5 - 5*b*; Bass Strait in 38 to 40 fathoms. *P. anatinæformis*, Tate; Eocene, Spring Creek near Geelong, and Table Cape, Tasmania.

Shell externally like *Thracia* or *Anatina*. Internally with a large subumbonal plate in each valve. The plate is broad, concave on its superior face, pendent from the umbo and more or less parallel with the umbonal cavity, its anterior side is confluent with the test, but ventrally and posteriorly it is free.

The shelly process in the umbonal cavity is peculiar in the family Anatinidæ, though a certain similitude is offered in *Mya*, but in that genus the plate is horizontal and not perpendicular; *Asthenothærus*, Carpenter, is doubtlessly related, but of it the information accessible to me is not decisive enough to permit of a critical comparison.

Thracia perscabrosa, mihi, does not belong here, and is I think, rightly located generically.

Phragmorisma anatinæformis, *spec. nov.*, Pl. xii., fig. 1.

Shell inequilateral, inequivalve, right valve compressedly convex, left valve flat; rounded in front, perpendicularly truncated behind, a slight angulation defines the post-dorsal area; the post-dorsal margin is straight, hardly sloping; the antero-dorsal margin is obliquely rounded; the ventral margin is straightish to about the middle, whence it gradually rises to the front margin. The surface is plicately wrinkled concentrically (the wrinkles are distant, narrow and low, except in the umbonal region where they are subangular and crowded), granular-striated in the umbonal region and thence half-way to the front in the medial area, the rest of the surface densely granulated (the granulation larger on the post-dorsal area. Umbos small, acute, and turned backwards. Hinge-line of left valve projecting as a thin plate before and behind umbo, the posterior projection much wider and forming a lunule-

* *Phragmos*, blocking-up, and *ereisma*, a support.

like depression beneath the umbo, the anterior projection narrow lanceolate. The medial shell-layer is pearly. Umbo-ventral diameter 33, antero-posterior diameter 58, anterior radius 26, posterior radius 32.

The example of this fossil analogue of *Thracia Watsoni*, which has served for the foregoing measurements, has approximately the same length and breadth as it; however the fossil is more inequilateral as indicated by the following measures of the anterior and posterior radii, in *T. Watsoni* they are 28·5 and 29·5, in *P. anatinæformis* they are 32 and 26; moreover the fossil is more attenuated posteriorly and the plications are slender. It is noteworthy that the successional type of this genus occupies the same area as its ancestor and in an intermediate latitudinal position.

Genus *Myochama.*

I am not aware if this genus, peculiar to Australia, is known in a fossil state, the discovery therefore of species in our tertiary deposits is of interest. The fossil representatives are *M. rugata* in the Eocene of Spring Creek and Gellibrand River, and *M. plana* in the Miocene of Reeve's River, Gippsland Lakes, and possibly the same species in the Older Pliocene at Dry Creek bore.

MYOCHAMA PLANA, *spec. nov*, Pl. xii., fig. 4.

Left valve almost flat; triangular, the sides diverging at about 100°, posterior side the longer, anterior margin slightly arched. Surface with irregular, narrow, flat, concentric plications and faint radial markings, except in the umbonal region, which is lightly corrugated. Right valve flat, attached by the whole surface or partially only. Dimensions:—Antero-posterior diameter 38; anterior side 22, posterior side 22, umbo-ventral diameter 30 mm.

Localities:—Miocene: Gippsland Lakes (five examples). Older Pliocene: Dry Creek bore (one attached valve).

MYOCHAMA RUGATA, *spec. nov.*, Pl. xii., fig. 5.

Right valve oval-triangular, flat, wholly or partially attached. An example (from Gellibrand River), growing on a polyzoon by a limited surface of the dorsal region, has the umbo quite free and resembles a cuneiform *Myadora* ornamented with sharp concentric ridges; the rest of the unattached surface has broadish flat concentric folds intricately wrinkled. Left valve slightly convex with wrinkled corrugations, antero-posterior and umbo-ventral diameters approximately equal from 17 to 20 mm.

Class Palliobranchiata.

Genus *Crania*.

Crania quadrangularis, *spec. nov.*, Pl. xi., fig. 12.

Attached valve unknown. Free valve with a transversely oblong outline, test very thick; the hinge-line is straight with sharply rounded angles, anterior and posterior margins nearly straight, ventral margin slightly outwardly curved, greatest width medially in a transverse direction; apex blunt and tumidly elevated varying in position from nearly central to about the dorsal one-third; surfaoe with subimbricating growth-folds and fine close radial striæ; interior with the ventrally situated scars rhomboid and separated by a stout septal ridge. Dimensions:—(Ex. 1) diameters 13 and 10, height 3·25; (Ex. 2) diameters 14·75 and 12, height 4 mm.

Locality:—Eocene: Waurn Ponds near Geelong (Mr. Mulder).

The more or less regular convexity of the free valve separates it from that of all living species which are distinguished by an apiculate vertex; however, it is only with *C. anomala* that I have made comparison with actual specimens. The tumidly convex valve and the septal ridge in the interior may prove to be distinctive characters.

Class Echinodermata.

Genus *Cœlopleurus*.

This name replaces my *Murravechinus;* the species represented has been described by Gregory as *C. paucituberculatus*.

Genus *Paradoxechinus*.

The two species quoted under *Temnechinus* belong here and are varieties of one species, *P. novus*, Laube.

Genus *Scutellina.*

The genus is restricted to the Eocene: *S. patella*, Tate, Trans. Roy. Soc., S. Aust., 1891, p. 279, uniquely represents it in the Australian beds.

Genus *Monostychia.*

Laube's genus should be restored; whilst *Arachnoides* can be still retained, as a representative of this more modern genus has occurred in the Miocene of the Gippsland Lakes, which I describe as follows—

Genus *Arachnoides.*

Arachnoides incisa, *spec. nov.*, Pl. xiii., fig. 3.

Test very flat, rising slightly towards the apical disk, the longitudinal and transverse diameters are approximately equal; the apical disk is slightly in front of the centre. The ambitus is sharp and *incised* at the end of each interambulacral groove between which it is *undulose.* The ambulacra are slightly sunken and abruptly declivous at the sides, they occupy about an equal space with the interambulacra. The poriferous zones reach about two-thirds way to the ambitus. The ornamentation in the interambulacra is obliquely banded and minutely granular; the granulations are without order in the ambulacral areas. The periproct is supramarginal, with a concave depression between it and the ambitus, which is here slightly incurved. The actinal area is flat. Antero-posterior diameter 54·4, transverse diameter 56·5, height 6·5 millimetres.

Localities:—Miocene: Red Bluff and beyond Meringa, Gippsland Lakes, (three examples).

The incised ambitus, which most markedly separates this fossil from the two known living species, recalls *Monostychia* from all species of which it is separable by the superior position of the periproct.

Except *A. zealandiæ*, Gray, which dates back to the Newer Tertiary of New Zealand, this is the first occurrence of an extinct species of the genus ; *A. conica*, Hutton, of the Oamuru formation (=Eocene) in New Zealand, is a *Monostychia.*

Genus *Laganum.*

I avail myself of this opportunity to make diagnostically known a species which belongs to our Older Tertiary ; the genus is essentially of recent date, as only one fossil species *L. multiforme*, Martin, is recorded, which belongs to an unknown horizon of the Javanese Tertiary.

Laganum platymodes, *spec. nov.*, Pl. xiii., fig. 4.

Outline of test subquinquangulated, varying from nearly circular to broadly elliptic, rarely moderately narrow-oval ; margin not inflated or very slightly so ; upper surface flat or a little elevated apically; petals elongate, extending three-fifths of the distance to the ambitus, lanceolate, closed ; genital pores four; periproct circular, situated at about two-fifths the distance between the margin and the peristome from the margin. Dimensions of a specimen of average size and shape :—length 34, breadth 31, height 6 mm.

Localities:—Miocene: Hallett's Cove and Aldinga Cliffs, east side of St. Vincent Gulf, South Australia (common).

The form of this species varies from that of *L. Bonani*, Klein, to *L. ellipticum*, Ag., but it has not the tumid margin of those species ; from the first it further differs, as also from *L. depressum* and *L. multiforme*, Martin, in its closed petals, four genital pores and submarginal periproct, and from the latter in its closed petals and four genital pores.

Genus *Sismondia.*

Sismondia Murravica, *spec. nov.*, Pl. xiii., fig. 5.

Outline subdecagonal, broadly elliptical, being a little longer than wide, width greatest in front of apex coinciding with a plane through the ends of the antero-lateral ambulacra ; actinal and abactinal surfaces flat with a high abruptly-rounded margin ; apical disc subcentral, posterior, forming a slightly raised boss ; genital pores four ; petals elliptic, the width about two-thirds the length, not closed, extending for about two-thirds of the radius of the upper surface. Ornament finely and closely scrobicular. Periproct at about one-half the distance from the peristome to the margin. Length 19, width 16·5, height 7.

Locality:—Eocene: River Murray Cliffs (several examples).

This echinoid differs from *S. occitana*, Defr., by its less tumid margin, more depressed shape, and raised (not sunken) apical disk.

Genus *Conoclypeus*, Agassiz.

The urchin which I refer to *Conoclypeus* has all the essential characters proper to the genus, viz., long open ambulacra, pores conjugate by grooves, central peristome with tumid bourrelets and without phyllodes, periproct marginal and transversely oval, ornamentation of small equal sunken scrobicules; but it differs in its depressed form and the flat apical disk (the unique specimen is, however, somewhat eroded in this part), and thus simulates *Plesiolampus.*

The hard matrix filling the peristome of the single specimen does not permit me to ascertain whether a perignathic girdle is present or not; but apart from this, the absence of phyllodes removes our fossil from the conoclypoid genus *Phylloclypeus.* On the other hand the imperforate and non-crenulate tubercles are not consonant with *Conoclypeus*, but rather with *Plesiolampas;* however I must not lay much stress here, because the somewhat defective condition of the surface makes it possible that I may be mistaken.

The genus is most fully represented in the Eocene, but there are a few Cretaceous and Miocene species.

Conoclypeus rostratus, *spec. nov.*, Pl. xiii., fig. 1.

Test moderately depressed, slightly longer than broad, broadly elliptical in marginal outline, broadest close behind the apical system; posteriorly with a conspicuous though slight truncated projection margined on each side by a concave depression just posterior to the postero-lateral ambulacra. The highest point of the test is at the apical system, which is a little anterior to the geometric centre, the surface slopes thence to the slightly tumid margin which is less tumid at the ambulacra. Under surface slightly sloping to the somewhat deeply seated peristome. The peristome is central, transversely oblong, with bluntly pointed bourrelets. Periproct is transversely lunate, inframarginal, the superior border just touching it. The ambulacra are long, narrowly open, the anterior is the shortest, and the postero-laterals are the longest; zones of paired pores are flush or very slightly sunken, extend to near the ambitus and show a tendency to inequality of length. Ornamentation of small imperforate and apparently noncrenulate tubercles in sunken subpentagonal scrobicules, which are very close together but not discontinuous. Height 24, length 57, breadth 54, major diameter of periproct 8 mm.

Locality:—Eocene: Table Cape, Tasmania.

Genus *Cardiaster*.

This Cretaceous genus has been extended in its range by the discovery of two species in the Eocene beds of the Aldinga Cliffs, viz., *C. tertiarius*, Gregory, and *C. latecordatus*, Tate; and though the announcement of its occurrence in the Eocene fauna of South Australia was made as early as 1877 (Q. J. Geol. Soc. Vol. xxxiii. p. 257), yet by an oversight it was omitted from my "Census."

Genus *Cyclaster*, Cotteau.

The species included under *Micraster* and *Brissopsis* are one, which is referable to the above named genus as I have already indicated (Trans. Roy. Soc. S. Austr., 1892, p. 193).

Genus *Gualteria*.

Is represented in our Older Tertiary by *G. australiæ*, Cotteau, "Mem. Soc. Zool. de France, 1890."

Genus *Rhynchopygus*, Duncan.

This generic reference must be expunged, as it was applied by Duncan to a distorted example of his *Holaster australiæ*.

Class Zoantharia.

Genus *Astrangia*.

Astrangia tabulosa, *spec. nov.*, Pl. xiii., fig. 2.

Colony incrusting. Corallites not sensibly raised above the cœnenchyma, which consists of thin bands supported by extremely thin perpendicular plates; the corallites are separated by varying distances, but usually less than that of their diameter. Calices circular (6·5 mm.) or elliptic (7 × 6 mm.), shallow. Columella of intertwisted trabeculæ in various degrees of compactness, but always more or less vesicular, about 1·25 mm. diameter. Septa not exsert (margin apparently entire), 18 to 21, those of the fourth cycle only slightly projecting into the interseptal spaces; the faces of the septa of the other cycles are distantly granulated, the granules are large and disposed in linear series on oblique faintly defined ridges; the principal septa of the cycles are continued on to the cœnenchyma as feeble ridges. The interseptal loculi are transversely septate at intervals of about 1 mm.

Eocene: Table Cape.

I venture to describe this species as new, for I am unable to compare it with all known species, because of its well-developed dissepiments. This is the first occurrence of a reptant Astræid in our Tertiary, though *Scolangia*, Ten.-Woods, is recorded from the correlated Ototara formation in New Zealand.

Class Rhizopoda.

Genus *Fabularia*.

This genus of Foraminifera, hitherto represented uniquely by *F. discolithes*, Defr., in the Eocene of Paris and Egypt, is represented in the Miocene beds at Muddy Creek by *F. Howchini*, Schlumberger, described in Trans. Roy. Soc., South Austr., 1891, p. 346.

EXPLANATION OF PLATES.

Plate X.

Fig.
1. *Spirulirostra curta*
2. *Concholepas antiquata*
3. *Distorsio interposita*
4. *Genotia fontinalis*
5. *Dolium biornatum*
6. *Diastoma Provisi*
7. *Genotia angustifrons*
8. *Genotia decomposita*
9. *Genotia Pritchardi*
10. *Isapis (Raulinia ?) elata*
11. *Isapis (Raulinia ?) eothinos*

Plate XI.

Fig.
1. *Semivertagus capillatus*
2. *Actæopyramis olivellæformis*
3. *Semivertagus subcalvatus*
4. *Risella alta*
5. *Harpa pachycheila*
6. *Ataxocerithium concatenatum*
7. *Triploca ligata*
8. *Basilissa Cossmanni*
9. *Litiopa punctulifera*
10. *Eburnopsis tessellatus*
11. *Colina fenestralis*
12. *Crania quadrangularis*

Plate XII.

1. *Phragmorisma anatinæformis*
2. *Pholadomya australica*
3. *Anatina dolabræformis*
4. *Myochama plana*
5. *Myochama rugata*
6. *Poroleda lanceolata*
7. *Colina apicilirata*

Plate XIII.

1. *Conoclypeus rostratus*
2. *Astrangia tabulosa*
3. *Arachnoides incisa*
4. *Laganum platymodes*
5. *Sismondia Murravica*
6. *Strophodus eocenicus*

ON AN APPROXIMATE METHOD OF FINDING THE FORCES ACTING IN MAGNETIC CIRCUITS.

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[With Plates XIV. and XV.]

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During the last three years I have had occasion to design a good many reciprocating electro-magnetic mechanisms, and have frequently felt the want of some simple method of making the necessary approximate calculations of magnetic forces. I have obtained very little satisfaction from the attempts I have made to calculate tractions proceeding by the method of finding poles and applying the law of inverse squares. This ill success led me to investigate the applicability of the methods established by Maxwell in the chapter "On Energy and Stress in the Magnetic Field,"—(Electricity and Magnetism, Vol. II., §§. 641 – 644)—with the following results :—

§ 1. Theoretical considerations.—The problem for solution in its simplest form is as follows: "Given an iron anchor-ring uniformly wound and interrupted at one point by an air gap of any given dimensions, to calculate the forces tending to draw the ends of the iron ring together when the strength of current flowing in the magnetising circuit and the data of winding are given."

2. The position established by Maxwell is as follows :—

(i.) The laws of magnetic force are such that magnetic forces may be regarded as the expression of a state of stress in the magnetic medium.

(ii.) The medium is stable under such a distribution of stresses.

(iii.) A series of expressions may be found for the stresses at any point in the magnetic field.

3. Maxwell's investigation does not explicitly include the case of a body with inconstant permeability, but I can not find that this in any way vitiates the argument. Professor J. J. Thomson shows (applications of Dynamics to Physics and Chemistry, §. 33), that Maxwell's results may be considered as being derived from the existence of a term $\frac{1}{8\pi}$ H B in the Lagrangian function for unit volume of a magnetic field. If the permeability is a function of the induction, however, in any part of the field, the more general expression $\frac{1}{8\pi}\int H\, dB$ must be substituted for the above and the results modified accordingly. I have not succeeded in doing this. It appears therefore that Maxwell's system as applied to iron does not cover all the ground, because a modification must be introduced on account of the inconstancy of the permeability, and also on account of the Villari effect as shewn by Prof. Thomson. There may also be other undiscovered additions to make.

4. A great step is necessary to pass from Maxwell's position, that magnetic forces may be regarded as the expression of stresses in the field, to the position that magnetic forces are such an

expression. There is all the difference that exists between a theory and a fact. Everything however tends to show that the fact is that the theory is probably true so far as it goes, and we will therefore provisionally adopt it and see first what additional hypotheses are necessary. It is obvious at once that the stresses are "stresses in a medium" while the forces are mechanical forces acting on matter. We must therefore consider that the medium is "attached" to matter so as to allow the stresses to appear as forces. Now the stresses in the medium depend on the nature of the matter which is permeated by the medium. Thus in the cut anchor-ring referred to above (1), the stresses in the medium in the air gap are not at all the same as the stresses in the medium in the iron. In our entire ignorance of the connection existing between the medium and matter, it is not at all clear to me that in calculating the magnetic forces tending to close the ring, we ought to consider the stresses in ether in air, and these alone. It is at all events conceivable that the nature of the connection between the medium and the iron may be modified in some manner by the internal stresses in the iron; also the ordinary laws of magnetic and electro-magnetic action received their experimental demonstration at low inductions, and we have no right to say without experimental evidence that some terms not contemplated by Maxwell might not begin to produce effects on the stresses in air at high inductions. In the parallel case in iron such stresses do in fact occur. I therefore attribute great importance to the experimental verification of the results deduced from Maxwell's theory as applied to the traction between iron bars in general and especially at high inductions.

5. Experimental position.—The simplest case is that of the traction between two plane faces of iron, the faces being either the terminals of an otherwise closed iron circuit, or of very long bars. The case of the ring has been implicitly investigated by Bidwell, (Phil. Proc. 1886), and the case of short bars by Bosanquet explicitly (Phil. Mag. 1886). The latter is the only investigation I know of in which simultaneous observations of induction

and tractive force were made. In both cases Maxwell's theory leads to the expression $F = \frac{B^2 A}{8\pi}$
for the force in air between two opposing plane faces of iron—infinitesimally separated—A being the area of one of the equal faces; and B the (uniform) induction density.

The net result of Bosanquet's work was to show :

(i.) When B is below 5,000 the tractions observed are generally much too large.

(ii.) The formula does not hold when the air gap is appreciable.

(iii.) It holds within about 5% up to very high inductions, (18,000).

It is obvious therefore that there is room for more work on the subject.

6. For the reasons given I felt very strongly that it was necessary to establish the truth or rather the approximate exactness of the theory in the simple case studied by Bosanquet before going on to apply it to other and more complicated cases. Consequently I investigated the following matters :

(i.) Influence of length of bars.

(ii.) Influence of kind and size of pole pieces.

(iii.) Influence of imperfections in the ballistic method.

(iv.) Cause of Bosanquet's failure to obtain agreement with theory at low inductions.

(v.) Cause of similar failure (?) with an appreciable air gap.

7. Method of experimenting—I wound a number of solenoids on brass tubes ; placed the iron bars to be investigated axially in these solenoids—observing the usual precautions ; and measured the force (by calibrated spring balances), requisite to pull the bars apart—the force being applied scrupulously parallel to the axes of the bars by means of links, pulleys and strings. Great attention was paid to the state of the cut surfaces. I tried surfaces of all kinds :

(*a*.) Merely filed by watchmakers' finishing files.

(*b*.) Ground on flat whetstones to a surface plate.

(*c.*) Scraped to a surface plate.

(*d.*) Ground by emery wheels.

(*e.*) Turned flat to a surface plate—this takes a little skill.

(*f.*) Optically ground by emery and diamond dust and finished with putty powder.

This last requires a note. Of course the bars must be provided with shoes of many times their diameter to make the process a success, and these shoes must be of similar material to the bars. In order to save circumlocution I may state that both I and my assistant, Mr. Cook, are fairly expert at this kind of work and we met with no real difficulty. The use of diamond dust instead of emery saves a little time but makes it more difficult to get a good result. I obtained two sets of bars with properly ground faces, one of these sets was of hard iron and was not so good as Brashear's celebrated test plates, on account of a slight convexity on the part of one surface and a corresponding concavity on the part of the other. The other pair of bars were of soft Swedish iron well annealed; they were less than 1 cm. in diameter and about sixty cm. long. The surfaces were as good as the test plates—*i.e.* perfect according to the present state of the art. I have little doubt they are as good soft iron surfaces as have ever been prepared. This means that there was no inequality comparable with a wave length of sodium light on either surface.

The bars were kept straight and aligned by well fitting glass, or brass, or fibre tubes at the plane of contract. The fit was always just so good that no correction for friction was necessary. The magnetising current was measured by a Siemen's Dynamometer which was compared with suitable members of a chain of Kelvin balances, it was found that in this dynamometer the readings were correct within the limits of accuracy of reading. The current was supplied by storage cells.

The induction coils were wound on brass bobbins with proper precautions. The bobbins were of different diameters, and were compared ballistically and found to give identical results—hence it was concluded that they were all free from leakage errors.

The ballistic galvanometer was a fine instrument specially made for this kind of work. It was calibrated by turning over a large coil which was splendidly wound and which has been checked in many ways. I made use of the values for the vertical force obtained about nine months ago by Mr. Farr from a long series of experiments in my laboratory, under the best and most careful conditions and with the Kew apparatus. In all cases the induction thrown on the galvanometer was checked by reversal of the galvanometer connections—except when experiment showed that nothing was gained by such reversals—the instrument being in another part of the laboratory to the magnetic system. In all cases large resistances from a box of coils constructed and calibrated by myself from Cambridge standards, were inserted in the circuit so as to give the best range for the galvanometer.

Results of experimenting.—The general result was that I got rather worse agreement than was noted by Bosanquet—especially at low inductions. I therefore set myself to find out the reason of this. I am ashamed to say how long it took me to clear up the difficulty. I investigated the following possible causes :

(i.) Imperfection of galvanometer law. This was got over by adjusting resistances till the same deflexion was obtained both on turning over the earth inductor and on magnetising the iron.

(ii.) Effects due to residual state of the iron. This was got rid of by demagnetising the iron by an alternator and slide resistance, and observing magnetisations with the current in both directions, and also on reversal. By comparing the three sets of deflections I assured myself that the discrepancy was not due to any error of this kind. A similar procedure when taking the tractions led to a like result.

(iii.) By using induction coils of different diameters I assured myself that I was really measuring the operative inductions.

(iv.) The state of the surface of the bars is an important matter. If the ends are rough of course the contact is at the points. This leads to a concentration of induction at these places, and is a very constant source of error. My best bars however gave just as anomalous results as my roughest ones, so that the deviation could not be attributed to this cause.

(v.) Finally I tried—without much confidence—the effect of a small indirectness of pull. This was done by winding two wide solenoids and leaving sufficient space between their ends to see what was going on at the plane of junction of the iron, a gas flame was put on the side of the junction remote from the observer.

It was then found that one side of the bar which was being pulled off invariably remained in contact after the other side had slightly separated—when this was prevented by slightly guiding the spring balance by hand the agreement was as good as at higher inductions. The explanation is now obvious, if the bars separate slightly at one side, two things happen : (1) The total reluctance of the circuit increases ; (2) the induction concentrates at the parts in contact. At low inductions the effect of (2) overpowers that of (1); at high inductions when the permeability of the iron becomes less the induction is less free to distribute itself and also the traction of the bars being greater, the phenomenon does not begin to manifest itself till rupture is just about to be produced or it produces a very much smaller percentage error. Of course all this might have been foreseen, but one's experience with strong magnets—in which case it is notorious that it is much more difficult to pull off an armature straight than slightly sideways—misled me.

On examining other bars which had given similar results at low inductions, I found I could similarly diminish or increase the apparent traction by varying very slightly the direction of pull. Thus with a pair of flat ended bars and an induction density of about 3,000 C.G.S. the calculated pull was one pound seven ounces, but the observed pull was always over two pounds, and in some experiments about three pounds. On guiding the bars so that no wedge-shaped gap appeared, the traction could be got down to about one pound eight ounces. I do not think it is possible to get much closer than this, for if proper arrangements are made to absolutely insure a really true and rigid separation, friction would inevitably come in to introduce errors. My results at higher inductions were so similar to Bosanquet's that they are not worth reproducing.

7. With regard to the reduced formula not applying to the case of non-magnetic gaps of sensible dimensions parallel to the lines of induction—as when Bosanquet separated the bars by wood and paper—the explanation is obvious. The lines of induction no longer leave the surfaces normally and the conditions postulated by the formula are not in existence.

8. Resulting position of the theory. When the bars are in contact, the stress theory and what I will call the magnetic fluid theory, lead to the same results, which is true certainly within about five per cent. and may be exactly true. In any case measuring tractions is not the way to get accuracy, though I have no doubt that rather better results could be got by going into the matter more elaborately than was done either by Bosanquet or myself. In what follows I shall suppose that the theory is true, and that the real cause of magnetic forces is to be sought in some condition of the ether mechanism which receives a sufficient mean definition from the induction diagram.

9. The effect of varying the kind of iron employed should be the same as varying the induction density, at least in so far as the phenomenon can be considered to depend on permeability. I used induction densities of from 2,000 to 18,000 but could not detect any effect, when the cause of error referred to above was eliminated. I also used all kinds of iron, from annealed Swedish iron to ordinary cast iron. I varied the lengths of the bars from 60 cm. to 6 cm., and the diameter from about 2 cm. to about ·6 cm. In no case could I detect any deviation from the predicted

traction which could not be explained by unavoidable experimental errors. With short bars and high inductions necessitating the use of very strong fields, some induction is included by the testing coil which does not help the traction and which tends to make the calculated traction appear too large. When this source of error was eliminated no greater discrepancies were observed with short bars than with long ones.

10. I conclude therefore : (i.) The traction produced by a given tube of induction when running out of air into iron and crossing the surface normally is independent of the nature of the iron or of its form. I had a difficulty in bringing myself to believe this, but the conclusion seems inevitable.

Corollary (i.) The magnetic forces are independent of the stresses in ether inside the iron.

Corollary (ii.) Setting aside Prof. J. J. Thomson's stresses, the ether stress in air is less than that in iron—assuming that Maxwell's "Magnetic Material" sufficiently represents iron. The difference of tensions is

$$\frac{B^2}{8\pi} - \frac{1}{4\pi}\left(B H - \frac{1}{2} H^2\right)$$

or

$$\frac{(B - H)^2}{8\pi}$$

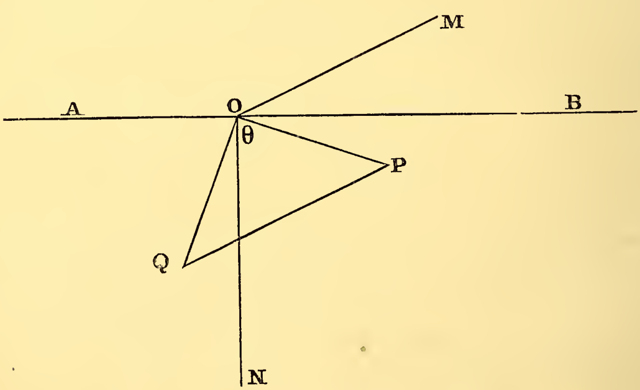
This is an unbalanced stress, and if the lines of induction in the iron give rise to forces similar to those produced in air, this must mean that the boundary tends to be pulled off the iron. Taking Prof. Thomson's stresses into account, this effect may easily be reversed in any actual case.

Referring to Prof. Thomson's investigation, (Physics and Chemistry), I cannot avoid the impression that there still remains a set of stresses depending on the variation of elastic constants with temperature. This would further complicate matters.

11. Each tube of induction is therefore a tube of force within the usual definition, but it does not follow that the only forces are those represented by the tubes of induction. If the tubes

leave the iron surface normally, then the pressural forces are tangential, and we get the formula we have been using, and similarly if the tubes of induction are tangential (*i.e.* when the infinitesimal air gap separates similar poles), the pressures operate alone, and we have a repulsion equal to the former attraction, as in the elementary theory. If the tubes of induction leave the iron at any angle to the surface between 0 and $\pi/2$ we must consider the effect of the pressural forces.

To calculate these effects, it is convenient and perhaps correct to assume, that just as the internal stresses of the iron do not affect the forces which are the expression of the external ether tensions, so they do not affect the forces corresponding to the hydrostatic pressures. If, therefore, we consider a line of force running out of iron into air and making an angle θ with the normal, we can estimate the direction and magnitude of the magnetic forces at once, thus :



Let A B be the trace of a plane boundary between air and iron, and O N a normal drawn outwards into air. Let O P be a vector in the plane of the paper representing the tensional force on an infinitesimal area about O. Draw O Q perpendicular to O P and in the plane of the paper. Then the pressural forces lie in a semicircle of which O Q is a radius and whose plane contains O Q. Since the pressures are symmetrical with respect to O Q, O Q is their resultant, and by the theory this is equal to O P, so that O Q is the vector representing the pressures. A force represented by O M equal and parallel to P Q is therefore the resultant force, and clearly in this case is a repulsion whose magnitude along the normal produced is

$$O\,P.\ \sqrt{2}.\ \mathrm{Cos}\left(\frac{3\pi}{4} - \theta\right)$$

an expression which gives no normal component at all when $\theta = \pi/4$. The force is therefore an attraction or repulsion according as θ is less or greater than $\pi/4$, and is a shear at this point. I tried to observe this, but could not get the lines to leave the surface at the exact angle. However the above way of looking at the matter is convenient when filings are used to trace the direction of the induction. This expression has been pointed out to me by Mr. Pollock as being identical with that given by Maxwell in Section 643 for the special reduced case here considered.

It is now evident why it was that Bosanquet got results differing from those calculated from the formula for normal inductions; because as filings show, a very small gap is sufficient to produce a marked spreading of the field.

12. By observing the distribution of filings about different air gaps it appeared probable to me that the following proposition might be true as referring to bars of different diameters. "With similar pole faces and the same permeability the induction (or filing) diagrams are similar when the length of the air gap is the same fraction of a standard dimension of the pole faces."

If this be true, it follows as a consequence that, with similar air gaps, the traction is the same fraction of the traction with the poles in contact, whatever be the actual dimensions of the poles. The greater part of the experimental work I have to offer refers to this point, for if established, we clearly have a method which will enormously facilitate the calculation of magnetic forces.

13. The observations made on this subject are sufficiently detailed in the tables, (Nos. 1 to 13) and the results will be understood by looking at the curve. The tractions were measured by

spring balances as before—measured pieces of brass being inserted between the pole faces. In a series of observations the induction was kept constant by varying the magnetomotive force. The observations were taken just as in the previous case. A little care is necessary in defining what is meant by the total induction. If the bars are long and thin then of course the solenoidal condition is fulfilled pretty closely, and there is no ambiguity, but with large air or brass gaps, say amounting to two diameters of the bars, the lines begin to leave the iron just in front of the middle point of each bar (at all events when the bars are about fifty diameters long). The "total induction" therefore has no very exact meaning with respect to the iron unless it be specified where it is to be measured. At the time the experiments were made I did not (as I now consider), sufficiently attend to this point, though I used a testing coil of about four times the diameter of the bars and kept this coil just to one side of the gap when the latter was large. It is probable, therefore, that I have considerably over estimated the tractions with the larger air gaps, for the induction must have been greater than I took it to be. I have decided not to reinvestigate this point, for the curve is of use in giving approximate ideas of traction only; and no one, after looking at it would design a mechanism with air gaps so long as those which are probably inaccurate. I have made a little allowance for this (most unscientifically of course), in drawing the curve. In fact my suspicions were first aroused by examining the part of the curve corresponding to the larger air gaps.

It will be seen that I examined a good many cases and the results show that when the non-magnetic field is of sensible dimensions, the differences in the permeability of the samples examined do not lead to any very abnormal results. The curve is drawn by reduction for a bar one centimeter in diameter, and the air gaps which must be expressed in diameters appear therefore in centimeters. The ordinates give the values of the tractions at corresponding points in terms of the calculated tractions when the surfaces are in contact. One set of observations refers to square bars. In order to utilise the results I assumed that the field would be distributed very much as if the bar were round and of a diameter equal to the mean of the diameters of the inscribed and circumscribed circles.

To use the curve it is only necessary to express the length of the air gap as a fraction of the diameter of the pole face, and refer to the table to find the proper factor to multiply the traction when the bars are in contact at the proposed induction.

14. In general, it is more convenient to take the magnetomotive force as given, and in this case the induction cannot be estimated without a knowledge of the reluctance of the circuit. Now methods of building up the characteristic curve of the magnet have been given when the air gaps are narrow, by Drs. J. and E. Hopkinson and others, but I thought that I might possibly be able to extend the method of similar systems, so as to include air gap reluctances. In similar induction systems the reluctances of the gaps should be roughly inversely as the linear dimensions. I examined three sets of bars to see how near such an approximation really was, but it will be noticed that the results would not reduce so as to give a single curve by any such simple process. The curves are therefore kept separate; they cover bars of from about one to three cm. in diameter. The induction was in these cases correctly measured at the centre of the bars. It was necessary to use the Ampère Balances to get a sufficiently accurate knowledge of the magnetising currents. The results are contained in tables 14 – 19, and are also plotted for the mean of all inductions. The reluctance of the iron and air circuits was measured before the bars were cut and plotted against inductions. It was assumed that, using bars of the length employed, the air reluctance (other than that at the gap) would not be materially changed by pushing the bars up to two diameters apart. The proper reluctance for the iron and air circuit was taken from the curve in finding the reluctance of the air gap.

Except with the largest bar there is no definite indication of the reluctance depending on the induction density. In this case separate curves might have been drawn, but I did not think it worth while to introduce a fresh sheet of curves.

I am not sure that a real reduction in air gap reluctance at about one diameter has not been smoothed out, but as the observations are marked on the curves every one will be able to form his own opinion.

It will be noticed that the curvature becomes very great when the air gap amounts to about ·3 diameters. It is perhaps not too much to say that the reluctance increases very fast as the gap increases to one and a-half diameters, after which it remains nearly constant.

15. I do not know whether a unit of reluctance has yet been adopted. It has been necessary for me to use one however. I take as unit reluctance, that reluctance through which unit magnetomotive force produces unit induction. By unit magnetomotive force I mean that magnetomotive force whose C.G.S. value is unity —*i.e.* that produced by $\frac{1}{4}\pi$ C.G.S. current turns. If the permeability of air be taken as unity, then one cubic centimeter of air has unit reluctance on this system. There are of course other ways of defining unit reluctance, but this is, I think, the only one that gets rid of the 4π.

16. The reluctance curves and traction curves are not unlike each other in general form, and enable us to draw some practically valuable conclusions as to the design of magnets intended to operate over air gaps. For instance, with a given induction the force at contact is inversely as the area, but the traction curve shows that this principle must not be pushed too far when we consider traction over an air gap. Thus I am told (though I do not believe it), that rock drills will not work with a shorter stroke than five inches, the traction curve shows at once that for a given induction (a case which does not practically occur in every instance), it is possible to make the pole pieces too small, if we wish to get the maximum work done during the stroke. This is independent of considerations arising when magnetomotive force is given.

17. We can make a comparison between the work done by a ring magnet when it is divided at one point, and the work done when the ring is divided at two points, but the reluctance data show that though the mean air gap reluctance may be larger than that of the iron, it is not very greatly so in any practical case, and we can therefore obtain no information by supposing that one is much greater or less than the other, but must proceed by actual trial from the curves to find out which is the most efficient arrangement.

18. In the case of a mechanism represented by a ring divided at one point only, we must remember that this involves a "sliding" magnetic contact, and if friction on the bearings is to be avoided, this practically ties us down to iron of symmetrical form.

19. Incidentally, I had occasion to observe the change of reluctance caused by cutting a bar and then grinding and polishing the ends. The reluctance corresponded to a separation of the bars by about twenty wave lengths of sodium light, but I am certain that the bars could not have been half so far apart as this, so the surface reluctance is still unaccounted for.

TRACTION OVER AN AIR GAP.—Tables 1 – 4.

Length of Bars.	Diameter of Bars.	Area of pole face.	State of pole face.	Thickness of distance pieces.	Gap as fraction of diameter.	Factor for multiplying traction with no air gap.	Traction.	
30 and 30 cm.	·895 cm.	·629 cm.	ground on stone	0	0	1	12·28 lbs.	The 12·28 lbs. is the computed traction. Sheet A, Table 1. B = 14770
,,	,,	,,	,,	·1 cm.	·11173	·3665	4·5 lbs.	
,,	,,	,,	,,	2·14 mm.	·2391	·25325	3·11	
,,	,,	,,	,,	3·38 mm.	·3777	·1517	29·8 ozs.	
,,	,,	,,	,,	6·9 mm.	·7710	·10775	21·17 ozs.	
,,	,,	,,	,,	0	0	1	3·068 lbs.	Computed Traction
,,	,,	,,	,,	1 mm.	·11173	·3208	15·75 ozs.	
,,	,,	,,	,,	2·14 mm.	·2391	·1833	9	Sheet A, Table 2.
,,	,,	,,	,,	3·38 mm.	·3777	·1451	7·125	B = 4646
,,	,,	,,	,,	6·9 mm.	·7710	·11585	5·687	
,,	,,	,,	,,	14·66 mm.	1.638	·1460	7·167	Erroneous, due to lines missing the [coil
28·13 cm. each	1·2507 cm.	1·227 cm.	optically ground not quite flat	0	0	1	8·99	Computed Traction
,,	,,	,,	,,	·192 cm.	·1593	·3241	2·915 lbs.	Sheet A, Table 3.
,,	,,	,,	,,	·256	·2124	·2740	39·42 ozs.	B = 9052
,,	,,	,,	,,	·466	·3808	·1870	26·9 ozs.	
,,	,,	,,	,,	1·074	·8912	·1397	20·115 ozs.	
,,	,,	,,	,,	0	0	1	17·94 lbs.	Computed Traction
				·192 cm.	·1593	·31655	5·679 lbs.	
				·256	·2124	·24415	4·381 lbs.	Sheet A, Table 4.
				·466	·3808	·1739	3·119 lbs.	B = 12790
				1·074	·8912	·1196	34·32 ozs.	

TRACTION OVER AIR GAP.—Tables 5–9.

Length of bars.	Diameter of face of bars.	Area of pole face in square centimeters.	State of pole face.	Thickness of distance pieces in centimeters.	Gap as fraction of diameter of pole face.	Factor for multiplying traction with no air gap.	Traction observed.	Traction computed.	Induction density.	Remarks.
26·77 cm.	1·02 cm.	·81713	perfect, round ends	0	0	1	10 lbs.	9·47 lbs.	11385	Table 5. Inductions probably all rather too large. Coil of large diameter used.
"	"	"	"	·1	·098	·446	4·34 "	...	"	
"	"	"	"	·212	·208	·2004	1·95 "	...	"	
"	"	"	"	·340	·333	·1584	24 ozs.	...	"	
"	"	"	"	·610	·598	·077	11·72 "	...	"	
"	square bars with square ends, length of side of sq. ·9265 cm. diameter of mean circles 1·1184 cm.	·8584	finelymilled	0	0	1	14·5 lbs.	13·01	13019	Table 6. The 'Diameter' of the square is taken as the mean of the diameters of the inscribed and circumscribed circles. Induction probably over estimated.
"		"	"	·1	·089	·3689	4·8 "	...	"	
"		"	"	·212	·1895	·2537	3·3 "	...	"	
"		"	"	·340	·304	·15375	2 lbs.	...	"	
"		"	"	·610	·545	·1167	25 ozs.	...	"	
one bar is 26·77 cm. the other 13·3 cm.	"	"	"	0	0	1	14·7 lbs.	13·01	13019	Table 7. Induction effect considerably over estimated, owing to the necessity for using a very strong field with the wider gaps.
	"	"	"	·1	·089	·3934	5·118 "	...	"	
	"	"	"	·212	·1895	·2422	3·151 "	...	"	
	"	"	"	·340	·304	·1568	2·04 "	...	"	
"	"	"	"	·610	·545	·097	1·26 "	...	"	
"	round faces used, diam. 1·02 cm.	·81713	perfect	0	0	1	11·975 lbs.	13·825 lbs.	13756	Table 8. Induction over estimated owing to testing coil being too large for the strong field employed. Not used for curve.
"		"	"	·1	·098	·2966	4·1 "	...	"	
"		"	"	·212	·208	·1808	2·5 "	...	"	
"	"	"	"	·340	·333	·1329	1 lb. 11 ozs.	...	"	
"	"	"	"	·610	·598	·07217	1 lb.	...	"	
"	"	"	"	0	0	1	...	4·208 lbs.	7590	Table 9. The induction being lower, the results are more reliable except with the largest gap.
"	"	"	"	·1	·098	·3639	1 lb. 8·5 oz.	...	"	
"	"	"	"	·212	·208	·2228	15 ozs.	...	"	
"	"	"	"	·340	·333	·1522	10·25 ozs.	...	"	
"	"	"	"	·610	·598	·1040	7 ozs.	...	"	

TRACTION OVER AIR GAP.—Table 10 – 13.

Length of bars.	Diameter of face of bars.	Area of pole face in square centimeters.	State of pole face.	Thickness of distance pieces in centimeters.	Gap as fraction of diameter of pole face.	Factor for multiplying traction with no air gap.	Traction observed.	Traction computed.	Induction density.	Remarks.
one bar is	round faces	·81713	perfect	0	0	0	12·44 lbs.	13·91	13799	Table 10. Exactly the same objection as in the case of Table 8. Not used for curve.
26·77 cm.	used diam.	,,	,,	·1	·098	·2782	3·87 ,,	...	,,	
the other	1·02 cm.	,,	,,	·212	·208	·1682	2·34 ,,	...	,,	
13·3 cm.	,,	,,	,,	·340	·333	·1093	1·52	...	,,	
,,	,,	,,	,,	·610	·598	·0643	14·302 oz.	...	,,	
,,	,,	,,	,,	0	0	1	15·88 lbs.	19·81	16465	Table 11. Suffers from the same defect as tables 8 and 10. B is probably too large by say ten per cent., owing to the coil used being of too large a diameter for the very strong fields, approaching 500 C.G.S. Not used for curve.
,,	,,	,,	,,	·1	·098	·2524	5 ,,	,,	,,	
,,	,,	,,	,,	·212	·208	·1464	2·9 ,,	,,	,,	
,,	,,	,,	,,	·340	·333	·1033	32·75 oz.	,,	,,	
,,	,,	,,	,,	·61	·598	·058	18·38 ,,		,,	
,,	,,	,,	,,	0	0	1	...	22·535 oz.	4391	Table 12. These results are normal though taken with wide coil. Included in curve because the field was low enough not to cause serious or even appreciable errors.
,,	,,	,,	,,	·1	·098	·385	8·688 oz.	...	,,	
,,	,,	,,	,,	·212	·208	·208	4·7 ,,	...	,,	
,,	,,	,,	,,	·340	·333	·145	3·28 ,,	...	,,	
,,	,,	,,	,,	·61	·598	·086	1·95 ,,	...	,,	
,,	,,	,,	,,	0	0	1	18·17 lbs.	17·25 lbs.	15370	Table 13. A testing coil having internal diameter 1·7 cm. and outer diameter 2·3 cm. with 400 turns was used. The field reached 500 and everything was very hot. This prevents much weight being attributed to the traction at greatest distance. Numbers used on curve.
,,	,,	,,	,,	·1	·098	·390	6·7 ,,	...		
,,	,,	,,	,,	·212	·208	·231	4 ,,	...		
,,	,,	,,	,,	·340	·333	·1528	48·42 oz.	...		
,,	,,	,,	,,	·61	·598	·04027	12·76 ,,	...		

Table 14.

Length of air gap in centimeters.	Length of air gap in terms of the diam. of the bar measured at the cut face.	Current in magnetising solenoid in ampères.	Deflection of ballistic galvanometer in scale divisions.	Total induction corresponding to observed throw of ballistic needle.	Reluctance of whole circuit in C.G.S. units. (Electromagnetic.)	Reluctance of air gap in C.G.S. units.	Deduced reluctance for bars of one centimeter in diameter.	Induction density.	Remarks.
0	0	·18	23	2887	·0881	0	0	2709	Bar 63 cm. long
0	0	·24	32	4017	·0844	0	0	3769	Diameter of face 1·165
0	0	·48	65·75	8255	·0822	0	0	7743	Bar uncut
0	0	·72	93·5	11739	·0867	0	0	11037	
0	0	1·0	111·25	13967	·1012	0	0	13103	
0	0	1·25	134·5	16887	·1046	0	0	15841	
·082	·0704	·34	55·25	6718	·1430	·0608	·07083	6303	
,,	,,	·6	94·5	11492	·1476	·0609	·07095	10780	
,,	,,	1·0	134·5	16356	·1728	·0682	·0794	15343	
·218	·1871	·4	59	7175	·1576	·0754	·0878	6730	
,,	,,	·66	94	11431	·1632	·0765	·0891	10723	
,,	,,	1·0	130	15809	·1788	·0742	·0864	14830	
·426	·3656	·4	55·5	6749	·1675	·0853	·0994	6331	
,,	,,	·7	93·75	11400	·1735	·0868	·1011	10695	
,,	,,	1·0	123·5	15019	·1880	·0834	·0972	14089	
·61	·5237	·42	56·25	6840	·1735	·0913	·1064	6417	
,,	,,	·72	95·5	11613	·1752	·0885	·1031	10895	
,,	,,	1·0	121	14579	·1939	·0893	·1040	13677	
·94	·8069	·44	57·5	6992	·1779	·0957	·1115	6559	
,,	,,	·72	92·5	11249	·1809	·0942	·1097	10553	
,,	,,	1·0	119	14471	·1953	·0973	·1133	13576	
2	1·716	·44	54·25	6597	·1885	·1063	·1238	6188	
,,	,,	·74	89·25	10853	·1927	·1060	·1235	10181	
,,	,,	1·0	114·5	13924	·2030	·1050	·1223	13062	

Table 15.

Length of air gap in centimeters.	Length of air gap in terms of the diam. of the bar measured at the cut face.	Current in magnetising solenoid in amperes.	Deflexion of ballistic galvanometer in scale divisions.	Total induction corresponding to observed throw of ballistic galvanometer	Reluctance of whole circuit in C.G.S. units. (Electromagnetic.)	Reluctance of air gap in C.G.S. units.	Deduced reluctance for bars of one centimeter in diameter.	Induction density.	Remarks.
0	0	·16	27·25	1986	·1138	0	0	2982	Bars uncut
0	0	·24	45·25	3298	·1029	0	0	4951	Half solenoid only
0	0	·4	69·5	5066	·1116	0	0	7604	
0	0	·6	99·5	7253	·1169	0	0	10886	
0	0	·5	129·25	9422	·1500	0	0	14143	Whole solenoid
0	0	1·0	154·5	11263	·2510	0	0	16905	
·082	·0890	·2	45	3213	·1760	·0731	·06732	4822	Bars 63 cm. long.
"	"	·32	73	5154	·1755	·0639	·0588	7737	Diameter ·921 cm.
"	"	·5	105	7414	·1907	·0738	·0679	11130	
"	"	·66	129	9109	·2048	·0548	·0505	13670	
·218	·2367	·2	40·75	2877	·1965	·0936	·0862	4319	
"	"	·34	71	5013	·1918	·0801	·0738	7525	
"	"	·54	105	7414	·2059	·0890	·0819	11130	
"	"	·72	128·75	9087	·2240	·0740	·0682	13640	
·426	·4625	·2	40·5	2860	·1977	·0948	·0873	4293	
"	"	·36	71·75	5066	·2009	·0893	·0822	7600	
"	"	·54	100·5	7096	·2152	·0982	·0904	10652	
"	"	·72	125·75	8879	·2293	·0793	·0730	13329	
·61	·6623	·24	45·5	3213	·2112	·1083	·0997	4822	
"	"	·36	70·75	4995	·2037	·0921	·0848	7498	
"	"	·54	100·5	7096	·2161	·0982	·0904	10652	
"	"	·7	121·75	8596	·2302	·0802	·0738	12904	
·94	1·0206	·2	39·5	2789	·2027	·0998	·0919	4186	
"	"	·36	70	4943	·2059	·0943	·0869	7419	
"	"	·54	99·75	7043	·2168	·0999	·0920	10572	
"	"	·72	124·25	8774	·2320	·0820	·0755	13169	
2	2·171	·22	38·5	2718	·2288	·1259	·1160	4081	
"	"	·38	67·25	4748	·2262	·1146	·1055	7127	
"	"	·6	102·25	7220	·2355	·1186	·1092	10840	
"	"	·9	135	9532	·2670	·1170	·1077	14310	

RELUCTANCE OF AIR GAPS—Table 16.

Distance between pole faces in cms.	Distance between pole faces in terms of the diam. of the pole face.	Current in magnetising solenoid in ampères.	Throw of ballistic galvanometer in scale divisions.	Total induction	Induction density.	Reluctance of whole circuit in C.G.S. units.	Reluctance of gap.	Reluctance × diameter.	Remarks.
0	0	·30	23·75	29740	4632	·02852	...	...	Bar of 'best' iron annealed
0	0	·64	51	63863	9945	·02830	...	...	Length 91·5 cm.
0	0	1·8	88	110200	17161	·0462	...	...	Diameter 2·8595 cm.
0	0	2·5	93·25	116770	18185	·0605	...	...	Length 32·75 diameters
·308	·1077	·6	21·25	26610	4143	·06374	·0352	·10065	Solenoid 60 cm. long.
,,	,,	1·5	55	68872	10725	·06157	·0310	·0887	Bar placed symmetrically.
,,	,,	3·6	85·5	107070	16673	·09505	·0500	·143	
·686	·2399	·8	25·5	31932	4972	·07082	·0423	·121	
,,	,,	1·7	54	67619	10530	·07107	·0420	·120	
,,	,,	4·0	86·75	108630	16917	·104	·0591	·169	
1·408	·4924	·9	24·75	30993	4826	·08209	·0536	·153	
,,	,,	1·8	51	63863	9945	·07968	·0511	·146	
,,	,,	4·2	87	108950	16965	·1089	·0634	·181	
2·850	·9966	·9	23·25	29114	4533	·08739	·0588	·168	
,,	,,	2·0	52	65115	10140	·08683	·0585	·167	
,,	,,	4·3	86·25	108010	16820	·1125	·0665	·190	
4·5	1·5737	1·0	24·25	30363	4728	·09311	·0646	·185	
,,	,,	2·2	51·75	64795	10090	·09598	·0676	·193	
,,	,,	4·6	86·75	108630	16917	·1197	·0737	·211	

AIR GAP RELUCTANCES.—General Table 17.

A. Bar ·921 cm. diameter, 63 cm. long.					B. Bar 1·165 cm. diameter, 63 cm. long.				C. Bar 2·8595 cm. diam., 91·5 cm. long.			
Air gap in terms of the diameter of the pole face.	Air gap reluctance, induction density about 5000.	Air gap reluctance, induction density about 7500.	Air gap reluctance, induction density about 11000.	Air gap reluctance, induction density about 13600.	Air gap in terms of diameter of pole face.	Air gap reluctance, induction density about 6000.	Air gap reluctance, induction density about 10500.	Air gap reluctance, induction density about 13000.	Air gap in terms of the diameter of the pole face.	Air gap reluctance, induction density about 4500.	Air gap reluctance, induction density about 10000.	Air gap reluctance, induction density about 16900.
·08903	·0731	·0639	·0738	·0548	·0704	·0608	·0609	·0682	·1077	·0352	·0310	·0500
·2367	·0936	·0801	·0890	·0740	·1871	·0754	·0765	·0742	·2399	·0423	·0420	·0591
·4625	·0948	·0893	·0982	·0792	·3657	·0853	·0868	·0834	·4924	·0536	·0511	·0634
·6623	·1083	·0921	·0982	·0802	·5236	·0913	·0885	·0893	·9966	·0588	·0585	·0665
1·021	·0998	·0943	·0999	·0820	·8069	·0957	·0942	·0973	1·5737	·0646	·0676	·0737
2·172	·1259	·1146	·1186	·1170	1·717	·1063	·1060	·1050	...	...	...	...

Mean of Reluctances at all Inductions.

Mean reluctances. Bar A. at distances given in table A.	Mean reluctances. Bar B. at distances given in table B.	Mean reluctances. Bar C. at distances given in table C.
·0664	·0633	·0387
·084175	·0754	·0478
·0904	·0852	·0560
·0947	·0897	·0613
·0940	·0957	·0686
·1190	·1058	...

LIGHT RAILWAYS FOR NEW SOUTH WALES.*

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DISCUSSION.

Mr. C. O. BURGE, in opening the discussion, submitted the following comparison of cost of construction and working of proposed light standard gauge railways, according to the estimate contained in the paper, with that of the two feet gauge lines of the type now constructed in France, applied to similar country, and on the basis of Colonial rates. In making this comparison he took the figures, converted into English equivalents, of M. Regis Tartary, an engineer in the French Government service, who had written on the latest extensive development of the two feet gauge system, of which there is over three hundred miles in France, and who, being strongly in favour of that system, was not likely to hide any of its advantages.

The only items substantially affected by gauge, as regards construction, were :—1. Earthwork ; 2. culverts and bridges ; 3. ballast ; 4. sleepers ; 5. rails and fastenings ; 6. laying road. 1. Mr. Burge made the saving in earthwork for the two feet gauge, for a light surface line to amount to per mile about £91 ; 2. culvert and bridges, about £21; 3. ballast, about £67; 4. sleepers about £92 ; 5. permanent way material, about £491 ; 6. laying the road, about £118 ; total per mile £880. The two first items of the above, which were about one-eighth of the whole saving, would be the only ones affected by the roughness of the country.

Working Expenses.—Excluding, for the present, the question of break of gauge, and merely comparing one gauge with another, it would be found that, practically, traffic expenditure was inde-

* The paper on which this discussion is based appears on pp. 54 – 75.

pendent of gauge. Maintenance, the same volume of traffic being assumed, was very slightly, if at all, affected. The narrower road took less labour to lift it, but on the other hand, a better top was required on the two feet road, as the lateral overhang of the rolling stock was so much greater. The lowest maintenance rate on the New South Wales lines with the present heavy engine stock, was 0·48 man per mile. On the French two feet lines, with about a quarter of the axle weight to bear, it was 0·44 man per mile, and if the standard gauge axle weight were reduced to eight tons as was proposed in the paper, it is probable that the French allowance of 0·44 would be sufficient on the standard gauge. On the Cape main lines, with much less traffic than on the New South Wales main lines, the maintenance force was 1·20 man per mile on the three feet six inches gauge, as against 0·82 on the latter standard four feet eight and a-half inches gauge, both main lines, but considering the comparative value of the white labour here and the black labour there, the rate would be about the same in each case. The total maintenance charges *per train mile* under the little Festiniog engines was only eleven per cent. less than on the London and North Western, according to statistics of the time when he was connected with the Festiniog line, both having heavy traffic, showing how little gauge had to do with maintenance.

With regard to locomotive power, wages, with that of the guard and including supervision, made up from three-quarters to four-fifths of the train mileage expenses of running and repairing an engine, and these wages and salaries did not practically alter much with the size of it. If therefore they had to deal with a long line having moderately heavy traffic, as some of these branches might eventually have ; so far from having a saving by the narrow gauge they would have a serious loss, as the same wages would be spent over less than one-third of the tonnage hauled and paid for. But they were now considering a light traffic on a short line, where in the case of the standard gauge, the train's crew would not be fully occupied, so he was content to leave the two gauges on equal terms in this matter.

Except therefore the saving in cost of construction there was practically no set off against the serious evils of break of gauge, and he would now compare the extra working expenditure, incurred by the break, with that saving.

Take for instance a short branch surface line of thirty-four miles on the two feet gauge, the saving in first cost would be £880 × 34 m. = £29,920, and the interest at four per cent. about £1,200 per annum.

The extra annual expenditure incurred by break of gauge would chiefly arise from—

1. Transhipment and demurrage.
2. Extra cost of providing sufficient rolling stock for inequality of traffic, and extra cost of repairs due to isolation.

As regards the first, he had calculated that 24,000 tons goods annually, with a similar proportion of passengers as obtains on country branches at present, will be required to be moved to pay working expenses and interest, on such a two feet line as that supposed; and the transhipment of this at seven pence per ton, will amount to £700 per annum. Demurrage arises from the fact that instead of the trucks as at present, at a standard junction, being merely shunted and taken on by the next main or branch train, as the case may be, they may be delayed during transhipment beyond that time. Counting the equivalent of only one truck load of the standard gauge being so delayed daily for twenty-four hours, £313 would be incurred annually. Quite as important a cause of demurrage would be the practical impossibility, through the exigencies of traffic, of always having the proper proportion of small trucks, and of the particular type, to suit the load, at the junction, to meet the standard trucks with loads for the branch, and *vice versâ*. While this adjustment was being made either demurrage would go on, or to release the trucks, a second and third transhipment at seven pence per ton each must be made. Though hardly calculable, the amount incurred was not likely to be less, and probably would be a good deal more, than that resulting from the other cause of demurrage already mentioned, viz., over £300 a year. So that these traffic charges alone, due to break of gauge, and taken at minimum figures, would exceed the saving in interest on first cost of the cheaper line.

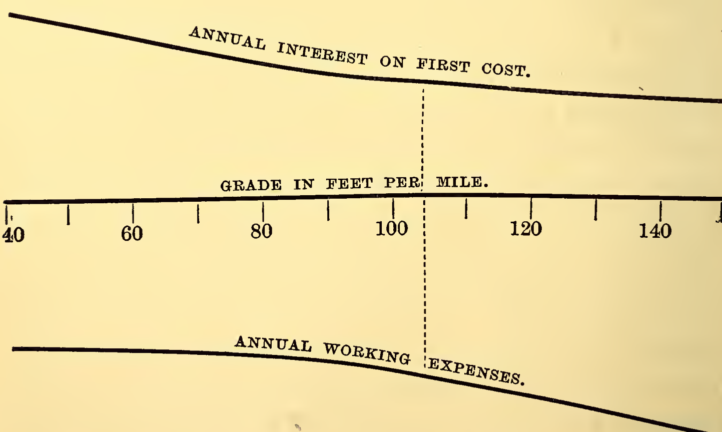
Now they had to add No. 2, the expenses of providing and maintaining the additional rolling stock necessary to meet occasional extra traffic, instead of being able to draw from over 11,000 trucks already in use on the main lines, and secondly, the serious increase to the repairs, due to isolation. Apart from break of gauge, the repairs of the narrow gauge stock would probably, for the same duty, be greater than the larger stock, for the repairs would not decrease in the same proportion as size, and, for the same duty, nearly three times the train mileage would have to be run. But when they added to this the necessity of maintaining separate appliances and skilled labour on the branches, which would be only partially employed, and when it was considered that under present circumstances when the main sheds were accessible, the average annual repairs to an engine, carriage, and truck were £350, £50, and £9 respectively, or say about £1,200 to £1,500 a year for such a branch as that supposed, it could easily be conceived how these items would mount up.

He had purposely taken the two feet gauge, as that gave the maximum of saving in first cost. The intermediate gauges would diminish this, while the expenses of the break in working would be as great. It must not be forgotten that while the saving in interest on first cost is constant on the credit side, every item he had mentioned on the other side, which had been calculated on the basis of the line just meeting its expenses, would increase as the traffic increased.

The figures of course in the foregoing calculations are necessarily approximate—the saving in construction might be more, the expenses due to break of gauge less—no calculation on these points can be decisive unless they could deal with each particular branch on its own data, but enough is shown to prove that before such a momentous change be taken, in the railway policy, as a break of gauge would involve, very great consideration should be given to the question.

Mr. H.W. Parkinson—considered that as the function of a railway was to remove goods and passengers from one place to another, the line that enabled that to be done with the least expenditure of time, labour, and money, was the true light railway. To confine attention solely to first cost, and neglect working expenses, would therefore be wrong. In considering the possibility of reducing the first cost of lines, it would be well to divide that cost into two parts: (A), a known and for any given line constant cost, and (X), an unknown and variable amount. (A) consisting of the cost of forming, ballast, sleepers, rails, etc., which for different designs might vary from £2,000 to £4,000 a mile, or a total variation of £2,000. (X) consisting of earthworks and waterways might vary from £1,000 or less to say £17,000, or a possible variation of £16,000. There was, therefore, generally far greater scope for reduction in (X) than in (A), although attention was more often directed to the latter. A so-called reduction, however, would be no reduction at all if it entailed an equal or greater expenditure in working expenses. The suggested reduction in the depth of the ballast to three inches seemed to him of questionable utility—certainly on portions of many roads it would prove very inadequate. If the line were designed for a definite and constant axle load, then since the stiffness increased inversely as the cube of the span but only directly as the square of the weight of the rail per yard, evidently economy would be consulted by using as many sleepers as possible. This number, to leave proper room for tamping, would be about two thousand five hundred per mile. He was glad to note that the author was in favour of sharp curves as a means of reducing capital expenditure in construction. There could hardly be any doubt that the adoption of five chain curves on branch lines would very materially reduce their first cost without any corresponding increase in working expenses. The mechanical difficulty of running round such curves with locomotives had been practically overcome, the greatest drawback being the limited speed due to the fact that it was not feasible to put in the enormous superelevation necessary for high speed. This would be certain to make such lines locally unpopular, however beneficial to the country as a whole. The money cost of loss of time was difficult to estimate, but was probably not great in country districts. In the location of lines where it was desired to avoid earthwork by adopting sharp curves, the contour grade line was of the greatest value. After curvature, the most important method of reducing (X) was by grading, but here great care was necessary, curvature and distance might be increased with but little addition to working expenses, but increasing the ruling grade altered the whole constitution of the line. The method of determining the most economical ruling grade was as follows:—Estimate the cost of building the line on several different ruling grades, and plot a curve representing the annual interest on first cost. (See Diagram). Then determine the curve of annual traffic cost, varying with the grade, and plot curve inversely.

DIAGRAM.



The position of the shortest vertical line intercepted by the two curves would indicate the ruling grade in feet per mile. Thus in the diagram the dotted line is the shortest vertical line it is possible to draw between the two curves, and cuts the grade line at one hundred and five feet per mile, or a ruling grade of, say, one in fifty. This solution, which he believed was due to Mr. W. H. Searles, assumed that trains could always be fully loaded, and referred only to goods traffic, but the number of goods trains was generally a fair indication of the number of passenger trains; if not, the correction could be made. Should the tonnage "up and down" differ greatly in amount, the branch or section must be considered as two lines, A to B, and B to A, and graded accordingly. Closely allied to fixing the ruling grade came grading in general, or location in elevation as it might be termed. The first cost could often be reduced without affecting working expenses by the adoption of momentum grades. Since an initial velocity of twenty-five miles per hour would lift a train through a height of twenty-two feet before bringing it to rest, wherever in ordinary working such a velocity could be relied on it was possible to introduce a hump in the ordinary grading to this extent, and thus often materially reduce cuttings. Sags to the extent of nearly twenty feet might also be introduced in the banks, since the velocity gained in descending served to carry the train over the corresponding rise. The switch-back formed a good illustration of momentum grading. Such grading was particularly applicable to undulating country, as some portions of the Western Plains. On the question of gauge, he fully agreed with the author that the narrow gauge *per se* reduced the first cost by only a small percentage, about five per cent., according to Mr. Wellington. The great reduction in first cost in the case of narrow gauge lines generally arose from the fact that sharp curves were adopted, but curves almost if not quite as sharp might be used on the standard gauge. As pointed out by the author, the question generally was not simply the standard versus the narrow gauge, but the standard versus a break of gauge.

Mr. G. R. Cowdery agreed with the author with regard to the gauge and curves, but was, however, of opinion that it was undesirable to depart from the minimum grade even where it could be shown that by adopting a steeper grade the working expenses in relation to the capital expenditure were actually lessened, and would remain so for the first few years. He considered that it was wiser to anticipate by a few years a heavy increasing traffic, than do that which would probably be a heavy drag on the working expenses for a life-time. Any one who has had any experience would know the difficulty and expense involved in lowering a grade, while that of increasing the radius of a curve was ordinarily a much more simple and less expensive matter. The adoption on light railways of motors similar to those used in Sydney was worthy of consideration. It might not be generally known that the strongest motors in use, with eleven inch cylinder, sixteen inch stroke, and thirty-five inch driving wheel, were capable of drawing six hundred and sixty-two tons on the level, one hundred and sixty-five tons on a one in one hundred grade, and ninety tons on a one in fifty grade. Taking a loaded truck to weigh ten tons, it would be seen that these motors were capable of taking nine loaded trucks up a one in fifty grade. As on a light line the services of a fireman were not required, the running expenses of a train were by this alone reduced thirty per cent. These motors were also capable of running round very sharp curves, even up to eighty-six feet radius. This, of course, was with the assistance of a guard rail, but were the depth of flange increased to the same as an ordinary railway line, they would successfully run round curves three and four chains radius without the assistance of the guard rail. A further saving would be in the capital cost of the motor, for which about £1,000 was a fair price, probably half the cost of an engine as described by the author; the cost of repairs also would probably be less. Motors had one great disadvantage, viz., their small water carrying capacity, which however, might be largely increased without much extra expenditure. He was unfavourable to the reduction in the number of sleepers, and considered that the Americans had shown their wisdom by keeping their sleepers close together rather than increase the depth of ballast. On the tramways he had found that where eight feet by nine inches by four and a half inch sleepers were placed two feet four inches centres apart, there was less difficulty in keeping a good top and line on the road, even where the traffic was three times heavier than on a similarly constructed road and like formation, but where the sleepers were two feet eight and a half inch centres. The question appeared to be one of low maintenance cost, rather than one of "safe limit" of rail span. Reducing the depth of ballast appeared to him one of the least objectionable methods of reducing the cost of a light line; it was an improvement to any line to be periodically lifted and repacked, as it improved the drainage and gave adhesiveness to the sleepers and ballast. The gradual ballasting of the line could therefore be carried out as the traffic and earnings increased, especially as the development of the country by the railway would probably make the ballast more easily procurable. A further considerable saving in first cost could also be effected by discontinuing the practice of cutting the low rail on curves in order to bring the points opposite. Although theoretically correct, an adjustment of the sleepers at the points would meet all practical purposes, the rails being cut only at the tangents. This had been done to great advantage on the tramway curves, for the wear on the inside of the head of the high rail was so severe that in order to obtain the most economical results the rails had to be changed from side to side, which of course could not be done if the rails were cut. He was opposed to the reduction of the weight of the rail to less than sixty pounds to the lineal yard, and would not favour any reduction in the weight of the sleeper fastenings, as it was essential in order to reduce the cost of maintenance to avoid frequent re-spiking and consequent damage to the sleepers. He had found that where forty-two pound rails were in use on the tramways, even on lines where the traffic was comparatively light, the ordinary maintenance had been greatly reduced by the use of heavy sleeper fastenings. He considered that the greatest disadvantage to any railway were steep gradients over which no mechanical device could economically work.

Mr. C. Vandevelde advocated the adoption of the two foot gauge for branch lines. The author stated that he had experience with several gauges, from the five feet nine inches gauge of Spain to the one foot eleven and a half inches of Festiniog, but he would be better qualified to speak if he had seen the latest and most improved development of the two feet gauge in France. These lines had been made for from £1,600 to £1,800 per mile, including rolling stock. They had rails of nineteen pounds to the yard, and curves of thirty metres. He thought the Government here should send an expert to France to report upon those lines and their adaptability to these Colonies. He considered that such lines would be superior to our present standard gauge branches, and if sharp curves were introduced with the present gauge, the existing carriages must be altered. Mr. Vandevelde would ask the author if he would now recommend that the Festiniog two feet line should be altered to the standard gauge. The author had said that light rails, steep gradients, light works, and light working expenses were nearly all more or less antagonistic to each other, but if the two feet gauge were adopted this would not be the case.

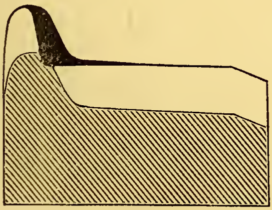
Mr. W. F. How was convinced that engineers who had to construct railways in foreign and thinly populated countries, which were expected to produce good financial results at an early date, were justified in adopting a very light and cheap construction in the first instance, and to do this sharp curves, heavy gradients, and light rails were necessary. As the population increased, the modification of the curves etc., could be carried out when desirable. He considered that as the lines proposed by the author would probably be constructed by a Government, the proposal to use fairly heavy rails, and to adhere to the existing gauge of railway would be justifiable. He pointed out that for many years English manufacturers could not see any advantage in departing from their long established practice with regard to the design of locomotives, but appeared to think that the types they had always made to suit the British tracks should work well everywhere, and the consequence was that in many instances, on cheaply constructed lines abroad, engines of English make were replaced by the more flexible American type, with the result that to this day the American engines have had a preference in most new countries. He once blamed an old friend and fellow apprentice, who had been for some years engineer and locomotive superintendent for a South American railway, for having ordered numbers of locomotives from the States, when he had obtained all his experience as an engineer in England, and he was assured that this was done with the greatest reluctance, because the road was so sinuous and had so many sharp curves, that the wear and tear upon the English engines was excessive; that English makers had been asked to modify their designs, but without avail, and therefore engines had to be purchased from the United States. This occurred about ten years ago, but matters had changed since then, as the British engineers had become more alive to the requirements of such railways, and some of the best of them manufactured locomotives with bar frames, bogies, and short rigid wheel bases to suit any requirements, equally effective upon rough and cheap roads, and superior in quality of material and workmanship to any that could be made in America. He had looked up some information relating to locomotives suitable for a four feet eight and a-half inches gauge of railway, and capable of meeting most of the requirements suggested in the paper, and tabulated the leading points of five such engines, which were capable of passing round curves of from three to six chains radius. They weighed from twenty-eight and a-half to thirty-nine tons when in working order, and the loads upon the axles could be arranged to be from five and a-half to eight and a-quarter tons. The loads they would draw upon an incline of one in forty at eight miles per hour varied from one hundred and twenty-two to one hundred and fifty-one tons exclusive of the engine.

BRIEF PARTICULARS OF LOCOMOTIVES MANUFACTURED FOR LIGHT RAILWAYS.

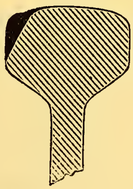
Number of engine.	Traction force in lbs	Load in tons exclusive of engine on level, at fifteen miles per hour.	Load in tons exclusive of engine, up incline of 1 in 40, at eight miles per hour	Rigid wheel base.		Sharpest curve, in chains (4′ 8½″ gauge)	Weight of engine in working order.				Weight of engine in working order, if it is made with tender in place of tanks.				Weight of engine in working order, if, instead of tanks and front and hind trucks it is made with eight coupled wheels only, and a tender.			
							Total weight of engine.		Max. weight on any axle.		Total weight of engine.		Max. weight on any axle.		Total weight of engine.		Maximum weight on any axle.	
	lbs.	tons.	tons.	ft.	in.	chains.	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.
1438	10714	930	134	...		3	28	13	9	13	24	5	8	5	...		...	
2010	12500	1078	151	11	3	5½	37	12	7	13	29	10	6	0	28	0	7	2
2167	10129	373	122	...		6	31	0	6	19	25	17	5	10	24	8	6	2
2179	11538	988	135	7	4	3	38	19	9	11	33	7	8	5	...		...	
2285	10782	921	125	8	6	5¾	38	3	8	10	32	7	8	0	...		...	

Mr. W. Thow agreed with the objections expressed by the author against the introduction of a narrow gauge of railways into this country. In South Australia experience of both the five feet three inches and the three feet six inches gauge led everyone to regret that the country had the burden of two gauges to carry. He also agreed with the author that the expedients tried for overcoming the break of gauge difficulty, of which many were put to actual test in South Australia, had all, so far, proved inadequate to lessen the evil. The only scheme of the sort that seemed to possess merit was to change the bogies of vehicles at the break of gauge stations. He had had plans worked out for doing so by hydraulic lifts. The carriages would be simply lifted (without any uncoupling) all at the same moment and the bogies of one gauge replaced by those of another. But this plan could only apply to bogie stock, and if required for merchandise traffic it would compel the employment of that stock in place of the short four-wheeled waggons now so common both in this colony and Victoria. He could not agree with some of the author's views, in their application to locomotives and rolling stock, that the tyres of rolling stock did not suffer much from curvature. That was entirely against his experience and, he thought, erroneous. He considered curvature was one of the most active destroyers of tyres, and of rails, as well as an enemy to economical working. In consequence of the rapid grinding away of flanges and rail-heads on curves, they had frequently to turn more material off tyres by the lathe in one day than would be worn off them in five years of running on straight lines. Sketch "A" would explain his meaning.

A



B



One fourth size.

The original form of the flange was shown, and the effect of curvature was to cut into it, reducing it (as shown by the dark section), rendering it unsafe for the road and apt to lift over the rail. Tyres in that condition had to be brought into the shops and the flanges restored by turning off the metal of the tread in the manner shown by the lower section; the space between the two lines being absolutely wasted material. Sometimes the tyres had to be reduced more than an inch in diameter in that manner, and the loss was entirely due to curvature. He was afraid the idea that curvature did not destroy tyres was a phantom, often responsible for inducing the constructive engineer to adopt curves in many cases where, by a little extra expenditure, straighter lines might have been used.

There was another remark by the author, which he scarcely understood. It was "an engine should be as like a snake as possible, using all its length for adhesion and propulsion." But that statement seemed to be contradictory in itself. An engine which used all its length for adhesion and propulsion must necessarily be a coupled engine, all its wheels must be coupled, if they are used for adhesion; and it must be without any bogie or flexible wheel base. But probably the author intended to direct attention to some of those abnormal machines, such as the "Fairlie" locomotive, which made some stir twenty or twenty-five years ago. That machine was really a double locomotive; it consisted of two complete engines, entirely independent of each other, except that they were pinned to one boiler. Such arrangements had been found to be deficient, and they were consigned to the scrap-heap long ago. The author incidentally referred to the engines used on the New York elevated railway as machines which possessed the virtue of being able to work readily round very sharp curves. They certainly could turn round very sharp corners, but then they were mere toys of locomotives, about as powerful as our tramway engines. They did not weigh seventeen tons in working order, which was less than the load on the driving axle of ordinary sized locomotives, and the adhesive weight of the four coupled wheels was only ten and a half tons. Such engines were useless for lifting paying weights over grades. The total gross weight that an engine of this sort could lift behind it over grades of one in forty at ten miles an hour was fifty tons of waggons and loading, so that to meet all expenses for wages, fuel, and stores, repairs of rolling stock, maintenance of way, supervision, interest, etc., they would get the rates derivable from only twenty to twenty-five tons of merchandise per train hauled. He gave these figures to show that the elevated railroad engines, which did so well under the conditions for which they were designed, would be practically useless on any light lines in New South Wales. But there was no difficulty in making locomotives flexible enough to work freely round any reasonable curves, provided a sufficiently good track was laid for them. They had, at the present time, English-built locomotives in this Colony, which weighed fifty-seven tons, carried on twelve wheels, spread over a wheel base of twenty-nine feet two inches, but of which the rigid base was not necessarily more than six feet two inches. These engines were certainly flexible enough, but they were no more disposed naturally to run in circles than the most rigid engine ever built. Locomotives, like other bodies in motion, followed the laws of nature, and moved in straight lines unless forced to change their direction by pressure and loss of power. This law of nature could not be overcome by merely making each axle radical to the curve. The pressure between the wheel flanges and the rails remained the same, and that pressure, with sharp curves, meant destruction of tyres and rails, limitation of loads, and high working costs.

In South Australia many miles of light lines had been built on the five feet three inches gauge. They were laid with iron rails originally of only forty pounds to the yard, but considerably worn, and engines were specially designed for moving a fairly heavy traffic over these light rails. They were tank engines, with sixteen and a half inch cylinders, carried on ten wheels, on any pair of which the greatest load was eight and three-quarter tons. The total weight of each engine was forty and a half tons, and they answered the requirements of the light road remarkably well. Tank engines were certainly the most economical for use on railways where conditions permitted of their employment. It was important to get rid of the tender, which was a mere carrying machine, and so much dead weight; but it often happened that water supplies were not sufficiently frequent to suit tank engines. The construction engineer said, "I cannot afford to give you water supplies every twenty miles, my estimate only provides them every thirty-five or forty miles;" therefore the locomotive man had to make tender engines for lines which could be worked more economically by tank locomotives.

He observed the author referred to the use of electricity as a possible method of increasing the bite or traction of locomotives, but he did not think there was anything likely to arise from that. When the Americans first started electrical traction, they were surprised at the success of their first attempts, and at the loads which they moved up steep inclines. They fancied that the electric currents, passing from wheel to rail, increased the tractive power of the motor; but when they put their machines to test at the friction brake, they found them developing such horse powers as readily accounted for the results observed. There were one or two other matters of sufficient importance to mention. The first was superelevation on curves. When passing through America two or three years ago, he met Mr. Theodore Ely, who was general locomotive superintendent of the Pennsylvania railroad. He was at one time resident engineer on that line, and therefore fully acquainted with the superelevation given by American engineers. He mentioned to Mr. Ely a peculiar action of some of the first American consolidation engines (brought to this Colony some years ago) when working round the sharp curves of the mountain line: the wheel of the bogie on the inner rail of the curves was found to lift clear off the rail, when running smartly, and spin round in the air. Mr. Ely said their practice was to give much greater superelevation than ours—as a rule, one inch elevation to the outer rail for every degree of curvature—and accounted for the peculiar action mentioned, by the insufficiency of superelevation. He might here mention that this lifting of the wheel off the inner rail was an evidence of the extreme pressure between flanges and rails caused by curvature. The pressure between the bogie wheel flange and the outer rail, due to the forcing of the engine out of the straight line of motion, was sufficiently great, when acting through the leverage of half the diameter of the wheel and the length of axle, to compress the bogie spring over the inner rail and allow the wheel to lift. Another matter, which had always appeared to merit more attention than it received, was the width of gauge on curves. He was of opinion that it was a mistake to widen the gauge, and would prefer to give no play. When vehicles were running round curves, the leading axle always slewed over towards the outer rail and the trailing axle went in the opposite direction or towards the inner rail, until their respective movements were checked by the pressure between the tyre flanges and the rails. Thus a short vehicle took np a position diagonal to the curve, and the wider the gauge the greater that divergence, which in many cases made the flange cut into the edge or side of the rail like a knife, and where the head had been worn away (as shown by the sketch "B"), which was always the case more or less on curves, the inclined direction of the worn head readily assisted the wheel to rise (especially under light loads or empty vehicles) and lift over the outer rail. He considered that many derailments, otherwise inexplicable, were due to that cause.

Colonel Wells said that having been for some years principal road engineer in the Colony, a few words from him in that relation might not be out of place. Since inland communication had of late been demanded and carried so far into the western interior, the necessity of other connections than common roads had become apparent to such an extent that the late Commissioner for Roads, Mr. Bennett, and himself had deprecated all attempt at making roads on the great black plains, but had advocated light railways instead. In many localities road material, even of the poorest description could not be met with for scores, even hundreds of miles, and all that could be done to maintain communication was to bridge the watercourses and allow traffic to plough its way over the black soil in the best way it could. Even this was very expensive, as in the case of embanked bridge approaches, and other places where traffic was necessarily confined. The expedient of using burnt clay in lieu of stone had been resorted to, but the expense even for such material was very great, varying from £1 to £1 10s. per cubic yard. As the swallowing capacity of the black soil was enormous, an idea might be formed of the cost of making and maintaining a road on the plains. It was manifest that in the plains country a common road would cost twice as much to construct and twice as much to maintain as a light railway. On such country he would in the matter of gauge give preference to the normal one, four feet eight and a-half inches, as works in general would be light, and double handling of cargo—principally wool and live stock—would be saved. In ridgy country, requirements might be met for many years by the common roads, which in the more settled parts of the colony would always be required, even after a railway had been constructed parallel with them, as witness their experience of the main Western and other roads which were maintained in better order than when carrying the main traffic of the interior. Should however light railways be required in such country as he spoke of, it might be advisable on account of cost entailed by heavy cuttings, curves, etc., to adopt a narrow gauge as advocated by Mr. Vandevelde, more particularly as such line might have its origin in some special local requirement, as a mine, etc., whose cargo could on light lines only be carried in small trucks, and would receive no damage by tipping into larger trucks on main lines.

Mr. J. W. Grimshaw considered that light railways really meant cheap railways for light traffic. For railways to be really cheap it was necessary that the trains be run at a slow speed in the day time only and be self-governed. Slow speed allowed of sharp curves, steep grades, lighter engines, lighter rails, fewer sleepers, less ballast, cheaper bridges; and when the trains were run in the day time, fences, gates and gate-keepers, signals and signal-men, could be dispensed with and lower wages paid. By the trains being self-governed, expensive buildings, station masters, ticket clerks, and porters could be dispensed with, and trains could more readily adapt themselves to the requirement of the traffic in their stopping places. It was not only the first cost of station buildings, fences, gates, and signals that was saved, but the cost of maintaining them in good repair. These points were fully realized in America and many railways were constructed and worked on these principles. Although the speed might be slow there was no reason why the passengers' comfort should be neglected or why the trains should not easily compete with coaches and drays, which had to contend with all the difficulties of country roads. What was really wanted were low freights. There was no economy in a break of gauge, and very little in a narrower gauge, but where the greatest of all economy could be obtained was in the careful selection of the route. It was inadvisable to open up a country by going over high mountains and through barren land when by going a somewhat longer distance, good country could be traversed; what an economy there would have been if the Western District had been opened up by a line from Dubbo to Muswellbrook, and into Newcastle, instead of having to haul everything over the barren mountains to Sydney. How easily could that terrible line from Wallerawang to Mudgee have been avoided. The lines could be shortened when the traffic justified it, as was constantly being done even in older countries with settled population. It must be remembered that in a new and rapidly growing country like New South Wales, what appeared to be but an insignificant branch line would probably, within a very few years, be part of an important main line, and they should endeavour to so construct the line, that the requirements of an increased traffic could be added without any expensive work already done becoming useless. As to the resistance of railway curves, he referred to the experiments made by the French Government, which appeared in *Engineering*, 23rd Sept., 1892.

Mr. Rennick was satisfied that narrow gauge railways for a national system would be a mistake. This was exemplified in America, where much money had been spent in converting the narrow gauge into the standard. In India, also, the metric gauge had not been a success. The capacity of a railway might be measured by the gauge, all other things being equal; thus, in coping with a certain amount of traffic, the capacity of a five feet three inches gauge to a three feet six inches gauge would be sixty-three to forty-two. For small traffic the effect would not be felt, but when the the traffic was fully developed the difference became very perceptible. The greater the number of trains required for a certain volume of traffic, the greater the working expenses would be, consequently any little saving in the construction of a narrow gauge line, would soon be more than balanced by the increased working expenses. Advocates of the narrow gauge seemed to overlook the fact that light rails and light rolling stock could be used as readily on standard as on narrow gauge lines, and would do more work because they would be better supported. In any ordinary country the increased cost of standard over narrow gauge lines would not be more than five or six per cent. Certainly sharper curves could be used on narrow gauge lines, but the number of places that it would be economical to adopt the sharpest curves possible would be but few, and would be a small proportion of the total cost. In America, curves as sharp as two hundred or three hundred feet radius were frequently adopted in rough country, and no difficulty was found in running over them, even with eight-wheeled coupled engines. So far as he was aware, curves sharper than that were never adopted for any gauge roads. In Australia, five chain radius curves were the sharpest in use. He considered that everywhere but in the most difficult country the standard construction should be adhered to, the rails to be not less than sixty pounds, minimum curves ten chains, and grades of one in thirty, where necessary, to keep down the cost, and eight-wheeled coupled engines should be used for freight trains. In very difficult country, such as North Gippsland, it would be necessary to adopt five chain curves, and grades of one in twenty, for the sake of economy. In very steep parts a central rack rail might be laid and worked by a locomotive on the adhesion and pinion principle, as had been successfully tried in Germany and South America, where they had grades of one in twelve and a half. For the sake of economy, steep grades and sharp curves were necessary in very rough country, and in such places the standard gauge had greater capabilities than the narrow, because apart from grades and curves, the narrowness still further restricted the train loads.

Mr. J. Trevor Jones said that the author had been careful to give separate consideration to the two heads into which the subject divided itself, viz., light lines on a narrow gauge, and those on existing gauges. Mr. Higinbotham, who was Engineer-in-Chief in Victoria in 1872, unequivocally advocated the retention of the five feet three inches gauge, though favourable to the adoption of light lines, and the whole Department supported his views; though there was a general understanding that in isolated country, with very steep and tortuous tracks, the narrow gauge might be found suitable. The lines, however, then under consideration were in no way such as to call for that treatment, being the Ballarat and Ararat line over undulating country. The then Minister, however, attributed the objections of officials to a repugnance to leaving beaten tracks, and directed that plans be prepared on the three feet six inches gauge. He afterwards relented so far as to order that alternative plans, with estimates, should be prepared, believing that the results would show a great economy of the narrower gauge over the broader. In this he was disappointed, and indeed the result rather surprised the Department, as the saving amounted to only about five per cent. There was considerable discussion among the public and the press as to whether this estimate was not in some way misleading, and the arguments which carried most weight in favour of the Department were somewhat as follows:—Assuming that rails of the same weight were used, no saving could be made by adopting the narrow gauge; nor could any saving be effected in the fences, which would be the same length in each case. In the bridges (timber in this case) and culverts there would be no saving on the longitudinal beams, or vertical timbers, or iron-work, and very little on the transverse timbers. There would admittedly be a saving on earthwork, but not so great as would appear at first glance, because the great bulk of the cost of a cutting was the opening of the gullet so that waggons could be taken through, when its width could be amplified at a cheaper rate. There would be saving in cubic measurement of earthwork, but the rate must be higher in order to compensate for the smallness of the payable cutting. The course would be longer, owing to its tortuousness, on the narrow than on the broad gauge, entailing more length of way and therefore increased cost for rails, sleepers, and maintenance. The saving in length of sleepers and transverse timbers on bridges was but trifling. These arguments, added to the very weighty ones of the interruption to passenger and freight traffic by break of gauge, and the difficulty of sending damaged rolling stock to central repairing shops, totally reversed public opinion, and the Minister heartily adopted this view and sanctioned the five feet three inches gauge. He was of opinion that the reasons just enumerated, added to the numerous and weighty ones adduced in the paper, left no room for the advocacy of the narrow gauge, excepting such arguments as have already been referred to. It was to be regretted that, in view of the intention to make light locomotives and rolling stock generally, and to run at low speeds, the first light lines in Victoria were made with fifty pound rails. Probably, if the low speeds had been maintained, the rails would have carried the traffic for a long time, but the exigencies of the traffic soon over-rode the instruction. The station accommodation was indifferent, the number of hands on an economical scale en tailed long delays at the stations, and therefore greater speed in the intermediate spaces to make up for lost time; so that in a very short time a message came from the resident engineer that the rails were too light, and recommending that nothing less than sixty pounds should be used in future. He believed that no more fifty pound rails were laid thereafter, and that sixty pound rails were now considered the minimum.

Mr. P. Allan had anticipated that mention would have been made of the danger in narrow gauge railways, of overturning due to wind pressure, accidents from that cause having actually occurred in New Zealand. He had been informed by one of the engineers connected with New Zealand railways that the underside of the carriages had since been loaded with rails, and that a wind fence had been erected on either side of the line. Having been intimately connected with the designing of some seven hundred traffic bridges throughout this colony, he might perhaps be permitted to offer a few remarks on this important item in connection with railway construction. Hitherto the use of timber in railway bridges had been in most cases restricted to small span structures, but as good sound ironbark had on the average an ultimate tensile strength of eight tons per square inch, or one-third that of wrought iron, there was no reason why full use—in the construction of timber bridges with fair sized spans—should not be made of this material, which oftentimes was in close proximity to the route of the proposed railway. If it could be shown that the annual cost of maintenance, plus the interest on prime cost, plus an amount per annum as a sinking fund to liquidate the cost of a timber bridge at the end of its life, was less than the maintenance and interest for an iron or steel bridge, then from a financial point of view, there could be little reason why such a saving in the revenue should not be taken advantage of. For the sake of comparison he had estimated the cost of the superstructure of a steel truss bridge and a timber truss bridge each of one hundred and twenty feet span, and to make the case favourable to the steel bridge he had assumed that the proposed site was three hundred miles by rail from Darling Harbour, and that, there being no suitable timber in the locality, the whole of the timber had to be brought from one of the northern rivers. Omitting in each case the rails and fastenings, the superstructure of a steel bridge would cost for one hundred and twenty feet span £3,000 including painting. Assuming the life of a steel bridge at one hundred and fifty years and taking interest at four per cent. the annual charge for interest, sinking fund and maintenance would be £150. The total cost of timber superstructure for one hundred and twenty feet span would be £1,870 for a truss bridge twenty-feet deep with twelve feet panels. Assuming the life of the iron work at one hundred and fifty years, and taking the life of the timber work at twenty-five years and interest as before at four per cent. the annual charge for interest, sinking fund and maintenance would be £125. In connection with the timber bridge it might be noted that provision only had been made for the liquidation at the end of twenty-five years, of the prime cost of the timber work and re-erection of iron work, the whole of the iron work being again utilised when timber superstructure was replaced at the end of its life. To recapitulate, the steel superstructure of one one hundred and twenty feet span would cost £3,000 as against £1,870 for a timber superstructure, or a saving in prime cost in favour of the timber bridge of £1,130 whilst the charge against revenue by the adoption of the timber bridge—after allowing for sinking fund—would be reduced from £150 to £125 per annum. If a saving of 37·7 per cent. could be effected in the prime cost, and 16·7 per cent. in the annual charge against revenue when timber had to be carried two hundred miles by water and three hundred miles by rail, how much more noticeable would this saving be when timber was in abundance close at hand.

Mr. G. Fischer considered that the paper might be divided into two portions, viz., a way was indicated how a cheap standard gauge railway could be constructed in New South Wales, and secondly, the author gave his reasons why he objects to a break of gauge. He could not agree with the author in the means employed to make a saving in first cost, by spacing the sleepers about three feet six inches centres, and putting only three inches of ballast under them. It was no doubt all correct according to calculations, but he considered that in practice it would not give satisfaction, the cost of maintenance of such a lightly ballasted line would be comparatively large, and as the ballast was calculated to cost only five shillings per cubic yard, the material could not be expected to be of very high quality, and such a thin layer would soon be converted into pulp by the sleepers, or disappear in the formation, and although the cost per mile taking it for the cheaper of the estimates, would be about ten per cent. higher, and by keeping to the present number of sleepers and allowing six inches of ballast under them, the additional interest on capital would be only £9 per annum per mile, and this would be fully saved in maintenance, besides giving a better and safer track on which higher speeds could be run with perfect impunity. Another point on which he disagreed with the author was the proposal to use existing road bridges for railway traffic. He did not think that many of the existing road bridges could be sufficiently stiffened to carry the loads which trains of the weight proposed would impose upon them ; besides in the majority of cases the approaches were entirely unsuited for the projected purpose. With regard to the author's objections to break of gauge, he would admit that he was not in favour of it so long as a standard line could be made to pay, even if only after some years. A railway was only a machine, and if a two hundred horse power engine would do all the work required, a five hundred horse power one would not be used, and similarly if it was found that a railway with say a two feet gauge could carry all the traffic that was ever likely to come on to it, and calculating all the drawbacks set forth by the author and capitalising the extra cost per annum due to them, it was then found that the two feet gauge would still leave a fair margin of profit, while the standard gauge would shew a loss, he would unhesitatingly say change the gauge. A properly designed two feet gauge line could be constructed at from one-half to two-thirds the cost of standard gauge lines; the saving with the metre or the three feet six inches gauge was not so large proportionately, and once a change of gauge was decided upon, the one which could do the work desired with the least capital outlay should be adopted.

The author had given some very strong reasons why the narrow gauge should not be introduced in New South Wales, and a great point was made of the fact that the asylum for old rolling stock would be closed up, but he himself had discarded the old engines by adopting a new design. The author proposed that passenger stations be cut out, guards doing the work of station masters, these duties no doubt would include sale of tickets. How was it proposed to manage this with our old rolling stock, excepting perhaps the comparatively few suburban carriages? If passenger platforms were to be abolished, how could passengers get in and out of the carriages without re-building them to suit the purpose? and if they were so re-built, how could an interchange be made with the main line passenger stock on the special occasions mentioned, such as shows, races, etc. These difficulties could no doubt be overcome, but if the cost of making these changes were calculated, it might be found in the end that it would be cheaper to construct special passenger stock for branches, as had been done for the Campbelltown to Camden and the Yass tramways, on which lines goods are taken on the main line trucks without transhipping.

Mr. Thomas Middleton said that he understood the author to express the fear that locomotive designers had not quite complied with his requirements; but there was no difficulty in designing engines for light lines, which would be "as snake-like as possible," have great hauling power, and be easy upon the road —indeed, such engines were actually in use at the present time. He supported Mr. Fischer's views, and would urge a three feet six inches gauge as a standard for light lines. Sir Edwin Watkin had last year supported the introduction of a third rail in Northern India, where five feet six inches and three feet three and three-eighths inch gauges abound. The metre gauge had proved itself in working equal to the performance of very useful work. The transhipment difficulty at junctions could be readily dealt with by using suitable appliances, such as cranes, etc.; the cost and inconvenience of handling goods could then be reduced to a minimum. As to sending all narrow gauge engines and rolling stock to Sydney and Newcastle for repairs, that would be unnecessary, for at the present time very extensive repairs were done to the four feet eight and a half inches gauge stock at many country stations. When it became absolutely necessary to send an engine up, it could be done by the use of temporary wheels and axles of four feet eight and a half inches gauge. In reference to what had fallen from one speaker, he would point out that in Japan, on a three feet six inches gauge, there were running locomotives having eighteen by twenty-two inch cylinders, which were more powerful than many of our Mogul engines here on lines of four feet eight and a half inches gauge.

Mr. T. R. Firth considered there was no doubt that some parts of the Colony could be satisfactorily served by a less expensive description of railway than had hitherto obtained, but few places could be so treated and enjoy the regularity that now existed in the railway traffic throughout the Colony. In parts of the interior, where the country for miles around appeared to be as level as a bowling-green or dead level, the rails might be laid with only a few inches of ballast under them, at a cost for earthworks of only about £100 per mile, or, including clearing and grubbing, of say £150 per mile, but such a line would only be available during dry weather for the lightest locomotives to pass over, and half a day's rain would be sufficient to stop all traffic for several days, as well as incurring heavy expense in putting the road in good order. No engineer of any experience would advise the construction of such a line, and the author's estimate of £300 a mile for earthworks on the most favourable country might be taken as the lowest at which a railway could be satisfactorily and economically made. Where the surface was apparently level or undulating only the higher portions should be on what is termed "forming" or surface levelling, and all depressions should have not less than one foot of embankment so as to raise the formation and keep a dry base for the ballast. In making the embankment from the side cutting it would also assist in draining the subsoil as well as giving the means of allowing the water to cross the line wherever there was a slight fall. On the Nyngan to Cobar line a very considerable portion was originally made as a surface line, but the first rains clearly showed that if left in that form, the expense of keeping the line open for traffic would be almost equal to remaking, every time there was rain, with a more than probable stoppage of the traffic and an element of danger as well, it was consequently deemed necessary to make the line in accordance with the views just enunciated. In hilly country of course no rough estimate of the cost could be given that would at all serve any good purpose, it depended first on the nature of the country, that is in its physical and geological characters, second on the curves and gradients that were to be adopted. A light line must necessarily have sharp curves and steep gradients, otherwise the only saving in first cost that could be made was by reducing the width of the cuttings, and from previous experience this small saving could not be recommended. The next item of importance was waterways; of whatever kind of material they were made they could not be restricted as to size, they must be large enough to carry off the heaviest rainfall, and the material must depend to a very large extent on the means of renewal when required without interfering with the traffic, thus in shallow banks timber might be used with safety, but when the earth-works were heavy or there were large streams or rivers to cross, concrete or steel must be used, and as these latter were comparatively everlasting, the question must be considered whether the light line was likely to become of sufficient importance to require heavy rolling stock. The bridges also should be designed either of the required strength or in such manner that they could be strengthened when necessary. He assumed that trains over light lines would not be run at great speed and in daylight as much as possible, so that fencing to a very great extent might be dispensed with, and as in the case of the Nyngan to Cobar line at the boundaries of property cattle stops which would not allow even a rabbit to pass, could be made across the line. The design of the permanent way must be guided by the description of rolling stock to be run over it or vice versa, and again this would depend entirely on firstly, gradients, secondly, probable amount of traffic, and thirdly length of line, whether a short branch service or the prolongation of a main trunk line with intermittent heavy traffic; if of the latter, it should be of sufficient strength to carry the usual class of rolling stock in use on that line. In any case it would be a fatal error to have the line so weak that only one special class of engine could be run over it as in the event of a break-down duplicate stock must be kept ready. As the tendency in the past had been always for enlarging and not diminishing the weight and power of the locomotives it must be taken as a self evident fact of the beneficial result which has been gained by experience, of having powerful motors.

He was of opinion that for intermittent heavy traffic the ballast might be four inches under the sleeper, and except on sharp curves three inches up the side or seven inches altogether, and on curves of small radii the sleepers should be covered. The number of sleepers taken with the weight of rail must be entirely guided by the weight to be carried on each axle. It was on the item of permanent way where a very large percentage of saving or otherwise could be made. The difference in cost in rails only between a forty pound and a sixty pound was £200 per mile, but with the same number of sleepers the latter would carry double the load of the former, and would therefore allow of steeper gradients if required, and be capable of doing more work, at the same time employing the usual rolling stock. If the light rails were adopted every ten miles would approximately pay the first cost of a light engine to work it for the same amount of money. Yet except under peculiar circumstances of, say a short branch line, it seemed the best policy and the most economical to have at the least sixty pound rails with eleven sleepers for each thirty feet of rail, equal to one thousand seven hundred and sixty sleepers per mile. The author of the paper proposed to use screws only for the joints, they might be dispensed with altogether, the dog spikes being quite as good; he also proposed to abolish platforms, this being done on the Lismore-Tweed railway, but this line was quite isolated at present and carriages were being prepared specially for it. Where the usual passenger carriages were run there must be passenger platforms or the whole of the carriages altered. Waiting sheds could take the place of stations and the expensive items of signalling and interlocking could be very much reduced. The real foundation of economy in making a railway except in flat country was in surveying and laying out the line, fixing curves and gradients. There was no doubt that frequently with a little more care and spending a few pounds more per mile in the survey thousand of pounds might be saved. Both curves and gradients must be guided by the natural features and without imposing any great strain on the locomotive engineers ; curves of eight chains radius and even gradients of one in thirty could be overcome in the future as they had been in the past. Although the author quoted an instance where by the expenditure of £53,000 a saving of about £9,000 a year would result, it must be borne in mind that the £53,000 had to be found, and if this course had been adopted when the line was originally made, the railways of New South Wales would have been kept back ten or fifteen years. It was only the bold stroke of Mr. Whitton, the late Engineer-in-Chief for Railways, of introducing curves and gradients that were then unknown and considered by many to be impracticable that the Colony was in a position to have the railways made, therefore although it might not be the most economical from a purely monetary consideration to have steep gradients at a moderate first cost, yet in very many instances it was better than being saddled with a heavy debt or perhaps have the work retarded for years. There was really no difficulty in making railways at prices from £2,000 per mile for fine weather lines in flat country to good, all the year round, lines at £20,000 per mile in broken country, but there was a strong objection to making lines that required their own special rolling stock and motors. One item of extra expense had always troubled the engineer viz., in not being allowed to lay ont the lines in the best direction. In order to meet the views and interests of unimportant places he was frequently compelled to increase the cost very considerably without receiving an equivalent in the form of revenue, and another item in the past had been the cost of land. Taking for instance the Illawarra line, the first twenty miles from Sydney to Heathcote, including four miles of the National Park cost an average of £7,000 per mile, and at the time the land was resumed there were very few buildings along any portion of the line. The question of gauges need scarcely be referred to as it was not probable that any change would ever take place in this Colony, and in order to reduce the cost of construction they must be content with sharp curves, steep gradients, save a little in ballast, dispense with fencing, and reduce the station expenses to a minimum, as well as private concessions in the shape of bridges and crossings.

Mr. W. Thow in some further remarks, referred to Mr. Higinbotham's opinion respecting the relative cost of five feet three inches and three feet six inches gauges. Either in 1870 or 1871, Mr. Higinbotham strenuously opposed the introduction of the three feet six inches gauge into Victoria. He was almost alone in his opposition to that suggestion, with the exception, of course, of the leading officers of his staff, and no doubt the people of Victoria had to thank him more than any one else for preventing the mistake being made of introducing a mixed gauge into that colony. Mr. Higinbotham had made very elaborate estimates of the relative costs of the two gauges for parliamentary purposes and the small difference between them surprised most people. It was the intention of the Government to extend the main lines then existing in various directions, and the opinion arrived at by Mr. Higinbotham was that so far as those lines were concerned, the increase would not be more than £261 per mile if made upon the five feet three inches gauge instead of the three feet six inch gauge, and he pledged himself not to exceed £350 per mile. His estimates were subsequently supported by the experience of South Australia. At the time that this discussion was going on in

Victoria, South Australia had only one gauge, viz., the five feet three inches, but the three feet six inches was afterwards introduced, and an extension on the five feet three inches gauge thirty-nine miles in length was constructed for £5,427 per mile, including rolling stock and all costs. Another line on the same gauge fifty-seven miles long, which for two-thirds of its distance was a heavy line having grades of one in sixty and one in sixty-five, cost including rolling stock and everything else, £5,600 per mile. Taking the narrow gauge lines which existed in South Australia and which embraced some of the heavier portions, as well as very easy roads through the long stretches of desert, nine hundred and fifty-six miles were constructed at a cost including rolling stock of £5065 per mile. For both these grades forty-one pound steel rails were used.

There was no special effort made to reduce the cost of the lines on either to the minimum, but they were made sufficiently strong, as it was thought, to meet the requirements of the country. It was however, very difficult to estimate the growth of traffic in some cases. One of these narrow gauge lines was built from Port Augusta which is at the head of one of the gulfs in South Australia and it extended to a place called "Government Gums" two hundred miles north. The contractors expressed the opinion and every one believed them at the time, that one train each way per week would carry all the traffic likely to go over the line, but as a matter of fact within two or three years the traffic necessitated as many as nine trains a day to accommodate the carriage of passengers, stores, and live-stock. He agreed with the views of the author of the paper, in his opposition to the introduction of the three feet six inch gauge into this country, and with his proposal to use sixty pound rails for the light lines in New South Wales. There would be no difficulty whatever in making engines flexible enough to suit that road or indeed to suit a lighter road, but it must be admitted that sharp curves and steep gradients, especially when combined, were antagonistic to light locomotive construction. If paying loads were to be hauled over roads of that construction character the locomotive must be powerful and therefore could not be light. The three feet three inches gauge in South Australia was originally laid with forty pound rails, and there were some powerful engines running upon them. The original Liverpool and Manchester road was laid with a thirty-five pound rail, and portions of the English North Eastern between York and the north had for many years forty pounds iron rails. There was really little advantage gained in making a three feet six inches gauge line in point of cost as compared with the four feet eight and a-half inch. It has been shown that the seven feet Great Western gauge in England only cost from seven to eight per cent. more to construct than the four feet eight and a-half inch gauge. The principal saving to be made by adopting the smaller gauge was in cuttings and embankments, and even there the narrow slice of earthwork saved amounted to very little. It has been shown by estimates made that for cuttings or embankments five feet deep the saving was 8·2 per cent., ten feet deep 6·2 per cent., fifteen feet 5 per cent., twenty feet 4·2 per cent., and so on up to fifty feet when the reduction is little more than one per cent. The saving in land required did not exceed one quarter of an acre per mile of railway. With regard to the break of gauge objections, it was quite possible to transfer without much difficulty, the ordinary merchandise and passengers, which could be changed readily; but, of course there was expense incurred in doing it. The greatest difficulty experienced in South Australia was with live stock, the bullocks coming from the north were so wild that when once taken out of a truck at the break of gauge stations it was difficult to get them into another, and that could be only effected by damaging their value considerably through rough usage. To obviate this evil, bogie trucks with duplicate bogies to them, suitable for each gauge were built. At the break of gauge stations the bogies were changed and the cattle brought down to Adelaide over the broad gauge without transhipping. The great objection often expressed to the three feet six inch gauge arose from the fact that the limit of capacity and utility was very early reached. It was found that to meet the circumstances of the South Australian narrow gauge lines the largest cylinders that could be put into the engines were fourteen or fifteen inches in diameter, and when these engines were tested by loading them to their limit and working them at their greatest power at a uniform speed up a gradient, the average maximum power obtained was equal to three hundred and twenty horses at thirteen and a-half miles per hour, whereas in this country there were engines working daily which could give a maximum average power of one thousand and twenty horses at a mean speed of twenty miles per hour. This difference of capacity was something to look forward to in connection with the standard gauge which the three feet six inches gauge could never hold out. It was ascertained by the Great Western Railway of England that the cost of working the seven feet gauge was less than on the four feet eight and a-half inches gauge for equal speeds, but he was unable to say whether that would apply to the three feet six inches gauge. The cost of working in South Australia on the narrow gauge was less than on the broad, but for very different speeds and accommodation. In railway expenditure as in other things, it was speed which killed. One matter that the author appeared to favour in his paper was the abolition of fencing upon light lines. If trains travelled at night, that would in his opinion, be a risky thing to do; for day travel fencing might be abandoned, but during the night and in hot parts of the country cattle are attracted by the cool ballast and frequently trespassed on an unfenced line lying down between the rails and endangering the safety of the trains.

Mr. H. Deane said that the name "Light Railway" was not a scientific term, but a popular one, and it was generally employed in a very loose manner, but was always supposed to imply the use of a minimum of material in structure and permanent way with the minimum of labour in fixing, and light rolling stock. He had heard many people say when asking for a railway in their district, "all we want is a tramway just laid along the road." That however was not how a cheap line could be made. A line laid along a main road must have its surface even with the road and a trench had then to be cut to let in the ballast, sleepers, and rails, and in order to preserve the track in good order for the rolling stock and still allow other wheeled traffic to pass over it, a guard had to be fixed to each rail, and the ballast had to be brought up to the level of the surface of the road, so that the cost of this kind of line was increased by having more costly formation, additional steel in guard rail and additional material and labour in its assorted ballast for the top surface. When completed this kind of railway seldom had good grades, as it had to adhere to those which happened to exist on the roads, which were very likely to be bad ones. The maintenance of such a line was always very costly, for unless the rest of the road was metalled and kept in very excellent repair all the wheel traffic would be attracted towards the tramway on account of the good surface, and the wear and tear would be enormous. As the grades were those of ordinary roads, traffic expenses would be high because the loads would be small. It was clear therefore that it would generally be better to go off the road to find a location for a light railway. The cheapness of such a line must necessarily depend upon the possibility of following the surface with easy grades and curves of not excessively sharp radii. If easy grades could not be obtained without running into cuttings, there would not be much cheapness about it. If the sixty pound rails were adopted as the minimum, then it would be in any case undesirable to use steeper gradients than one in sixty. This was the ruling gradient on the Molong, Parkes, and Forbes line. It was only obtained there with some difficulty. Curves of ten chains radius might be taken as comparatively unobjectionable. This was the radius of many of the curves on the Milson's Point extension railway, and was there adopted in order that the requisite distance to give as flat a gradient as one in fifty, might be obtained. As regards number and kind of sleepers, it was undesirable to put them wide apart, the spacing produced by putting eleven sleepers to the ten yard sixty pounds rail gave a very good result.

As a rule iron bark was the best timber to use, but in some parts red gum or even white box, which were very durable timbers might be employed with advantage. For the cheapest class of line there was no objection to a rough sleeper shaped like a fencing post but stouter, in place of a rectangular one. These would be much cheaper as they could be obtained in some parts of the country at the rate of about two shillings each delivered, in others they would cost more on account of carriage. The quantity of ballast the author mentions would no doubt be quite enough at the outset. He himself had proposed to use for this class of line one thousand two hundred cubic yards per mile, which did not differ much from the author's quantity. The depth under the sleepers would be three inches, but this would have to be added to afterwards. In any case it would not be advisable to lay the ballast direct on the ground as had often been advocated. Such a practice would be contrary to all sound experience in railway or road making, as the formation required draining and it would only get into a state of bog unless a low embankment, even if only a few inches in depth was thrown up. He mentioned this because it had actually been proposed to lay the ballast on the surface over the plains in this country. Those who knew the black soil would never have suggested such a method.

In country where the surface of the ground could be strictly adhered to the cost of such a line would be about £2,000 per mile. He would be sorry to say a word which might lead anyone to think he would advocate the adoption of a different gauge, but he thought that the disadvantage of a break of gauge had sometimes been overstated. There might be circumstances when it would be better to risk the difficulties and inconvenience likely to arise after twenty years, than not to have a railway at all. He was strongly of opinion however that to make any extension or branch of the present system on any other gauge than the standard one would be a fatal mistake. In those parts of the country where light railways, that is cheap railways, were applicable there would be little necessity for curves sharper than, or even as sharp as those he had already mentioned, viz., of ten chains radius, but using the term in a relative sense and calling a railway costing £6,000 or £8,000 per mile, a light railway compared with one costing double those amounts, a great deal could be said about methods by which this cheapness could be obtained. It had been said by the advocates of the Eden-Bega railway, that all they wanted was a light railway. Anyone who knew the district and had any railway engineering experience, was also aware that in such a country a cheap railway was impossible even with a two feet gauge. There were numerous important watercourses to cross and the spurs of the hills were so sharp and steep that it was not possible to go round them with anything like ordinary curves, and constructing with very sharp curves such as of two chains radius, would greatly increase the length of line. The connection of the coast with the tableland had been attempted in several places, but after the most careful surveys it had in all cases been shown that the connecting railways would cost from £12,000 to £20,000 per mile. This was of course due to the rugged nature of the country traversed, and the heavy earthworks, tunnels and bridges necessitated. Were it possible to run curves of five or six chains radius the cost of construction would be greatly lessened, possibly in some cases by one-half, in others by one.third. Mr. Thow had told them how objectionable sharp curves were in the wear and tear they caused to the flanges of the wheels of the rolling stock, but granting this, might it not sometimes be worth while to risk such wear and let the cost of repairs go against the interest saved in construction. Suppose for instance, that by the adoption of sharp curves the cost of a heavy mountain section of a line fifty miles in length could be reduced by £4,000 per mile, thus affecting a saving on the whole length of £200,000, the interest on this sum at four per cent. would be £8,000 annnally, surely this would pay for the turning up of a good many worn out tyres and for keeping a stock of spare wheels in readiness to replace those worn. He thought that this was a matter which deserved much attention from locomotive engineers, especially in a country like this where parallel to the coast for its whole length ran a mountain barrier from two thousand to four thousand feet in height.

As bearing on this part of the subject, he would like to make a few remarks with regard to certain types of engines, but not pretending to be a locomotive engineer he submitted them with all modesty. The Fairlie Engine which he first saw running on the Festiniog line in North Wales, was designed for the double purpose of getting flexibility, for working sharp curves, and of utilising the whole weight of the locomotive for adhesion. The first of this type looked like two engines back to back, and really consisted of two boilers rigidly connected, placed on two bogies provided with separate pairs of cylinders. The improved Fairlie had one boiler and fire box, but the use of the bogies was continued. There was a serious difficulty in connection with all these engines, viz., that of keeping its steam connections tight. High pressure steam had to be conveyed down through the centre pivot to the cylinder, and this was a source of great trouble, therefore it was quite possible that as Mr. Thow said, engines of this type had often been consigned to the scrap heap. There was another type of engine however which seemed more promising, and was doing good work on the St. Gothard, Central Swiss, and other lines, and this was the Mallet type. In this the high pressure cylinders with the main framing were made with a fixed connection to the boiler, while the low pressure cylinders which were placed at the front end on a bogie were made to swivel under the boiler. The steam pipes were said to give no trouble, flexible connections were only required to convey steam of reduced pressure to the low pressure cylinder, and to take the exhaust steam to the blast pipes. On the Central Swiss line tank locomotives of sixty tons distributed on four axles in two pairs were used. On the St. Gothard line locomotives of eighty-five tons on six axles in two sets of three were being run. These must be very powerful machines, as all the weight was available for adhesion, instead of from only fifty-five to sixty per cent. as in the cases of the usual type of engines, and they must possess great flexibility. It followed that by the adoption of a flexible type of locomotive, great economy in railway construction would result, and even if the type were more costly and the repairs heavier, it was a question whether this disadvantage could be said to weigh against the saving in interest on construction, especially when on the other hand the advantage of using the whole weight of the locomotive for adhesion was borne in mind. It seemed to him that only by the adoption of some such type of locomotive could the principles of light railways be extended to rough countries.

Mr. C. O. BURGE in reply, said the discussion had displayed an interest in the subject which had justified him in taking it up, and had amply repaid the trouble taken over it. Messrs. Parkinson and Cowdery both regarded the proposed spacing of sleepers as too wide, the characteristic of the proposed permanent way being comparatively heavy rails and wide spacing. Mr. Parkinson said very truly, that, as the road was weakened in proportion to the *cube* of the spacing, but only to the *square* of the weight of rail, economy would point rather to reverse the process, increasing the sleepers, and reducing weight of rail. Now, looking into this matter in its practical light, which Mr. Parkinson apparently had not done; with two thousand five hundred sleepers, as he suggests, he could have the same stiffness as proposed in the paper with twenty-nine pound rails, and the cost would be reduced by £100 per mile, justifying his theory so far, but, having put the £100 in his pocket, he would find that during the ordinary life of a sleeper, he would have to renew nine hundred and sixty more sleepers, the capitalized cost of which would amount to over £200, so he would have made a loss, so to say, to begin with; then he would have only half of the material for rail head wear and tear, and lose the easiest means of strengthening the road afterwards, according to increase of traffic, which should be one of the main characteristics of any proposal for light lines.

Mr. Cowdery followed by stating that he had found, presumably with the same axle weight and rails and other conditions, that a saving of maintenance took place with more sleepers. Of course it did, it was a truism—but this was not the question. The question was, having to lighten your railway, presupposing decreased axle weight and decreased speed, what was the best way to do it? It had been shewn in the paper that what was proposed as regards stiffness in the road, bearing surface, and fastenings, had been actually for years in successful operation elsewhere under similar axle weights. It was not a theoretical proposal. And, in proportion to axle weight, the proposed railway was a heavier one, and therefore lighter for maintenance than most existing roads. It may be mentioned here, that, in proportion to its duty, which must always be kept in mind, the total weight of the proposed road, including sleepers, was high in comparison to existing ones. The London and North Western road with heavy axle weights and high speeds, weighs, per mile, three hundred and forty-four tons; the New South Wales present lines with about sixteen tons axle weight, weighs two hundred and eighty-two to three hundred and eighty-four tons; the Madras Railway, main lines, with twelve tons axle weight, weighs two hundred and sixty-nine tons; Cape railways, main lines, eight tons axle weight, weighs one hundred and twenty-six tons; proposed light branches, eight tons axle weight, weighs two hundred and twenty-six tons. The inertia of these weights in proportion to the duty, which is greatly in favour of the last, had an important effect on cost of maintenance.

Mr. Vandevelde was an able advocate of the introduction of the two feet gauge into the Government railway system of this Colony, and he has shewn his wisdom in keeping clear altogether of the break of gauge question, which was the only objection to that system raised in the paper, or in the opening of the discussion. Since the paper was read, Mr. Burge had ascertained that transhipment costs in France four pence per ton, with labour at two shillings and seven pence per day, sevenpence therefore, estimated in the paper, p. 72, as the cost here of transhipment, might have been considerably increased.

Mr. Vandevelde's figures as to the cost of two feet lines in France, allowing for the difference in rate of wages, agreed closely with the £880 per mile saving in first cost over standard gauge lines estimated by Mr. Burge in opening the discussion. Mr. Vandevelde had asked him if he would advise now, that the Festiniog line should be altered to the standard gauge, evidently thinking that he was hostile to the smaller gauges, whereas his hostility was only to the *mixture* of them. He should not only oppose the change he refers to, but would probably adopt the two feet gauge if the line had to be made anew. Besides a small tourist traffic, the great business done was conveying slates from the quarries to the seaport. When he was engaged on it, there were eight hundred and fifty trucks specially made for slates, out of a total of eight hundred and ninety-two, weighing thirteen to nineteen cwt. each, and carrying two to three tons of slates, a ratio of dead to live load impracticable for this heavy material in the wider gauges; there was no connection with any other line, and if there was, there could be no interchange of traffic, as it was crowded to its utmost capacity in the conveyance of slates from quarry to port. There was no analogy whatever in this to New South Wales branch lines generally, and the reference only showed the mistakes which might be made by founding arguments on conditions essentially different. The paper was not on light railways generally, but on light railways for New South Wales.

The remarks of Mr. Thow, from his experience as head of the Locomotive Department in New South Wales, and formerly in South Australia, carried great weight. There was no difficulty as regards the engine question for the flatter country. It was where heavy grades and sharp curves occur, to obtain light construction that locomotive engineers hesitated about meeting them. Mr. Thow would see, on looking at the paper again p. 59, that Mr. Burge did not ignore, as he thought, the difficulty of combining flexibility and adhesive length, nor, in the previous page, that extra complication of parts and increased expenditure for repairs would have to be faced. The question was not between good and bad types of engines, as to which no one in the Colony was such an excellent practical authority as Mr. Thow, but what would make the best balance sheet on the whole Government expenditure in the matter; in fine, was it not better to incur extra annual repairs on special type locomotives, than to pay more than that annually in interest on expensive construction, to accommodate superior engines? It was a matter for calculation, and he had no fear of the result, and others would, he thought, agree when they considered it in this way; on the Western main line, mountain section, for instance, which had excessive curvature, there was probably twenty-five to thirty engines passing daily over every mile. It was obvious that large expenditure was justified there, in making things easy for them, and cutting out curves, every curve telling on that number of engines daily. In the lines now considered, probably two engines would be the daily average, whereas the cost of such improvement to a main and branch line would, *ceteris paribus*, be the same. Again, one of the helps against curve resistance—superelevation—could only be fixed for one average speed, and on the main line great varieties of speed were unavoidable, from slow goods to fast expresses. On the light branch, the one or two mixed trains daily could be at uniform speed generally, and superelevation could be fixed to that speed.

The English locomotive was one of the most magnificent machines the world had yet seen, and he quite understood the reluctance with which one, like Mr. Thow who knew them so well, would see admittedly inferior types in one respect—complication—preferred, but he did not think the development of the country by light lines should be retarded, because, by a transfer of expenditure favourable on the whole to the Government, it should fall on one branch rather than on another. Mr. Thow, he was sure, had no such narrow view, though he might not agree with Mr. Burge in expecting the results to be as favourable as he did.

Professor Warren quoted from Professor Bowes that it was a safer plan to make a line light at first, strengthening gradually as might be required, rather than to make it equal to a standard, the necessity for which might never be reached, and from which there was no drawback. Assuming that it was done with judgment, he entirely agreed with this, and thought, especially when money was getting dearer, that they might take a lesson from America in this respect, though without going to her extremes. As to the transition curves mentioned by Prof. Warren, they were already provided for in all the later construction and surveys in this Colony, on the principle of the cubic parabola, the practical application of which was brought before the Royal Society a few years ago by Mr. Walter Shellshear, M. Inst. C.E. They were therefore not mentioned in the paper. There is no doubt that they would reduce the severity of sharp curvature in a high degree.

Mr. Rennick, whose high authority as Engineer-in-Chief for Railways in Victoria, added much to the interest of his contribution, paid, unconsciously, a great compliment to the paper, as though he had not seen it when he supplied the information which had been now read, he agreed with the conclusions of the paper mainly, especially in the matter of maintaining at least a sixty pound rail, going as far as five chain curves and shewing that light lines are everywhere possible without meddling with the gauge.

Mr. Trevor Jones' information as to what decision had been arrived at in Victoria, on this matter, and the grounds for it, some years ago was a very valuable addition to the paper.

Mr. Fischer and other speakers questioned the wisdom of the wide spacing, and of the small depth of ballast suggested, but the reduced axle weight must be had in view, and though some definite figures must be put forward in a proposal such as that in the paper, these must not be supposed to be unalterable. Where good timber was plentiful and ballast was scarce and vice versâ, modifications might be made to suit, without violation of the general principle.

Mr. Middleton, who spoke as a locomotive engineer, said, Mr. Burge was glad to see that there was no difficulty in designing an effective engine to meet the requirements set forth in the paper. Mr. Middleton thought that narrow gauge proposals should be considered with regard to extensions, where it was a question of narrow gauge or nothing. This is a frequent argument, but rested on false premises in this case. Mr. Middleton had not had the opportunity of hearing the author open the discussion, when he was enabled to show that where change of gauge occurred, the ultimate cheapness, on which this argument rested, did not exist.

Mr. Firth objected to any line which main line engines could not run over without danger, and also to the proposed omission of platforms. These were admittedly defects, but a mechanical device might easily be contrived to prevent a heavy engine going on the branch, and if they were to have cheap lines they must do without many conveniences, of which platforms were one. They were rarely used in America.

Mr. Thow thought fencing should not be omitted when there were night trains, but such branches as were now in view were not likely to be used at night. Should the traffic become so important as to necessitate night trains, the light railway would become a heavy one, when this and other things would be added.

Mr. Burge was glad to have the high authority of the Engineer-in-Chief for Railways, Mr. Deane, generally in accord with the principles advocated in this paper, with the important exception of the sleeper spacing,—but it must not be forgotten that this is based entirely on the limitation of the axle weight to eight tons, and, as regards support, was surely justified by long experience in the Cape, where, even in main lines, the same weight was supported by the same area as now proposed. He thanked the Society for the close attention they had given to this paper, and for the valuable additions they had made to it in the discussion now closed.

THE TREATMENT OF MANUFACTURED IRON AND STEEL FOR CONSTRUCTIONAL PURPOSES.

By WM. FIELD HOW, Assoc. M. Inst. C.E., M. I. Mech. E., Wh. Sc.

[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

DURING the execution in Great Britain of contracts for the New South Wales Government and other large purchasers of material and works of various descriptions, the author had to deal with constructional work built of iron and steel, and this paper has been prepared with the hope that members of the Royal Society of New South Wales will be interested in matters relating to some of the methods adopted by firms of the highest repute, when executing such contracts in accordance with strict specifications and instructions.

No attempt is made to describe the manufacture of the iron and steel, that being entirely beyond the scope of this paper, rolled material and the treatment to which it is subjected only being considered.

WROUGHT IRON.

Wrought iron is largely used for the manufacture of light girders, roofs, &c., owing principally to the fact that the superior strength of steel cannot be taken full advantage of by using thin plates, angles, channels, &c.; as those details are not at present rolled from that material of the small dimensions required, unless at a considerable extra cost. Again, in some instances, thicker plates than actually required are used to ensure rigidity in light structures.

It is therefore cheaper in such cases to use the thicker iron, which also possesses an advantage where oxidation occurs to any extent. The loss by rust of iron and steel being practically the same, the percentage of reduction of the effective strength of the thinner steel plates would be greater if that material were used.

Good iron is more reliable than steel where much forging of the rolled material is required, and it is undoubtedly preferable to use it for details that have to be welded. Again, iron being structurally of a laminated character, it is but slightly injured by punching and shearing.

Owing to the fibrous formation of wrought iron its strength across the length in which it has been rolled is generally considerably less than in the direction of the length of the plate, bar, &c., and care has to be taken that the rivets in long and comparatively narrow details, such as the webs and tie bars of girders, are kept well from their edges and ends.

The author has found from experiments that in iron work, where the ultimate tensile strength and elongation in the lengths of the web plates of iron girders have been twenty-two tons and twelve per cent. in ten inches respectively, specimens cut from such webs at an angle of forty-five degrees (that is, in the direction in which the stresses from the tie bars act), possess a tensile strength of nineteen tons per square inch, and only 6·8 per cent. of elongation in a length of five inches. Such specimens have broken across in the direction in which the iron has been rolled.

When the stress has been directly at right angles to the length of the plate, the ultimate tensile strength was only eighteen tons per square inch, and elongation four per cent. in five inches.

Mild Steel.

During recent years, so much progress has been made in the manufacture of mild steel, that it can now be produced having a tensile strength and ductility of surprising regularity, and owing to its uniformity in these respects and great tensile strength, it is being rapidly adopted by the most eminent Engineers for the construction of bridges, roofs, boilers, etc.

Steel has the advantage of possessing the same tensile strength and elongation with and across the length of the plates, and it will be readily understood that this is especially valuable in many cases of constructional work.

It is of the greatest importance that material of a ductile and reliable character, such as mild steel, should be used in the manufacture of bridges &c., because no matter how carefully the design may be prepared, some unforeseen events may arise, such as a slight movement in the foundations &c., that will throw greater stresses than were anticipated upon some member of the structure. As an instance of this, the author has known of cases in Australia where the outside tension members in the bottom boom of a truss girder, have had to be protected from the sun's rays, by boarding; as they became bent owing to their expansion by heat, and stresses they were designed to carry, were thrown upon the adjacent and similar members.

There are two descriptions of steel largely manufactured for constructional purposes; one generally termed the "Siemens Martin," and the other known as the "Open Hearth Basic." The former is made by the open hearth process from high-class hematite iron practically free from phosphorous; and the latter by the same process from iron possessing an amount of that element which would produce cold shortness in the finished material if it were not eliminated in the furnaces during the process of manufacture. The former, or as it is frequently termed, open hearth steel made by the "Acid Process" is in the best practice, specified for boiler plates where steel is used, and steel produced by both methods is employed for bridges and works of that character.

Tests.

The following are the tests usually required by some of the best known British engineers, for iron and steel for bridges, and steel for boilers.

Iron for Bridge Work.

	With length of Plate.		Across the Plate.	
	Stress per sq. in. without fracture	Ultimate Elongation in 10″.	Stress per sq. in. without fracture	Ultimate Elongation in 10″.
Plates	22 tons	10 °/o	18 tons	3 °/o
Angles, tees and flat bars ...	23 tons	12 °/o		
Rivet and bolt iron	24 tons	15 °/o		

The iron plates and bars must also be capable of being bent cold, without signs of fracture, to an angle of forty-five degrees, the radius of the inner angle being not more than twice the thickness of the plate. The rivets must be capable of being bent double, when cold, without signs of fracture.

Steel for Bridges.

The steel for bridges must be manufactured by the open hearth process, and have an ultimate tensile strength of not less than thirty tons or more than thirty-three tons per square inch, with an elongation of at least twenty per cent. in eight inches.

Strips cut lengthwise or crosswise, one and a-half inches wide, heated uniformly to a low cherry red, and cooled in water at eighty-two degrees Fahr. must stand bending in a press to a curve of which the inner radius is one and a-half times the thickness of the steel tested.

Steel rivets must be capable of being bent double when cold, and also after having been heated to a low cherry red, and quenched in water, the water having a temperature of eighty-two degrees Fahr.

Steel Plates for Boilers.

The steel plates for boiler shells are to be manufactured by the open hearth process from hematite ore, and must have an ultimate tensile strength of from twenty-six to twenty-nine tons per square inch, with an elongation of not less than twenty-five per cent. in eight inches.

Strips cut lengthwise and crosswise, one and a-half inches wide, must stand being bent in a press to a curve of which the inner radius is one and a-half times the thickness of the plate, and similar pieces must stand the same test after having been heated uniformly to a low cherry red, and cooled in water having a temperature of eighty-two degrees Fahr.

Some engineers, instead of the first bending test described, stipulate a "punch test," and in the case of an ordinary locomotive boiler plate, require strips to be cut from it, three and a-half inches wide, having a five-eighth inch hole drilled in it equidistant from the three edges at one end, which must withstand being drifted to one and five-eighth inches without fracture.

For steel boiler flues the same bending tests are required, but the ultimate tensile strength is kept between twenty-four and twenty-seven tons per square inch.

The tests of iron for boilers are omitted, as the requirements of engineers, with regard to the strength, ductility, and brands of material used, vary considerably, but it may be mentioned that three classes of iron are frequently adopted, namely: "Best Yorkshire," for the furnaces, "Flanging Plates," for the ends, and a less expensive quality for the shells.

Many locomotive boilers are still manufactured entirely of best Yorkshire iron, which material can certainly have the holes made in it by punching, and the forged portions can be safely dealt with by workmen who have not the special knowledge of the proper treatment required by steel during and after forging; but this knowledge is now very general, and it is becoming the practice of most of the highest locomotive authorities to make boiler shells of mild steel, costing about one-half the amount of Yorkshire iron, and as it is at the same time, of a more uniformly strong character and free from laminations, it is believed, that in the near future, steel for locomotive boilers will be universally adopted.

When specifying tests for material, it is most usual to state the "ultimate tensile strength" and "elongation" required, but in some cases the "tensile strength" and "reduction of area" are stipulated. It is not advisable to state the tensile strength per square inch and elongation, and also the reduction of area, as this only creates indecision in the minds of the inspecting officers.

For instance, if any particular metal will withstand the required number of tons per square inch, and elongate the stipulated amount, it would be unwise to reject such iron or steel if it were not to give the required reduction of area. Yet this occasionally has to be done if the inspecting officer is not at liberty to exercise his own judgment, or cannot readily communicate with his principals.

In dealing with the results of tests, engineers usually take the whole of the results into consideration, before accepting or rejecting iron or steel, and their decision is guided by the purpose for which the material is to be used.

As an instance; if it be specified that certain bridge iron shall withstand a stress without fracture of twenty-two tons per square inch, and elongate ten per cent. in ten inches, they would not hesitate to accept it if the tests showed that the specimens broke under a stress of 21·5 tons and elongated fifteen per cent. in the ten inches. Yet this iron, which is really of a more reliable character than that stipulated for, would have to be condemned if the specification were literally adhered to.

The test of tyres is also a case in point. These portions of a wheel are usually required to stand being deflected by blows from a falling weight until they are bent one-sixth of their internal diameter, and pieces cut from them are required to have a tensile strength of from forty five to forty-eight tons per square inch, and elongate not less than ten per cent. in two inches. Now, if the tyre deflects the required amount, surely this is a sufficient guarantee of its ductility, and it is exceedingly hard upon manufacturers to have numbers of such tyres rejected simply because the required elongation has not been recorded by the tensile testing machine. There are many other instances of daily occurrence where material has to be condemned which capable supervising officers know to be perfectly good and reliable, and suitable for the purpose intended.

Where falling weight tests are not required, the elongation is, in the author's opinion, the best criterion of the ductility of material, because the metal that has given a good extension generally shows that it must have stretched fairly over the whole length of the specimen before the "yield" point was reached; whereas, a piece of an irregular character might have a soft place in it which would give a great reduction of area at the breaking point, but the other part of the bar might be hard.

When tests are to be made from steel boiler plates the most strict specifications require six strips to be selected from the rolled steel before it is sheared to its required size, viz., three with and three across the length of the plate. Two of these, one with and the other across the length, are tested by tensile stresses, two by cold bending or some other experiment such as punching and drifting to ascertain the ductility, and the other two by bending cold after having been heated to a cherry red and quenched in water having a temperature of eighty-two degrees Fahr. Should the specimens so tested comply with the specification, the plate is accepted.

This apparently large number of tests is insisted upon to provide against the possibility of a brittle steel plate being used in the manufacture of a boiler, but from the material to be used for the manufacture of bridges, roofs, and work of that character, it is usual to test only a limited number of specimens taken from plates made from the same cast of metal.

With regard to the specified tests for bridge plates; the tensile specimens being cut from the plates and tested in the exact condition in which they are to be used, ensures the character of the metal being correctly ascertained as regards its ultimate strength and ductility.

If all the strips were heated and quenched, and then tested, a plate that might have been worked when too cold, viz., at a blue heat, would, by the heating and quenching process, become annealed, and after having been so treated, both tensile and bending tests would be satisfactory.

If the plate be hard, a high tensile result and low elongation would be obtained and consequently show the material to be unsuitable for constructional works.

Elastic Limit.

When testing a specimen, under a certain stress the metal will sensibly yield, and this "yield point" may, for all practical purposes, be considered to be the "Limit of Elasticity," and is recorded as such by many experienced experimentalists; but it is well known that the term "Limit of Elasticity" should be applied to the lowest stress to which a specimen can be subjected without creating a permanent set, and this is reached before the yield point.

Material used for constructional purposes should have an elastic limit of at least twice the stress the member is designed to carry, but it has been found from experiments that if material is loaded frequently, its elastic limit and ultimate tensile strength are increased, and it is not, therefore, actually dangerous should the stresses occasionally exceed the original elastic limit of the material, but it is not advisable to so strain iron or steel, as by so doing, its ductility is decreased.

Ultimate tensile strength and elongation appear to be sufficient recommendation of iron and steel for constructional purposes; a high elastic limit can be obtained from hard and brittle material. In fact, the elastic limit varies with the treatment to which the material or specimens have been subjected before testing.

Considerable inconvenience has been caused by some engineers adopting different standards of length in which to ascertain the elongation of specimens. Mr. David Kirkaldy, the pioneer of scientific mechanical testing, introduced the system of taking the elongation in a length of ten inches, and this was generally adopted until mild steel began to successfully compete with iron, when for some reason unknown to the author, eight inches became to be considered the correct length for a specimen of that material to be put under tensile stress.

Some people do not understand that the length of the specimen is of the greatest importance in recording the extension, and omit to state the length in which the elongations have been taken.

To obtain some idea of the difference in the percentages of elongation with specimens of various lengths, the author had samples cut from two bars of steel. From each of these bars, pieces were cut of suitable lengths to enable specimens to be turned from them, having lengths under tension of ten, eight, six, five and two inches, and the results are attached hereto. Each of the specimens were marked off in inches, and the percentage of elongation was taken in the total length and also in the two inches at the point of fracture, as per sketch.

These results have been of use upon many occasions, but they can only be considered to give general information. To obtain very accurate and more reliable data, a series of such tests should be carried out; but, as indicated, they have proved of service where an elongation in a length of, say five inches, has been recorded, and it has been desired to obtain some idea of the elongation of similar metal in a length of eight inches.

The author would suggest for the consideration of Professor Warren, who has such admirable testing plant at the University, the advisability of carrying out a number of experiments in this direction.

It has been proved that when specimens of the same material are being tested, the percentage of elongation is exactly the same until the maximum load the sample will carry has been reached, no matter what the length may be. They then begin to fail and generally elongate at one point. It is due to this local elongation that the recorded results vary so much in the different lengths under stress.

It will be noted that the breaking strength of the specimens two inches long, was greater in both cases than in the other samples and that the elongation was less when it was taken in two inches than in the longer bars. These results surprised the author until it was explained to him that very short lengths of fair diameter, such as the samples referred to, invariably give higher tensile results than is the case with longer test pieces from the same material. This is considered to be due to the close adjacent sides supporting the metal in the short samples, and it has been found that if holes be drilled in a straight line across a plate, the metal of which has a certain tensile strength, the strength of the plate across the holes is not reduced in proportion to the sectional area removed, but, owing to the fact referred to, is about ten per cent. greater.

Owing to the circular form of tyres, it is not, in many cases, possible to machine pieces out of them that would permit of a greater length than two inches being under tension, and as the test specimens are usually ·25 inch in area, the high tensile strength and low elongation recorded are no doubt different to that which would be obtained if longer lengths were possible, and one would naturally think this would be the case from the manner in which such tyres bend and stand shocks under the falling weight tests.

As the tensile and bending qualities of iron and steel have a distinct relation to each other, engineers who have had practical experience in the testing and examination of material, can obtain a fairly good idea from the behaviour of the iron and steel when bent and from the appearance of the fracture, if it is likely to stand the specified tensile tests. Such bending tests afford a ready means of judging, at the site of delivery, if material supplied is equal to that ordered and suitable for the purpose intended. Bending tests should not be carried out by people inexperienced in the proper treatment of iron and mild steel. Such persons, through unreasonable treatment and faulty preparation of specimens, cause the material to break when bent through very small angles; and again, it is possible by sharp and repeated blows to cause iron to break with a crystalline fracture, whereas, if it were treated more kindly, it would have a fibrous and satisfactory appearance.

To show the different fractures of good, bad, and indifferent material, the author has had specimens placed upon the table for the inspection of those members who have not had opportunities of observing such fractures.

It is occasionally desirable to obtain some idea of the quality of material, such as rolled joists used for building purposes, when it would be too costly and inconvenient to cut any of them for the purpose of obtaining specimens sufficiently large for tensile tests. In such cases it is recommended that some tests be made by bending and breaking the corners of the top flanges, in the manner shown on some of the samples, and this would not usually interfere with the fixing of the girders, or impair their strength. Iron joists are frequently rolled from brittle and dangerous material, and it is particularly important to architects who use them to a very considerable extent, that such simple tests as have been described should be carried out.

The author believes that, as a rule, architects do not take sufficient care in ascertaining the quality of the iron and steel of the girders they purchase, but rely upon the statements they receive regarding it from the importers. It is certain that they would be exceedingly cautious if they were aware of the very inferior character of some of the iron joists that are supplied, especially those made on the Continent of Europe.

With regard to the bending tests of plates &c., required by the specifications, the engineers who carry out such tests usually provide themselves with a sheet of paper upon which to place the specimen and scribe round it with a pencil directly signs of fracture are noticed. It is then usual to continue to bend the sample until the two halves are about to separate, when another scribing is taken within that first made, and thus a record of the bending tests is kept.

Records of bending tests are, however, never so reliable as those made by an accurate tensile testing machine, where the treatment of the prepared samples cannot be varied as they may be by the different operators when the bending experiments are carried out.

Preparation of Test Specimens.

Care is required in the preparation of specimens for testing purposes, and particular attention is given to the selection of samples from plates, bars, &c., to see that they are free from flaws. The selected pieces are then cut out by a parting tool, or, if more convenient, punched out, and the punched portions planed off about one quarter of an inch beyond the edge of the punched holes. This is especially necessary in dealing with steel plates.

The samples should not be sheared from the plates, as it invariably distorts the pieces and makes it necessary to straighten them before they can be tested; and although this straightening is of little moment in the case of bending tests, it is not advisable in any case to distort the material to be tested, by hammering it before the experiments commence.

Specimens for tensile testing are most carefully prepared. The edges are usually milled, and when finished, no roughness is permitted to provide starting points for fractures. This is particularly avoided in the case of experiments with steel. The points between which the elongations are to be taken are of a very light character. When deep centre punch marks are made in specimens of steel, they really constitute flaws. Not only should deep marks not be made in specimens for testing purposes, but brands of only the very lightest description should be made upon finished steel articles such as tyres, axles, &c.

As the experiments are to ascertain the qualities of the steel proposed to be used in a structure, it should be tested exactly as it is cut from the material, and in the case of plates, flat bars, &c., no planing of the surfaces or annealing is permitted. If the pieces are annealed the character of the material is altered, the tensile strength being reduced and the elongation increased. Consequently they would bend better than the plates from which they were cut, and could not be a criterion of the material proposed to be used.

For tensile tests it is usual to keep the sectional area of the sample as near a square inch as possible, but it is not advisable to test wide widths of thin plates &c., because the stress is seldom uniformly distributed over such specimens, and then fractures will first commence from one edge, unless special precautions be taken with the grips or other means employed to hold the sample.

The usual method of fixing a specimen cut from a plate or bar in a tensile testing machine, is by means of two taper wedges provided with serrated teeth on the faces placed next to the specimen, and it is of great importance that these serrated wedges should be perfectly accurate and that the portions of the specimen they grip be quite parallel. Otherwise, a bending stress is thrown upon the sample, one side of it will be strained to a greater extent than the other, and in such cases, it is natural to suppose that the fracture will first take place from the side subjected to the greater stress. Strips of plate to be subjected to bending tests, have the edges planed as previously mentioned, and the edges are carefully rounded at the corners. If this removal of the angles is not carried out, cracking will commence at the sharp corners and rapidly extend across the pieces of plate, whereas the samples will bend through an angle of many more degrees if the edges are taken off.

When in England, the author had brought before his notice some bending tests that were carried out upon a mild steel plate one and one-eighth inch thick. A specimen sheared from the plate broke like cast iron when bending was attempted, but a sample cut from the same plate bent in a most satisfactory manner after it had had its sheared edges planed off and the sharp corners rounded.

With regard to the number of tests required, that is usually decided by the engineer. In a light structure, composed of few bars and plates, the number would be limited, but in larger works where there are many similar members, a greater number of tests are made. It is not possible, in constructional work, to stipulate the percentage of tests as is done in the case of tyres, axles, and such like details.

Manufacture.

Before the material is dispatched to the bridge yard, manufacturers frequently arrange to have it inspected at the rolling mills by a reliable man who will carry out tests, and if it complies with the specification, he will carefully examine the plates &c, to see that they are free from flaws, that they have been carefully and truly sheared, that their dimensions are correct, and that their weights do not exceed the permitted deviation, which is usually two and a-half per cent. above or below the calculated amounts. Payment is generally made upon these weights, unless some arrangements are made.

The inspection to ascertain the weight of material is of importance, because if the manufacturers are to be paid by weight and no estimated quantities are to be worked to, the plates are frequently rolled "full," the result being that the girders &c. made from them exceed the engineer's estimates. This is an advantage to the manufacturers if the actual weights are paid for, but a loss to them if only a small deviation from the estimated weights is permitted.

The plates, with the results of the tests, are sent to the bridge manufacturer's works, where other tests are usually required by the engineer to confirm those already recorded, and if the tests carried out at the rolling mills are confirmed, the manufacture of the work is allowed to proceed.

Plates of large area are always slightly thicker at their centres than at their edges, owing to the bending of the rolls, and this is particularly noticed in thin plates where it is desirable to keep down the total weight of manufactured articles, such as gas holders for railway carriages, and at the same time ensure a maximum strength at the welded joints by keeping up the thickness of the edges.

The chief officials in good firms are invariably anxious that no material shall leave their works that will not give perfect satisfaction and reflect credit upon the works over which they have charge; but the workmen, who would be blamed for turning out a quantity of faulty material, naturally endeavour to dispose of it when made, and it is, therefore, advisable to employ an inspector who has no connection with the works, and who is perfectly independent with regard to giving offence to any of the works contractors, and who will do his best to see that no faulty material leaves the rolling mills for his employers.

Steel requires to be most rigidly examined for flaws, because, owing to its homogeneous character, a defect would cause a fracture in that metal which would only extend a short distance in iron. Steel is therefore rejected for defects that would be passable in iron. The harder the steel is, the more closely should the inspection for flaws be carried out, and in such articles as rails, where the steel has a breaking strength of about forty tons per square inch, they are not accepted if they have defects that have a sharp appearance or of such a form that would start a crack.

All plates, bars, &c., that may have been bent in transit are straightened either by rolls or press. None of them should be warmed; the smiths term this "taking the chill off," but by so raising iron or steel to what is termed the "blue heat," about six hundred degrees Fahr. and then working it at that temperature, the character of the material is altered and it becomes brittle. This is especially noticeable in steel. Again, iron and steel both deteriorate if heated to too great an extent, and if iron is made too hot and burnt, it becomes both "red short" and "cold short." Steel is more easily injured when raised to a high temperature; and the harder the steel the greater the injury; and not only does the raising of such material as tool steel to a high temperature permanently alter its character and make it "cold short," but if the heat be lower than the burning point and is maintained for a considerable time, the same injury is effected.

In high class bridge and boiler work, the plate edges are planed, and although this is not very necessary for wrought iron flange plates for bridges, yet it adds greatly to the appearance of a structure, and is usually specified when well finished work is required.

For bridges made of steel, it is of the greatest importance that the plates and bars constituting the tension members should be planed or have rolled edges; because such members, if left sheared, constitute a real weakness, and it would be far better to plane up any sheared edges that might otherwise exist and so slightly reduce the effective sectional area, than permit the sheared edges to remain, having starting points of rupture due to the slight initial cracks caused by shearing, which are so serious to steel subject to tensional stresses.

It is usual to have all plate edges in a steel bridge planed, as well as the butting surfaces; but the planing of the longitudinal plates in the compression members is not of great importance. It is, however, invariably insisted upon for work of the best character on account of the improved appearance it gives.

For built up iron girders used by architects, it is not necessary to have expense incurred in planing the plate edges, as such girders are seldom exposed to the sight; but if steel plates are used in their construction, it is of great importance to the strength of independent girders, that the edges of the bottom flanges should be planed, and if the girder be continuous, the edges of both top and bottom flange plates should be machined.

For boilers, all plate edges are planed, whether the material be steel or iron; and when lap joints are employed, the edges have an angle of about seventy degrees, to enable the plates to be "fullered" both inside and outside, special attention being given to the inside.

Caulking used to be adopted for completing joints in boilers, in which case a tool, somewhat similar in shape to a cold chisel, but instead of having a cutting edge, that end was made about one quarter inch deep and was driven into the edge of the overlapping plate of the boiler shell, closely against the outer surface of the adjacent shell plate, with the effect of temporarily stopping leaks, but permanently separating the two plates between the rivets and edges. To provide against this defect, deep flat ended or deep convex ended tools are used, which, when driven against the planed edges of the plates, force the bottom surface of the outer plates to bear, within some little distance from the edge, against the adjacent ones, instead of tending to force them apart as is the case when the old fashioned caulking tool is used.

Rivet Holes.

For cheap bridge work and ordinary builders' girders built up of wrought iron plates, and wrought iron joists, or wrought iron plates and angles, the rivet holes are usually made by punching, and if carefully done the material is little injured; but if the holes are carelessly made, then very rough treatment is required to enable the rivets to be passed through them. In such cases of careless workmanship, the workmen have to use drifts having a long and acute taper, and the author has seen such drifts used; with satisfaction to the workmen; when they have been just able to see daylight through the holes in two or three thicknesses of plates.

Punched holes should in all cases be marked off from carefully prepared templates, clamped over the plates or bars to be dealt with, and a centre punch used, the body having nearly the diameter of the hole in the template. Accurately punched holes are made by nipple punches, care being taken that the plates &c. are adjusted so that the projection or nipple, enters the centre punched holes in the plates. This system is adopted in the best works in England and on the Continent of Europe, where the work is treated with so much care, that the author has seen girders having as many as four thicknesses of five-eight inch plate and an angle iron, so truly punched that at first sight they appeared to have been drilled.

The dies at the works referred to are carefully made and attended to, and have such little taper in them that the punchings are almost parallel, the taper being hardly noticeable with the callipers.

Many manufacturers of rough girder work make a wooden template of doubtful accuracy, through which they make a circular white mark upon the plate or bar to be punched, and the material so marked is guided by a workman under the flat ended punch, and it depends upon the experience of the workman in adjusting the plate, if the punch makes the hole in the place required, or not. In such works no time is lost after punching one hole in throwing the punch out of gear and adjusting the plate for the next hole. The plate is simply moved forward, and if it is not in the right position when the punch comes down, the hole is made in an incorrect place.

In steel plates all holes should be drilled, but if the steel be of a mild character, such as is used for constructional work, they may be accurately marked off, punched small in the manner recommended for iron plates, and then drilled out to the required finished sizes, the largest diameter of the punched holes being three-sixteenths of an inch less than the finished sizes. In steel of a harder character, such as is used for permanent way rails, drilling out of the solid should invariably be adopted.

To roughly ascertain the effect of punching some of the New South Wales Government seventy-one and a-half pounds steel rails, the author had pieces, each six feet long, cut from the same rail. One of these pieces was tested as cut from the rail; the second piece had a one and one-eighth inch hole drilled through the centre of the web in a similar position to that occupied by a fishing hole; and the third specimen had a hole of the same size and in a similar position punched through it. When these pieces were placed upon bearings three feet six inches apart, with the holes adjusted directly under the drop, the first and second pieces, being without hole and with hole drilled, respectively, withstood three blows from a ton weight falling six feet, followed by two twelve feet blows from the same weight, and the deflections in each case were practically the same; whereas, the punched specimen broke under the first blow and after the ton weight had fallen upon it from a height of only two feet. This experiment, which was carried out upon pieces cut from several rails and always with practically the same result, shows how dangerous it is to punch holes in any position in steel if it be at all hard.

The falling weight test described—modified to suit varying sections—is invariably applied to rails, and is the most reliable that can be adopted to ascertain the capabilities of such material to withstand the jars and shocks to which it will be subjected when in use. The amount of deflection under the blows readily informs the inspector of the quality of the rolled steel, and if the deflection is too great, the steel is too soft and has inferior wearing properties. With tyres and axles, as their dimensions vary considerably, the hardness of the material is usually ascertained by carrying out tensile tests after the falling weight experiments have been performed. Although these remarks relate to material that is not used in constructional work, the author has referred to them, as he thinks they may be of interest to some members.

Reverting to constructional work; in dealing with plates for boilers, after having been planed, they are bent by small increments at a time to the required curvature and not in one operation, as such treatment is unfair and injurious to the material. Small holes are then made to bolt the work together and the rivet holes drilled out of the solid and through the plates when coupled together.

For wrought iron boiler shells, the plates are frequently punched before being bent, but this is not a good practice, as a flat place is formed at the ends of the plates due to the metal bending more readily at the punched holes, and the joints are not, in consequence so perfect as they would have been had the plates been bent before the holes were made. With regard to the flanged ends of boilers, the best practice is to form them by hydraulic pressure and to thoroughly anneal them after forging. This annealing is especially necessary if any of the forging &c. is done by hammer. Angle and tee stiffeners for girder work are also best manufactured if bent in presses or under a hammer having suitable dies.

In dealing with large forgings, such as crank and propeller shafts, the plan now adopted in the largest English works is to use hydraulic squeezers, which takes the place of the hammer and treats the metal in a more satisfactory manner. The effect of blows from a hammer upon a mass of metal such as a shaft, is felt principally upon the outer surface, and this is shown by the ends of the shaft so forged being concave; but when such a shaft is forged by the hydraulic squeezers the effect is felt throughout the whole mass, including the portion at the axis which is forced outwards, and the ends of a shaft so forged are convex.

The treatment of rolled steel by fire is avoided as much as possible, and angles, channels, tie bars, &c. for bridge and roof work, are cut to the required lengths by cold saws. When it is necessary to weld and forge, the portions so treated are heated and allowed to cool gradually after the operation, otherwise, initial stresses might be set up in the metal and cause fractures. Many cases of failure of forged mild steel plates and steel forgings have occurred which seemed inexplicable at the time, but were ultimately traced to the worked pieces not having been carefully and uniformly annealed, after portions had been treated in the smithy.

With iron, the treatment by fire is not so injurious; but the appearance of a structure is improved if the ends of the bars are cut off by a cold saw instead of by a smith, and it is frequently found that smithing in such cases is more costly, as bars are occasionally split and spoilt when cutting them by fire, and this is especially the case when the material is "red short."

Rivetting.

Where possible, rivets are now put in by machines, in preference to the older practice of hand rivetting. In nearly all cases the latter have the best appearance, but they are not so effective, as they do not completely fill the holes. There are, however, many boiler makers who maintain that they can make tighter work by punching holes in the plates—arranging the larger ends of the holes outwards—and rivetting by hand; but as most engineers now particularly require holes in boilers to be drilled, the hand rivetting has, in nearly all cases, been superseded by hydraulic or steam rivetters. Many machine rivetters have been invented, but the majority of those in use are worked by hydraulic pressure and were invented by Mr. Tweddell.

Before any rivetting is done, the drilled plates are separated and the burrs removed. The plates are then drawn metal to metal by the free use of service bolts. If the work is not bolted together at every third or fourth hole, faulty rivets will result, and spaces between the plates will exist for oxidation to take place. For boiler work the best rivetting machines are arranged to force the plates together before the rivets are closed, but the machines used for bridge work are not so designed.

Mild steel rivets having a tensile strength of from twenty-four to twenty-seven tons per square inch are usually used where steel plates are adopted, but the author thinks that for boiler work, superior wrought iron rivets are preferable. The tensile strength, shearing resistance and ductility of such iron varies very slightly from the rivet steel referred to, and it is known that iron is not injured to the same extent as steel when it is worked at a low temperature. There is certainly some advantage with regard to first cost in favour of mild steel, and there is no reason why steel rivets for bridge and such like work should not be adopted.

During rivetting, care is taken to heat the rivets in a clean fire and to knock them while held in the tongs, with the object of removing as much of the scale from them as possible. The rivet boy is instructed to do this. If this scale is not removed, the rivets, when put in place, will appear sound to the tap of the hammer, but if the head be cut off by a cold set, the resulting jarring will pulverise the cinder and oxidized surfaces, when the body can be easily pushed out. The rivets are well heated all over the shanks ; if this is not done and the ends only are made hot, the portions near the original heads will not fill the holes, even when put in by hydraulic machinery, and the rivets will appear to be loose, if those forged heads are tried by the hammer.

To obtain sound rivetting when hydraulic machinery is employed, the rivets are the exact length required to fill the holes and form the correctly shaped heads. If they are too short, mere buttons are formed instead of heads, and the bodies of the rivets are not forced out laterally—the consequence being loose rivets. When the rivets have been correctly made, it is usual, in boiler work, to keep the pressure on them until they have become slightly cold.

In some well known firms steam rivetting for boilers is still employed, and the manufacturers maintain that by so closing the rivets, they ensure tighter work than could be obtained from hydraulic pressure, the blows from the steam rivetter being sharp and decided, whereas the hydraulic machine forms the rivet more slowly.

Before concluding these remarks about rivetting, the author desires to state that he is satisfied too much attention is usually given by inspectors to the perfect shape and appearance of rivets. It is of course, advisable to insist upon manufacturers paying particular attention to the neatness and finish of the rivets, but practical engineers would prefer sound and reliable work to that having a neat appearance but being of a less substantial character. When it is remembered that rivets in the flange plates of a bridge are mostly in shear, and that many of those put in principally serve the purpose of keeping the plates together and weather-tight, it will be acknowledged that, to cut out a rivet in a tension member of a bridge which has been put in by hydraulic machinery, only serves to injure the plate around the rivet hole, and that, when such a rivet has been replaced, the actual strength of the work is seriously impaired by the injury done to the plates when the rivet was being removed. Again, when work has been rivetted by hand, in many cases it would be better to leave a few loose rivets in place, rather than cut them out and loosen the adjacent ones during the operation, and this nearly always happens.

In manufacturing girders of small spans, it is usual to completely erect them at the manufacturer's works. The main girders, cross girders, &c., being in position, every possible care is taken that the holes in the joints are perfect and that there will be no trouble in re-erecting the structure at the site it is to occupy. If this is not done, complaints may be made by those who have charge of the completion of the bridge, which complaints are in many cases justified, but are seldom reasonable if the work has been carefully coupled together before leaving the maker's hands.

Manufactured Work.

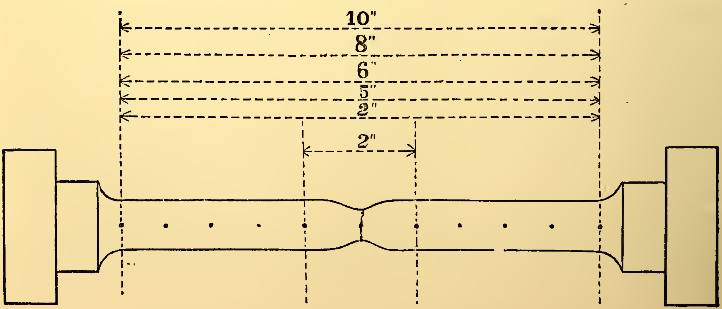
When the work has been manufactured and passed for accuracy of dimensions &c., it should, if possible, have all the black oxide scale scraped or knocked off and be thoroughly cleaned before any paint is placed upon it. Many people stipulate that the plates shall be coated with oil before being manufactured into bridge work, &c., but in the author's opinion this is a mistake unless such plates be exposed to severe oxidation during a long transit, such as from Great Britain to Australia. If the scale is not removed, no matter how good the paint may be, or how carefully the work may be coated with it, some galvanic action will take place between the black oxide and the iron or steel, and the former will peel off, carrying with it all protecting coating that may be upon its surface. The importance of carefully removing this coating of oxide from iron and steel work manufactured in Great Britain for exportation, was mentioned to the author many years ago by our past Chairman of the Engineering Section of this Society, Mr. Darley, and it was found that there were fewer complaints made about faultily painted exported work, when it was allowed to weather during manufacture, until it could be effectively scraped before being painted.

When the completed work has been temporarily erected at the manufacturer's yard and carefully drawn together at the joints by correctly shaped drifts having but a slight taper at the points, the remainder of the body being parallel, well fitting service bolts are then used and all the work properly coupled up. Some specifications stipulate that no drifting will be allowed, but practical men know that a little drifting to bring the work properly together is very necessary, and in some cases good work could not readily be ensured if this were not done. Engineers occasionally require bridges to be tested by loading them at the manufacturer's works, in which case, turned bolts to fit the rivet holes must be used; but such testing is very seldom insisted upon.

When erected on the maker's premises, the work is carefully painted, and in the case of bridges, considerable facilities are afforded to those who have the handling of the work at the site of delivery, if the main girders are painted different colours, and the portions of the cross girders adjacent to them also coated with the same shades. In lattice bridges, it is advisable to paint the bottom portions of the bars, and the webs of the booms to which they are fixed, black, upon which the stencil marks show up clearly; and in addition to the stencil marks, the figures and letters are also stamped into the work, to provide against any painted marks being obliterated in transit. Plans showing the colouring and marking of the work are also supplied for use of the erectors.

In concluding this paper the author would point out that to ensure good workmanship and material, it is advisable to place contracts in the hands of reliable firms. If they are let to manufacturers who have not a high reputation, who will, if possible, scamp their work and evade portions of the specification, then it is impossible to obtain reliable and uniform material and workmanship, no matter how capable and strict the supervising officers may be.

Results of some experiments made upon five pieces of Spike Steel, three-quarter inch diameter, cut from one bar, and five pieces of Bolt Steel, seven-eighths inch diameter, cut from one bar.



Date.	Test No.	Original Dimensions. Diam.	Original Dimensions. Area.	Length of Specimen under Stress.	Breaking Strength per Square Inch.	Elongation. On Specimen.	Elongation. In two inches.	Reduction of Area.	Remarks.
1890.			sqr. in.			per ct.	per ct.	per ct.	
Sept. 20	1	·564	·25	10 inches	32 tons	24·0	40·0	64·7	Specimens cut from one bar of Spike Steel, ¾" diameter.
,, ,,	2	·564	·25	8 ,,	32 ,,	25·0	39·0	62·8	
,, ,,	3	·564	·25	6 ,,	32 ,,	25·0	37·7	61·9	
,, ,,	4	·564	·25	5 ,,	32 ,,	26·0	38·0	60·6	
,, ,,	5	·564	·25	2 ,,	34 ,,	32·0	32·0	60·0	
,, ,,	1	·564	·25	10 ,,	40 ,,	20·5	33·0	57·4	Specimens cut from one bar of Bolt Steel, ⅞" diameter.
,, ,,	2	·564	·25	8 ,,	40 ,,	20·0	35·0	57·4	
,, ,,	3	·564	·25	6 ,,	40 ,,	22·1	34·0	58·1	
,, ,,	4	·564	·25	5 ,,	40 ,,	22·4	33·5	56·9	
,, ,,	5	·564	·25	2 ,,	41 ,,	30·0	30·0	53·6	

Each of the specimens tested was marked off in inches, and the elongation per cent. taken in the total length and in the two inches at point of fracture, as per above sketch.

ON THE ORIGIN OF MOSS GOLD.

By A. Liversidge, M.A., F.R.S.,
Professor of Chemistry in the University of Sydney.

[With Plates XVI. – XVII.]

[Read before the Royal Society of N. S. Wales, September 6, 1893.]

In 1876 I had the privilege to read a paper before this Society "On the Formation of Moss Gold and Silver" (Jour. Roy. Soc. N. S. Wales, 1876, Vol. x., p. 125); since that time the matter has had to be more or less laid aside; but as opportunity offered, the investigation as to the cause of the moss like form of gold met with during the roasting of auriferous mispickel has been proceeded with, and in this note the results are given of additional experiments which appear to afford a solution as to the peculiar forms assumed by the gold, described in the above mentioned paper.

Without going into details, it may be mentioned that the paper referred to contained the results of experiments made with the object of ascertaining the condition in which the gold existed in certain rich specimens of mispickel, obtained from a mine near Orange in New South Wales; these specimens were roasted in a muffle so as to drive off the arsenic and sulphur, and with the intention of afterwards dissolving away the iron oxide with hydrochloric acid so as to ascertain whether the gold was crystallized; on removing the specimens from the muffle, exudations of ochre coloured matter were seen on their surfaces. These exudations on closer examination were found to be gold in cauliflower-like aggregations, and under the microscope these were seen to be made up of spicules and spirals of gold [See Plates 16, 17] (afterwards proved to contain some arsenic), the temperature of the muffle was kept between the fusing points of tin and zinc, so as to make quite certain that it was never hot enough to fuse gold. The residual iron oxide never showed any traces of fusion.

For these and other reasons I concluded, in my former paper, that the gold had not been fused; my later experiments, however, show that although the temperature was insufficient to fuse gold, it was quite high enough to melt the very fusible compound of gold and arsenic, which was either present in the specimens under examination or formed during the roasting.

In the Mineralogical Magazine for 1877 and following years, there are several communications from Mr. T. A. R. Readwin upon the formation of moss gold. He is of opinion that metallic growths of gold, silver, electrum and native copper take place at ordinary temperatures, and cites a number of cases of specimens in his cabinets which appear to have "grown" since they have been in his possession. In the case of easily oxidisable sulphides rich in gold, this is probably not impossible.

In the former paper an experiment is given in which gold was fused in a crucible with mispickel under borax; on roasting the auriferous button moss gold was obtained as from the natural specimens but of much smaller dimensions. The following additional experiments have been made which more conclusively prove that mispickel, iron pyrites and other sulphides take up gold when fused with it, and in the case of the mispickel give up the gold, on roasting, in moss-like forms.

The following experiments with gold and various sulphides were made in 1877; in each case the sulphide was loosely mixed with the gold (sovereign gold rolled into a thin ribbon and cut up into minute squares) or the gold was only laid on the top and the whole covered with a layer of borax and fused.

Description and weight of sulphide in grammes.	Weight of gold used in grammes.	Percentage of gold used.	Weight of gold separated as a button in gms.	Percentage of gold in regulus.
30 Mispickel ...	3·25	10·80 (3)	none	3·60 (1)
30 „ ...	1·20	4·00	1·05	not assayed
30 „ ...	·90	3·00	·75 (5)	not assayed
25 „ ...	·50	2·00	·3	·80 (1)
30 „ ...	·30	1·00	·15 (6)	not assayed
30 Iron Pyrites ...	3·25	10·80	none	12·25
25 „ ...	·50	2·00	·39	·44 (2)
80 „ ...	1·17	1·46	none	·80 (4)
80 Copper Pyrites	1·17	1·46	none	1·00
80 Antimonite ...	1·17	1·46	none	4·42
80 Galena ...	1·17	1·46	none	1·20

(1) The regulus of mispickel in each case showed a crystalline structure on fracture, and the fracture under the microscope, was seen to be studded with gold; there was also some moss gold over the surface of the button and in the cavities. On roasting, the mispickel regulus always yielded moss gold.

(2) A white brittle button separated during fusion, containing streaks of gold—weight ·3 grammes.

(3) Precipitated spongy gold was used in this case.

(4) Yellow malleable button.

(5) Very brittle, intersected with a white crystalline vein.

(6) Colour nearly white.

In some cases the percentage of gold found in the product or regulus was greater than that added; this, of course, was due to a part of the original mineral having been removed in the slag or volatilized. Moss gold was only obtained from the regulus of mispickel, none of the other sulphides yielded any.

The above experiments however only show that an artificial mixture of gold and mispickel will yield moss gold.

The next series of experiments was upon the preparation of sulpharsenide and arsenide of gold and the production of moss gold from them.

Gold, Arsenic and Sulphur.

Experiment 1.—A solution was made of sodium chloraurate and sodium arsenite and hydrogen sulphide passed; the precipitate of the mixed sulphides of arsenic and gold and free sulphur, was dried and roasted, a cauliflower-like residue of gold was left similar to that exuded by auriferous mispickel, which under the microscope was seen to contain a few fine filaments.

Experiment 2.—The experiment was repeated with the same result.

Experiment 3.—Some of the mixed sulphide of gold and arsenic was compressed into small cylinders, by means of a steel diamond mortar and two of these were carefully roasted at the mouth of the muffle. In both cases the gold was left as a porous mass with sponge like perforations running through it in all directions—with filaments of gold, visible under the microscope.

Gold and Sulphur.

Experiment 4.—Some experiments were made in 1878, upon gold sulphide obtained by passing hydrogen sulphide through the solution of the sodium chloraurate, this sulphide on roasting yielded ordinary dull brown gold, but in parts it appeared to be more or less crystallized. This experiment was repeated more than once with the like results.

Experiments with Gold and Arsenic.

In making the arsenide of gold, in the first experiments in glass tubes, the gold foil was placed in a porcelain boat and the vapour of arsenic driven over it, but it was afterwards found that the boat could be dispensed with. A piece of hard glass three-quarter inch combustion tubing was closed at one end and some metallic arsenic filled in to about one inch, then a plug of asbestos and upon this the spirals of gold foil were placed, the tube was held in an inclined position in a retort stand and the arsenic volatilized by a bunsen flame, when the air had been displaced by the arsenic vapour the gold was heated to redness by the blowpipe; it quickly began to fuse and to run down upon the asbestos. (The blowpipe flame was quite incapable of fusing the gold by itself in the tube, even when the blast was kept up for an hour or so and the tube softened out of shape, but in the arsenic vapour the gold ran down with great readiness at a dull red heat.) The compound of gold and arsenic formed is very fusible and remains liquid for some little time after removal from the flame and when it has much cooled down ; the globules are large and much rounded so that its surface tension is great, like that of the liquid alloy of potassium and sodium, in fact the appearance of the fluid arsenide reminded me very much of that alloy, except that the arsenide is of a yellow colour.

The gold arsenide solidifies suddenly on cooling (superfusion) and sometimes spirts a good deal, the small projected globules attach themselves to the glass tube, but can be readily removed. The cooled mass is often coarsely crystallized on the surface, when it presents a bright lustrous gold colour and appearance, but underneath it is seen to be honeycombed in every direction. In the cavities the microscope shows spirals and spiculæ of gold or of the gold-like arsenide. It is very brittle and breaks readily ; inside it is crystalline and may be cavernous, in places there are patches of a bright metallic grey colour. This may be due to the presence of free arsenic or to a grey alloy, but I have not yet had time to determine this. In other cases the resulting compound has the dull ochre colour of moss of precipitated gold.

The alloy first formed by simple fusion seems to greedily absorb more arsenic, *i.e.*, when a piece of arsenic is pushed up against it; the alloy wets the arsenic and on slowly withdrawing the arsenic the alloy follows it like a streak of water, for from one quarter to half an inch. The apparent absorption of the arsenic may be partly due to the arsenic being volatilized by contact with the fluid alloy. See experiment No. 9.

Experiment 5.—In the next experiments for the formation of the gold arsenide, arsenic was filled into a hard glass three-quarter inch tube to the depth of one to one and a half inch and a plug of glass wool placed upon it, the gold plate or foil was next dropped in, followed by another plug of glass wool, the tube was then rendered vacuous, sealed and heated to redness in a combustion furnace. On cooling, the spirals of gold were seen to have fused down into one large globule one-third inch across, scattered about were a number of small globules which were flattened and attached to the glass tubing, extending over two inches of the length of the tube, this scattering seems to have taken place on the solidification of the large globule and was probably due to the expulsion of an excess of arsenic. This experiment was repeated with a similar result; in the next experiment mispickel was used as the source of arsenic. On cupellation the first globule yielded 90·36% of gold and 9·64 of arsenic (by difference). The globule of gold arsenide from the mispickel yielded only 1·82% of arsenic.

It was afterwards found that the combination could be brought about by heating the arsenic and gold, separated by an asbestos plug, in an ordinary small hard glass tube of one-quarter inch bore, in the first trial the alloy melted down into a pear shaped globule, which was very brittle, and crystalline. On cupellation, the loss was equal to 5·54% of arsenic.

Experiment 6.—Next ·411 g. of pure gold was treated as in the last experiment, on removal from the lamp after I thought it had solidified, the globule still remained fluid, for an air bubble was seen to slowly make its way through the globule, (as in a tube containing mercury) the globule solidified immediately, but the channel caused by the bubble was left. In this channel, minute spicules and spiral filaments of gold (moss gold) were seen when examined under the microscope.

The globule was weighed and found to have taken up 6·16% of arsenic, the amount was really larger but some of the alloy was lost by spirting on solidification. On cupellation of part of this globule the loss was equal to 7·5% of arsenic.

Afterwards larger amounts of gold were converted into arsenide in this way. On introducing cold gold into the arsenic vapour it became coated with a grey deposit of metallic arsenic, but as it became hotter the gold recovered its usual colour and lustre, but as soon as the gold became just red hot it rapidly fused down at the edges, just as when a strip of lead is held in a flame. In dealing with this larger quantity of gold in the large combustion tubing (three-quarter inch diameter) it was found necessary to use a gas blowpipe as a bunsen was not quite sufficient.

Experiment 7.—In this case the globule from 1·3627 g. of gold was shaken just as it was about to solidify, the whole suddenly became solid, with strongly marked crystalline surface and of a very bright lustrous gold colour, but cavernous at the base and exceedingly brittle. On cupellation it lost weight equal to 4·61% arsenic.

Experiment 8.—On roasting and fusing a portion of the alloy obtained in this experiment in a muffle without cupellation it lost weight = 3·29% of arsenic, although it showed, when fractured, grey specks of either arsenic or a grey alloy.

Experiment 9.—In this case after a globule of the arsenide had been formed, fresh supplies of arsenic were pushed down against the molten alloy (the supply of arsenic vapour from the bottom of the tube being still kept up) when it was apparently rapidly absorbed by the fluid alloy, the alloy "wetted" the plate of arsenic at once, and when the plate was drawn slowly backwards followed it as a streak (like water) to about one-third inch in distance.

As the quantity of arsenic increased the alloy became less fluid and less brilliant in lustre; whether much more arsenic was really absorbed and whether the arsenic was only volatilized by contact with the fluid alloy is difficult to tell. On solidifying, the alloy seems to expel arsenic vapour and this condenses on the inside of the tube, but it is difficult to watch the operation because, the atmosphere of arsenic vapour used for producing the alloy also condenses on the sides of the tube soon after its removal from the lamp.

This specimen on cooling was of a dull brown colour just like the moss gold from mispickel, very hollow and blown out into a secondary globule on one side, the cavities contained spicules and spirals of moss gold.

It was very brittle and on cutting it with a sharp chisel more or less powder was produced, the fracture was coarsely crystalline and of a dull gold colour, which under the microscope was seen to be intermingled with grey. On cupellation it lost weight = 3·2% of arsenic.

Experiment 10.—In this case a weight of 7·3674 g. of fine gold was alloyed with arsenic; on the gold first fusing down or "burning" in the arsenic vapour a very fusible alloy was formed, but this like the last became less fusible as more arsenic (solid) was pushed into it (the arsenic had been previously sublimed in glass tubes for this purpose) and on cooling it lost its metallic lustre, became covered with cauliflower-like growths and spirted a good deal; the cavities contained the usual spicules and spirals of moss gold. On cupellation the loss was equal to only 2·8% of arsenic.

Experiment 11.—This arsenide was of the colour and lustre of freshly cast bronze. Loss = 5·9% As. on cupellation.

Experiment 12.—Also of a bronze colour. Loss = 4·9% of As.

Experiment 13.—Of a bright gold colour and matt lustre; this had formed directly in contact with the arsenic and had solidified on the arsenic itself—the alloy was pitted in places and had a very strong resemblance to a nugget. Its fracture showed a few grey streaks mixed with the gold, on cupellation it lost weight = 9·9% arsenic.

Experiment 14.—The moss gold obtained by roasting the auriferous mispickel from the New Reform Mine, Lucknow, was cupelled with lead when 2·3668 grammes lost ·057 or 1·98%.

From the foregoing experiments it will be seen that the amount of arsenic taken up by the gold varies very much: thus the alloy from Experiment 5 (from arsenic and gold) lost 9·64% arsenic, and from mispickel and gold 1·82% of arsenic.

Experiment	6	(from arsenic	and gold)	lost	7·5%	of arsenic
"	7	"	"	"	5·61%	"
"	8	"	"	"	3·29%	"
"	9	"	"	"	3·2%	"
"	10	"	"	"	2·8%	"
"	11	"	"	"	5·9%	"
"	12	"	"	"	4·9%	"
"	13	"	"	"	9·9%	"
"	14	"	"	"	1·98%	"

The lowest containing only about 2% and the highest nearly 10% of arsenic.

While the arsenic is hot it feels sticky when touched with an iron wire and the fragments cohere to a certain extent.

The excess of arsenic left in the lower part of the tube as well as the sublimed arsenic shows well developed crystals.

Experiment 15.—Precipitated gold was mixed with powdered purified arsenic in about equal bulks, and compressed into small cylinders by means of a diamond mortar and then roasted slowly in a muffle; the gold was left as a porous cylinder, but with excrescences of moss gold in places and lining the cavities.

Experiment 16.—Moss gold was also obtained by roasting a cylinder composed of mispickel 1 g. and ·75 g. of precipitated gold.

Experiment 17.—Gold ·75 g. arsenic ·5 g. and sulphur ·5 g. were compressed, on roasting, it at once fused down into an irregular cake with a very cavernous and spongy structure; the surface was like that of moss gold and under the microscope the usual spicules and spirals were seen. The cupel used as a support was stained of a purple tint and this penetrated to nearly one-eighth of an inch deep, just as if the gold had been in solution.

Experiment 18.—To ascertain if finely divided gold would burn in arsenic vapour, I introduced some gold leaf; it combined in much the same way as the foil, but more quickly.

Experiment 19.—Gold leaf introduced into the vapour of sulphur was apparently unchanged.

Experiment 20.—Thin sheet gold, thinner than that used for making the gold arsenide was heated in a piece of combustion tubing for nearly an hour, with the hottest flame obtainable with the blowpipe lamp used for making the experiments on gold and arsenic, but without fusing it or causing any signs of fusion to appear on its edges, hence there is no possibility of the gold having been fused in previous cases, *i.e.*, its fusion was due to the formation of a fusible compound with the arsenic. This test was repeated with the same result in both cases.

Experiment 21.—Some precipitated gold was made into an amalgam and roasted at a low temperature in the front part of a gas muffle, the gold was left as an ochre coloured lustreless cauliflower-like mass; under the microscope, however, it is seen to have the usual colour and lustre of metallic gold; the innumerable bright points which reflect the light being too small to be seen by the unassisted eye; the general appearance is much like that of the excrescences of gold from roasted auriferous mispickel; but the spiral and moss like growths are almost absent, although a number of hair like filaments of gold are seen in the cavities and recesses of the mass.

When the pieces of amalgam were roasted at a high temperature they fused and coalesced, the appearance was rougher from the boiling and more rapid expulsion of the mercury, but the number of capillary growths and filaments was not increased. Doubtless most or all of the compounds of gold with volatile elements would yield moss gold on roasting.

Compounds of gold and arsenic do not appear to be mentioned in modern English works of reference upon chemistry. In Aiken's Dictionary of Chemistry and Mineralogy, p. 537, London

1807, there is an account of Hatchett's experiments upon them from Phil. Trans. 1803, as follows :—

"If a small crucible containing gold be inserted in a larger one containing arsenic and an inverted crucible be luted on by way of a cover and the apparatus be heated strongly in a wind furnace, the arsenic will be raised in vapour, and the gold being fused in the arsenicated atmosphere, will combine with a small portion of it. The alloy hence resulting is of a grey colour, a coarse granular fracture, and very brittle.

"A heat equal to that of melting gold is by no means necessary to effect this combination, for if a plate of gold is merely brought to a full read heat in an atmosphere loaded with arsenic, the latter will unite superficially with the gold, and the alloy hence resulting being very fusive, will trickle in drops from the plate, till the whole of it is thus arsenicated. The alloy is scarcely decomposable by mere heat, and at a high temperature the arsenic that is driven off, carries a considerable proportion of gold with it."

An abstract of the above appears in Gmelin's Handbook of Chemistry, Vol. VI., p. 238, London 1852, after which such compounds are ignored by more modern English writers, except a bare statement in Watt's Dictionary of Chemistry Vol. I., 1872, that gold combines with arsenic.

In Brough Smyth's Gold Fields and Mineral Districts of Victoria, Melbourne 1869, there is a statement that a quantity of arsenical gold was found by some Chinamen in the rubbish from disused roasting kilns at Stawell in Victoria, this was examined by Mr. Newbery, who stated that the gold had probably taken up the arsenic (when the latter was in a state of vapour) during the roasting of arsenical ores, as native arsenides of gold were unknown in Victoria.

A. Deschamps (Comptes Rendus lxxxvi., 1022-3 and 1065-6), states that Au_3As. is formed as a dark red powder when metallic arsenic is placed in a solution of gold chloride. By fusion with potassium cyanide a yellow metallic button of Au_4As_3, sp. gr. 16·2, is obtained.

The above references were made after I had completed the experiments given in this paper, and they are quoted merely as of historical interest.

As a result of the foregoing experiments and observations I conclude that the peculiar form of the moss gold is due to the formation of a fusible compound with arsenic, which behaves in much the same way as fused bituminous coal—to which I referred in my first paper (Jour. Roy. Soc. N.S.W., Vol. x., 1876, p. 125) as follows:—" The general appearance of these peculiar cauliflower-like excrescences of gold would at first sight tend to give one the impression that they had been formed in somewhat the same way as the blebs and excrescences often observed on coke, which are so familiar to us in a fire made of the so-called bituminous coal, *i.e.*, caking coal, in which we constantly see portions of the coal fuse and swell up into fantastic blebs and bladders until the imprisoned gas breaks through the outer thin skin and inflames with a brilliant light. After the more combustible portions have been volatilized and consumed a hard clinkery and more or less cauliflower-like excrescence is left." In the cavities of such cinder we may often see spicules and acicular threads of coke.

In that paper I came to the conclusion that the moss like forms of gold could not be due to fusion, because the experiments were conducted at temperatures far below the fusing point of gold or mispickel, but my later investigations show that the moss gold is due to the fusion of the very fusible gold arsenide and to the escape of arsenic from it, blowing it up into excrescences, spicules and spiral threads, and that the crystallised appearance in places is due to the ready crystallization of the alloy on solidification.

In the auriferous mispickel the gold appears to be in the free condition, but to be converted into gold arsenide during the roasting, and it is from this gold arsenide that the moss gold is produced.

ON THE CONDITION OF GOLD IN QUARTZ AND CALCITE VEINS.

By A. LIVERSIDGE, M.A., F.R.S.,
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[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

THE condition in which gold occurs in veins and other matrices has long been a matter of interest to me, and from time to time I have made occasional experiments, as opportunity offered between other duties, to ascertain whether the gold, scattered through quartz veins and other gangues, is crystallised or not.

When the gold occurs in a soft matrix like calcite or serpentine it very often is crystallised, so also when it occurs in cavities, such as those left by the removal of iron pyrites, but it is rather difficult at times to decide whether gold present in a hard matrix is or is not crystallised. To answer the question one cannot crush the specimen under a hammer or in a mortar, because this treatment would destroy the form of the gold as well as remove the enclosing matrix.

In order to remove the gangue, usually quartz, the auriferous specimens were placed in the form of fragments, as large as possible, in a platinum crucible, or dish according to size and condition, and acted upon by the ordinary solution of hydrofluoric acid, until all the quartz or gangue was either removed, or so much disintegrated as to be easily removed or washed away from the gold.

A piece of the porous white siliceous matrix resembling geysirite from Mount Morgan was attacked by hydrofluoric acid, but only one speck of gold was left, and that was not visible until after the residue from the mineral had been crushed in an agate mortar.

On treating the stalactites of auriferous brown hæmatite from Mount Morgan with hydrochloric acid, as described in a paper read before the Royal Society of N. S. Wales, December 2, 1891 (On some New South Wales and other Minerals, Note No. 6), a residue of silica was left. In some cases the residue consisted of gelatinous silica, in others of porous quartz resembling the so-called geysirite, although before such treatment in most cases no quartz was visible nor was there anything to indicate its presence; the original colour of the stalactites being dark brown to lustrous black, as in the typical brown hæmatite, neither did the fracture reveal the presence of silica.

As the solution went on and the iron oxide was removed the stalactites gradually presented an outline in soft transparent gelatinous silica, this increases until finally nothing but gelatinous silica, or a mixture of it and ordinary silica, was left. No gold was visible in the residue, either in the first or second sample tried, even after crushing the residue in an agate mortar.

In a third specimen the silica also was got rid of, by hydrofluoric acid; on grinding the residue, mainly insoluble iron oxide, in an agate mortar, no traces of gold could be seen. This appears to indicate that the particular specimens were either free from gold, most unlikely, or that owing to its finely divided condition it had floated away during the treatment.

When acted upon by hydrofluoric acid the stalactitic brown hæmatite soon acquired a white appearance, and the various fragments became more or less cemented together into rounded masses, with numerous vent holes, through which the volatile silicon fluoride, acid and steam escaped, so that they looked like many a New Zealand Hot Spring in miniature. The quartz is rendered soft and friable long before it is removed by the hydrofluoric acid.

A fourth specimen left a residue of very finely divided gold, but without any recognisable crystalline form. A fifth specimen left the gold as a dull brown powder.

A rich specimen of gold quartz from New Caledonia Reef, Queensland, was treated in the same way when a considerable amount of dull brown gold was left; but with no traces of crystallisation.

A specimen of quartz from Armageddon Reef, Gilbert River, Queensland, showing "spider leg" gold, was treated with hydrofluoric acid to remove the quartz; the gold set free was seen to consist of striated wire-like forms and of cavernous octohedrons joined together into chains.

An exceedingly rich specimen of water worn quartz and gold, containing more gold than quartz which was thought might show the gold crystallized, was next treated, but after removal of the quartz, the gold, although presenting a very bright and lustrous appearance did not show any recognisable crystalline form, it and the quartz had apparently solidified together and neither had been free to crystallise. Several other specimens were examined, but in none was any distinct crystalline form recognisable.

The gold set free from vein quartz by hydrofluoric acid shows no sign of fusion (the old theory that the quartz of veins had originally been in a molten condition and had been ejected from below into fissures is of course nowadays no longer held) neither does it as a rule show any well marked cavities or in other favourable condition for assuming such forms.

It usually presents the appearance of irregular films, plates, threads and masses which are more or less connected together, sometimes so closely, that when the quartz is wholly removed, a rough spongy or cavernous mass of gold is left retaining more or less completely the outlines possessed by the fragment of auriferous quartz before it was acted upon by the acid.

A specimen of the auriferous mispickel in calcite, from Lucknow, weighing about three ounces, was treated with hydrochloric acid to dissolve away the calcite; the residue consisted of mispickel, quartz, and a white asbestiform mineral, the latter was not previously visible; in addition to the more massive pieces thin plates of mispickel were left, and these had apparently surrounded crystals of calcite since some of them were arranged so as to form hollow rhombohedrons, some of the rhombohedrons were cut in half by diagonal films of mispickel.

On treating these plates with nitric acid to see if they contained any free gold, they were in some cases found to consist of quartz, merely coated with mispickel. In this instance no free gold was left, neither by the calcite nor by the mispickel.

Another piece of the auriferous mispickel in calcite from Lucknow, was roasted and yielded large excrescences of moss gold, this was removed and the residue of iron oxide, lime, silica and undecomposed mispickel was treated with hydrochloric acid until only some silica and a little gold were left. The gold was very finely divided and floated readily on water, but appeared as if somewhat crystallised.

The calcite from another specimen, but unroasted, was removed by hydrochloric acid, and a small amount of fine free gold was left together with some powdery mispickel and silica which had been enclosed within the calcite—under the microscope the gold was seen to be more or less crystallised.

In the rich gold calcite specimens from the above and other New South Wales mines, as well as those from Gympie, Queensland, the gold can be seen to be crystallised, so also in the serpentine from Gundagai and Lucknow, and some of the clear auriferous quartz from New Zealand, but in the majority of cases, for I have only quoted a few out of numerous trials, the gold embedded in massive quartz is remarkably free from any traces of crystalline form, and the larger the fragments of gold the less crystalline form does it present.

A splinter of gold with octohedral faces on both ends, enclosed in a small rock crystal is stated by Selwyn and Ulrich (Phys. Geog. Geol. and Mineralogy of Victoria, 1866, p. 43) to have been obtained from the M'Ivor Gold Field, together with other crystallised specimens of quartz containing non-crystallised gold.

Crystallised gold is not usually met with in the quartz of the reef itself, but in the upper portions of the ferruginous and argillaceous casing of the reef and in the detritus near its outcrop.

Some alluvial gold which I obtained on the spot at Fairfield, New England, N.S.W. was examined; on removing the fine sand from this by washing, the gold under the microscope did not look waterworn but obscurely crystallised, a more or less complete octohedral face being occasionally seen. The gold was obtained from a spot close to the reef, and had evidently not travelled many feet.

The really good crystals of gold all appear to have formed in what are now cavities, usually left by the removal of iron pyrites, or else in very soft matrices like iron oxides, clay, calcite, and serpentine as already mentioned.

ON THE ORIGIN OF GOLD NUGGETS.

By A. Liversidge, M.A., F.R.S.
Professor of Chemistry in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

From time to time various theories have been put forth to account for the existence of alluvial gold and nuggets, *i.e.*, other than the old and generally accepted one, viz., that such gold has been derived or set free from mineral veins and rocks by the ordinary processes of disintegration and denudation.

The one first propounded by Mr. A. R. C. Selwyn, C.M.G., F.R.S., when Government Geologist to Victoria, has always interested me, and within the last two years I have been able to make some experiments bearing upon the matter, but before stating the results I will refer briefly to some of the theories above referred to.

Simpson Davison advanced a theory (*The Discovery and Geognosy of Gold Deposits in Australia*, p. 132, London 1860)— "that alluvial or placer deposit gold has been distributed and deposited horizontally by means of an igneous liquid or perishable lava, and that quartz veins as well as some other dykes traversing constants had been the fissures of discharge,—the only unchanged existing solid remains of the ejected matter being gold, quartz, and some few other minerals besides clays and ferruginous earth ;" he advanced the theory because alluvial or placer deposit gold has often a fused appearance, and the metallic grains frequently present ragged and irregular surfaces, such as must have been destroyed by abrasion. He also gives other reasons, but they are equally valueless and unimportant.

Mr. C. S. Wilkinson, F.G.S., formerly Government Geologist of New South Wales, refers in a paper read before the Royal Society of Victoria, 11 Sept. 1866 *On the Theory of the Formation of Gold Nuggets in the Drift*, p. 11, to Selwyn's hypothesis viz. :—" that nuggets may have been formed, and generally that particles of alluvial gold may gradually increase in size through the deposition of metallic gold (analogous to the electroplating process), from the meteoric waters which circulate through the drifts, and which must have been, during the time of our extensive basaltic eruptions of a thermal, and probably highly saline, character, favourable to their carrying gold in solution," and states that " Daintree had on one occasion prepared for photographic use a solution of chloride of gold, leaving in it a small piece of metallic gold undissolved. Accidentally some extraneous substance, supposed to be a piece of cork, had fallen into the solution, decomposing it, and causing the gold to precipitate, which deposited in the metallic state, as in the electroplating process, around the small piece of undissolved gold, increasing it in size to two or three times its original dimensions." Wilkinson then made certain experiments to test Daintree's theory. " Using the most convenient salt of gold, the terchloride, and employing wood as the decomposing agent, in order to imitate as closely as possible the organic matter supposed to decompose the solution circulating through the drift, I first immersed a piece of cubic iron pyrites taken from the coal formation of Cape Otway, and therefore less likely to contain gold than other pyrites. This specimen (No. 1) was kept in a dilute solution for about three weeks and is completely covered with a bright film of gold."

He also used galena, copper, and arsenical pyrites, antimony (*i.e.*, antimonite?), molybdenite, zinc blende and wolfram, with similar results. Brown iron ore only gave a deposit of gold powder. He found that when iron pyrites was tried with metallic copper, zinc and iron, the gold was only deposited as a fine powder at the bottom of the vessel, and came to the conclusion that organic matter was necessary to form a coherent coating of gold on the nucleus, for without the presence of wood, or similar organic matter, he found that the six sulphides were unaltered.

In his second experiment with iron pyrites, he found that the gold was deposited on it in a mammillary form, analogous to that presented by the surface of nuggets.

To sum up Wilkinson's paper, his points are 1° that gold is deposited upon sulphides in the presence of organic matter; 2° that the organic matter is essential; 3° that the coating is mammillary in some cases; 4° that gold is probably present in solution in mineral waters; 5° that nuggets are purer than vein gold and that this may be due to the nuggets having been deposited *in situ* from a solution of gold.

The next to take up the subject was Mr. J. Cosmo Newbery in a paper *On the introduction of Gold to, and the formation of Nuggets in, the Auriferous Drifts* (Trans. Roy. Soc. of Victoria, 1868, p. 52). In this he admits that some nuggets and alluvial gold may be derived from the denudation of reefs, but points out that the largest masses are sometimes found at great distances from the reefs and in the sand overlying the gravel, both of which are inexplicable when the very great specific gravity of gold is taken into account. He also states that the presence of gold in pyrites which has replaced the roots, branches and stems of recent trees, is a proof of the existence of gold in meteoric waters of the Tertiary Times.

He quotes Selwyn's hypothesis, and Selwyn and Ulrich (*Physical Geography, Geology, and Mineralogy of Victoria*, 1866) to the effect that all the large nuggets have been found on the western gold fields where extensive basaltic eruptions have taken place, while on the eastern and northern fields, where basaltic rocks are wanting or only of limited extent, the gold is usually fine and nuggets of more than one ounce are rare. He also states that Bischof has found gold sulphide to be soluble in pure water, and he has suggested that it may occur in that form in meteoric waters.

Newbery dissolved some gold sulphide in an alkaline bicarbonate and found that when a cube of pyrites and a chip of wood were introduced that small irregular grains of gold were deposited, and states that the gold is not deposited without the organic matter (*i.e.* the wood).

Newbery repeated and confirmed Wilkinson's experiments. Newbery points out that there is little proof in nature of pyrites having acted as a nucleus; it carries gold both internally and attached externally, but we do not meet with *gilded pyrites* such as are obtained in laboratory experiments, and that in nature the two appear to have been deposited together.

Newbery, out of one hundred samples of pyrites, found none with any coating of gold such as is obtained experimentally, but it was present in irregular grains and small octohedral crystals; in exceptional cases pieces of gold were found projecting, but all proved that the pyrites had not formed a nucleus for the gold but the reverse has been the case in the majority of instances, *i.e.*, the gold has been deposited first; and he suggests that the gold may have been deposited first in the drift wood, as seen when organic matter, flies, &c., fall into a gold solution, and the pyrites afterwards deposited around it.

He also refers (Laboratory Report, Melbourne, 1876) to Daintree's discovery of an enlarged fragment of gold in a bottle containing chloride of gold, and states that "Ulrich, who was present when Daintree discovered the enlarged piece of gold, says that the original piece was a small fragment which remained undissolved after making some chloride and the bottle was closed with a cork, when again observed the solution was colourless and the fragment of gold of such a size that it could not be removed from the bottle through the narrow neck."

Newbery, like Skey, found that hammered pieces of gold did not increase in size, but he had little doubt of others with a rough or natural surface doing so.

Mr. Newbery was followed by Mr. W. Skey, F.C.S., Analyst to the Geological Survey of New Zealand, in a paper *On the Reduction of Certain Metals from their Solutions by Metallic Sulphides, and the relation of this to the occurrence of such Metals in a Native State.* (Trans. N. Z. Inst., 1870, p. 225). Mr. Skey also repeated Wilkinson's experiments and obtained the deposits of gold on various sulphides and arsenides, and further found that the presence of organic matter is quite unnecessary for bringing about the deposition of gold upon the above minerals. He also found that silver nitrate and acetate, and the salts of one or more of the platinum group of metals, are reduced by the metallic sulphides and arsenides. He points out that the metallic sulphides possess much greater reducing power than organic matter, and that a single grain of iron pyrites will reduce $8\frac{1}{6}$ grains of gold. And that although organic matter may have had a share in the reduction of gold, he is of opinion that the greater portion of the deposits—especially the deep seated ones—have been due to the deoxidising effects of pyritous minerals.

In a succeeding paper, *On the Electro-motive Power of Metallic Sulphides* (Trans. N. Z. Inst., Nov. 12, 1870, p. 232), Mr. Skey describes experiments which he made to show that when such sulphides as pyrites and galena are placed in dilute acids or saline solutions and connected by a platinum wire, the current generated is sufficient to throw down gold in separate vessel from its chloride. He points out from these experiments and Mr. Fox's statements as to the existence of currents of electricity in the earth's crust that each pyritous vein or mass with its surrounding walls and exciting solutions may constitute a true voltaic pair on a grand scale.

A third paper by Mr. Skey is entitled, *On the Mode of Producing Auriferous Alloys by Wet Processes.* (Trans. N. Z. Inst. 1872, p. 370). He states, amongst other matters, "that when chloride of gold is added to an alkaline argentiferous solution of this nature (silver chloride in *alkaline* chlorides; silver chloride in either acid or neutral solutions is not reduced by iron pyrites,) such mixed solution is capable of depositing the metals contained in it in the form of coherent alloys upon metallic sulphides." Also that such alloys can be formed by voltaic action. Further "that as the water permeating rocks is usually alkaline it seems probable that native alloys of gold and silver have been deposited from alkaline solutions by the metallic sulphides."

He further remarks, that many substances will reduce gold from solution, but the only common ones likely to occur in the interior of rocks are ferrous sulphate, organic matter and the metallic sulphides, these also reduce metallic silver from certain of its solutions, but only the sulphides will reduce the two metals simultaneously and throw them down in coherent forms.

Mr. Skey continued his investigations and published still further results in the following paper—*Critical Notes upon the Alleged Nuclear Action of Gold upon Gold reduced from Solution by Organic Matter* (Trans. N. Z. Inst. 1872, pp. 372 – 5.) In this paper Mr. Skey gives the results of his attempts to confirm Daintree's and Wilkinson's experiment, but, as he says, unsuccessfully; he accordingly describes minutely the methods which he adopted, and found that when a weighed piece of sheet gold was placed in a dilute solution of sodium chloraurate with organic matter until all the gold was precipitated, that the piece of gold only increased in weight ·0005 of a gramme, and by calculation he found that no more gold in proportion was deposited upon the gold plate than upon the sides and bottom of the glass vessel, and even the surface of the liquid itself—the experiment was repeated four times. He points out that the conditions in Daintree's accidental result are so vague and uncertain that it is impossible to credit the organic matter with producing the phenomena described. Neither the volume nor the weight of the undissolved gold was taken, hence he considers that the statement that after some time the fragment of gold had increased in size is of but little value, as it depended entirely upon the eye memory of the original size of the gold particle, and an ocular estimate of its increased dimensions.

In his next communication, *On the Formation of Gold Nuggets in Drift.* (Read before the Wellington Philosophical Society, Oct. 23, 1872—Trans. N. Z. Inst., Vol. v. for 1872, pp. 377 - 383). Mr. Skey says, "we cannot avoid the conclusion that gold is now being deposited and aggregated in many of our drifts, and that such depositions have been going on from remotest times." He thinks that this gold is derived from the metal disseminated through slate, sandstone or schist rocks rather than from that of our reefs, and that we may reasonably suppose it is present as sulphide and is brought into solution by alkaline sulphides from which it is again eventually redeposited as nuggets etc., by the reducing effects of metallic sulphides—a mass of iron pyrites only two pounds in weight being sufficient to cause the deposition of a nugget such as the "Welcome" weighing one hundred and eighty-four pounds troy.

Sir Rod. J. Murchison (Siluria, 5th Edition, 1872, p. 465) after referring to Mr. A. C. Selwyn's suggested explanation as to the formation of nuggets, and to Mr. Wilkinson's experiments, says that he "prefers to remain in his old belief, that the large nuggets found in the drift are simply the reliquiæ of the chief masses of gold which once occupied the uppermost parts of the reefs, and that like the blocks of many an ancient conglomerate, they have been swept from the hilltops into adjacent valleys by former great rushes of water."

Mr. Brough Smyth, F.G.S., in his work on *The Gold Fields and Mineral Statistics of Victoria,* 1869, p. 361, discusses the origin of nuggets and points out that most of the large nuggets have had a great quantity of quartz adhering to them or intermixed with them, clearly indicating that the nuggets must have come from a quartz reef, or else the gold and quartz must both have been deposited together from meteoric water in the drift.

In Mr. W. Birkmyre's list of nuggets quoted by Mr. Brough Smyth, he says of the Welcome nugget, weight one hundred and eighty-four pounds nine ounces (Troy) that it was apparently water worn and contained about ten pounds of *quartz*, clay and oxide of iron.

The Blanche Barkley which weighed one hundred and forty-five pounds three ounces, apparently contained two pounds of *quartz*, clay and oxide of iron.

The next in his list weighed one hundred and thirty-four pounds eleven ounces, contained dark coloured quartz.

In fact he mentions the association of quartz with nearly all the very large nuggets, and expressly states that many of the smaller ones were free from quartz; as we might naturally expect.

Brough Smyth remarks that, "much stress is laid on the fact that nuggets are sometimes found at a considerable distance from a quartz reef"; but it may be, that the reef from which the nugget has been set free may have been completely denuded away, its matrix need not necessarily have been the nearest now existing reef. He quotes Ulrich's remarks in support of Selwyn's hypothesis of the formation of gold nuggets *in situ* in alluvial deposits: (*Notes on the Physical Geography, Geology and Mineralogy of Victoria* by Alfred R. C. Selwyn and Geo. Ulrich, Melbourne, 1866, p. 43), but points out that if such is the case in the present day, then the older sedimentary rocks ought from the greater lapse of time to contain large masses of gold. Moreover large nuggets are not confined to deep leads, but many have been found only a few inches below the surface. He also says that the statement that all the large nuggets have been found on the western gold fields where basaltic eruptions have been prevalent is erroneous, many large nuggets have been found remote from basaltic areas, and Mr. Birkmyre's list shows that the fields most remote from basaltic areas have produced the most large nuggets; in Gippsland if not large they are numerous.

Mr. G. Attwood in a paper on *Gold from Guayra, Venezuela, S. America*—(Journ. Chem. Soc. London, 1879, p. 427-9), concludes, from an examination of one particular specimen, that gold nuggets do gradually increase in size owing to the accumulation of fresh particles of finely precipitated gold.

Prof. Whitney, in a paper—*The Auriferous Gravels of the Sierra Nevada of California*, Cambridge, U.S.A., 1880.—says that "it does appear as if there was some truth in the idea that the finding of large pieces of gold in the gravel is not justified by what we see of the occurrence of the metal in the quartz. It is certain, at all events, that the form of the ordinary nugget is something different from that which is offered by the gold as originally deposited. In quartz it is either quite invisible or else it is scaly, foliated, filamentous, arborescent, or crystalline, quite unlike the rounded and smooth or flattened pieces met with in alluvial deposits." He, however, points out that this difference could be produced by attrition, and he thinks it highly improbable that masses of gold in gravel could be enlarged by any chemical influence.

The bark of some of the tree trunks found buried in the blue gravel (Cal.) is largely replaced by iron pyrites and this is rich in gold, "hence we cannot deny that some gold has been deposited in the placers from solution, but this certainly does not include the nuggets and gold dust." He also says, "if the gold of placers were deposited from solution, we should necessarily find much of it crystallized and forming strings and sheets running through the porous material; whereas, as a matter of fact, crystals are never found in placer gold, nor are sheets or threads. Scales, grains, pebble-like nodules, round battered masses, these are what we find."

Prof. J. S. Newberry, in a paper—*On the Genesis and Distribution of Gold* (Sch. of Mines Quarterly, III., New York, 1881), does not support Selwyn's hypothesis. He points out that a mass of vein gold was obtained, weighing ninety-five and a half pounds, and originally one hundred and forty pounds, from the Monumental Mine, Sierra Buttes, Cal., which proves that large masses do occur in veins as well as in the form of nuggets.

He thinks that the proportion of large masses from veins is quite equal to that from placers or alluvial deposits. The smaller proportion of silver in alluvial gold, he thinks, is accounted for by the greater solubility of silver in various solutions, and its consequent removal just as in the process of "pickling" by jewellers.

Other "nuggets" from veins might be cited *e.g.*, a mass of gold and quartz celebrated as Dr. Kerr's "hundred weight of gold" was found in 1851 in the Meroo or Louisa Creek, River Turon, N.S.W., at a place now known as Hargraves. Although in three pieces when discovered, it apparently had formed one mass; the three pieces weighed one and three-quarter hundred weight and yielded one hundred and six pounds troy of gold. Another mass of gold and quartz which yielded one hundred and twenty pounds of gold on being pounded with a hammer was found at Burrandong near Orange, in New South Wales, in 1858. Some very large masses of gold were found in Beyers and Holtermann's quartz reef at Hill End, N.S.W. From ten tons of quartz 102 cwt. of gold were said to have been obtained. (A. Liversidge—*Minerals of N. S. Wales*, p. 21, London 1888).

Walter B. Devereux, E.M., in a paper—*On the occurrence of Gold in Potsdam Formation, Black Hills, Dakota* (Trans. Am. Inst. Mining Engineers, 1881, p. 465), states that careful observation in the field and consideration of the facts have led him to reject the theory that the gold has been deposited in the conglomerates from solution, and he regards it as a purely mechanical constituent; but states, p. 471, that "the larger the grain of the alluvial gold the greater the amount of silver it contains."

Prof. Egleston, in his work upon *Metallurgy of Silver, Gold, and Mercury in the United States* (New York, 1887, Vol. II., p. 57) takes up the question of the origin of nuggets, and quotes a letter from Mr. Selwyn, 28th March, 1882, in which Mr. Selwyn stands by his original hypothesis as follows :—"The cause (*i.e.* of nuggets) was the percolation through the gold bearing strata of very large quantities of saline and acid thermal waters, during the period of great volcanic activity, which produced the basalts. This action accompanied, but to a great extent succeeded, the phenomena which produced the present placer deposits. This gold from meteoric waters deposited on that already in the sands, produced the nuggets. He further states that his opinion is confirmed by the fact that large nuggets only are found in the western gold fields, as at Ballaarat, Daisy Hill, &c., where immense basaltic eruptions had taken place all over the district. In the eastern and northern districts, as Gippsland, Ovens, &c., where streams of basalt occur only to a very limited extent, or are altogether absent, the gold is generally very fine, and nuggets over one ounce in weight are of the greatest rarity." Brough Smyth, however, states otherwise (see p. 311).

Prof. Egleston urges that in cases where the "gold does come from the destruction of veins, the surfaces are rounded and worn smooth." . . . "This is in entire contradiction to the mammillary structure of the nuggets." . . . They would have been water worn on the outside, and the cavities "would have been in the condition in which they left the vein, and the edges of any crystals found there would have been sharp; while in the nuggets the mammillary form exists even where crystals or the commencement of crystallisation is observed, the edges of the crystals are very often blunted or rounded, showing both deposition and solution on these edges."

Egleston also urges, as others have done, that if the gold had come from the eroded rocks it should have the same composition as that of the veins of the district in which it is found; whereas he says it is well known that vein gold is usually poorer than the alluvial gold of the same district, *e.g*,

—	California	Australia	Transylvania	Nevada
Nuggets	800 to 980	992·5 to 966	...	...
Veins............	730 to 860	...	600	333 to 554

Egleston states, " that the violence of the old placer currents was very much greater than that of the ordinary streams of these days," and that " if this were the whole process and no further action had taken place, the gold would have been found in the comminuted condition exclusively." Further " that, gold is, however, also found as nuggets, and in small particles in rocks which have never been disturbed from their original positions, but which have been decomposed to a considerable depth and it then has the same mammillary form, occupying positions which make it evident that it must have been formed *in situ*, and never have undergone any abrasive action. The nugget found in 1828 in Cabarrus Co. N. C., which weighed thirty-seven pounds, and also the one found in the valley of Taschku Targanka near Miask in Siberia, which weighed ninety-six pounds were both found under such circumstances in a decomposed dioritic rock. In some few cases it has been definitely ascertained that the gold has been dissolved and precipitated in the decomposed rocks, for it has penetrated only just so far as the decomposition has allowed it, the yield in gold ceasing entirely at the point where the rock allowed no further filtration; while in other rocks of a more porous nature in the same district the gold has penetrated to a depth not yet ascertained."

"There is a tradition prevalent in all the shallow placer gold mines of the south, and in those of some other districts, to the effect that gold *grows* from the *seed* gold which is not extracted, so that every few years the tails of the old mines are reworked, generally with a profit; the quantity separated each time, according to the local tradition, being in proportion to the length of time the material has remained undisturbed." This admits of an easy explanation, although Prof. Egleston does not offer one, viz., that the gold is, of course, not wholly removed by the ordinary processes of extraction, and some, although a smaller amount, is almost certain to be obtained by each successive treatment, moreover the material becomes more broken up by the further handling and weathering, and more gold is thus set free both mechanically and probably by chemical changes also.

He then cites, page 64, experiments of his own similar to Wilkinson's, Newbery's, and many others, to show that gold is precipitated from its solution as chloride by petroleum, cork, peat, leather, leaves, &c. The petroleum threw down long crystals of gold resembling Chester's hexagonal crystals, and the peat a mammillary mass resembling the form of nuggets.

He then tried, p. 65, the solubility of gold in solutions of salts; ammonium sulphate and chloride, potassium chloride and bromide placed in sealed tubes with spongy gold for eight months gave no reaction; on heating them for five hours at 150° to 200° C. only the potassium bromide gave a reaction.

Pure sponge gold was sealed up for three months with ammonium sulphide with no reaction; but both potassium and sodium sulphides gave black precipitates and a strong reaction for gold was given by the liquid in each case; the ammonium sulphide heated for six and a-half hours at 145° to 180° C. was unchanged but reacted strongly for gold; the solution of potassium sulphide also reacted and the glass was much attacked, further there was a black precipitate of gold; the sodium sulphide acted much more feebly. Other salts and solvents were used but with no very striking results.

He states, p. 72, that, "the same conditions which cause the solution of the gold in certain cases cause also the solution of the silica." And "many of the causes which produce the precipitation of the gold would also cause the reduction of soluble sulphates to insoluble sulphides, the gold being retained within the mass. This would account for the almost constant presence of gold in pyrites."

"No single agent is so powerful a solvent of gold as chlorine. Very few drainage waters are free from some compound of it, and no soil is without the nitrogenous materials necessary to set the chlorine free, and therefore capable of attacking the gold and rendering it soluble." . . . . "The readiness of filtration through the relatively easily permeated gravel causes the gold to precipitate so rapidly that there is no time for any but a mammillary deposit, which in vein deposits the extreme slowness of the deposition allows the gold to assume the crystalline shape."

Melville Attwood, E.M., in a paper—*On the Source or Origin of Gold found in Lodes, Veins, or Deposits* (Report of the State Mineralogist of California, 1884, Vol. VIII., p. 773) quotes that "M. Laur (*On the Origin and Distribution of Gold in California*, communicated to the Academy of Sciences, Paris) mentions having found metallic gold in deposits, *evidently* derived from some hot springs."

M. A. Daubrée, in his *Les eaux souterraines a l'epoque actualle* (Paris, 1887, p. 33) says:—"Plusieurs géologiques (MM. J. P. Laur, A. Phillips, et Egleston) ou cru reconnaître qu'en Californie de l'or se dépose encore actuellement, particulierement dans des graviers. On prétend aussi avoir trouvé ce metal dans l'eau de Louèche et plus récemment, d'apres Götll, dans l'eau de Gieshübl et dans celle de Carlsbad."

Posepny *Zur Genesis der Metallseifen* (Œsterr. Zeits. f. Berg. und Huttenwesen. 1887, XXXV.) is of opinion that the formation of large masses of gold in the vein are more easily accounted for than in alluvial deposits.

E. Cohen—*On the Genesis of Alluvial Gold* (Jahr. f. Min., 1889, i. Ref. 439-440 from Mit. Ver. f. Neuvorpommern u. Rügen, 19, 198) is of opinion that the greater part of alluvial gold is derived by the disintegration of older deposits, but that separation from solution also occurs in a subordinate manner.

Mr. H. P. Washburn in a paper entitled—*A Theory on the formation of Gold into Specks and Nuggets* (Trans. N.Z. Inst., 1889, p. 400) opposes the hypothesis that nuggets have been formed *in situ* in alluvial deposits.

Composition of Vein and Alluvial Gold.

In the preceding references there are several statements as to the greater purity of alluvial gold over vein gold, and this is by many assumed to be a proof that the nuggets and other forms of alluvial gold have had a different origin to the vein gold and that the alluvial gold has been deposited in the way suggested by Selwyn and other writers.

If we examine some of the assays of vein and alluvial gold, we shall see that there are differences but that they are not very material, and further the vein gold is sometimes richer than the drift gold.

Selwyn and Ulrich (*P.G. G. and Min. of Vict.*, 1866) p. 42, refer to the greater richness of alluvial gold.

D. C. Davis, F.G.S.—*Metalliferous Minerals and Mining* (London, 1880, p. 50) in speaking of "the gold bearing drift of the Sierra Nevada says, the particles of gold are found of larger size and contain more silver at the bottom than at the top of the ancient drift, and are worth less by two shillings and sixpence per ounce. It is supposed that their difference in quality is caused by the larger size of the fragments below resisting more effectually the action of sulphuric acid which, set free by the decomposition of pyrites, has eaten the silver out of the smaller grains at the top of the deposit.

He also says, p. 36, "Gold is most plentiful in it (drift in the Urals) where the drift is most largely charged with iron;" and Brough Smyth, in a *Report on the Gold Mines of the S.E. portion of the Wynaad, &c.* (London, 1880) states that "the gold obtained in the Wynaad is unequal in fineness, that from the soils being of the best quality. It has been observed in other countries that the finer the particles of the gold procured from alluvial deposits the higher is the quality."

P. Nisser—*On the Geol. Distribution of Gold, with special reference to some Auriferous Rocks in South America* (Trans. Phil. Institute, Vict., IV., 1860, read 30th March, 1859) points out

(p. 17) that in the province of Antioquia, North Granada, the gold from the veinstones differs very greatly from the alluvial gold: the former averaging $14\frac{1}{12}$ carats fine, and the latter eighteen to twenty-two carats. He states that W. Birkmyre found that vein gold from Clunes, Victoria, was poorer than the alluvial gold, and that the same thing was observed by other assayers; and he finally concludes that since the South American alluvial gold differs so much from the vein gold that it must have had a different origin.

Bernhard von Cotta in his treatise *On Ore Deposits*, New York 1870, in speaking of the placer deposits of the Urals, says that the gold is generally more or less argentiferous, the amount of silver varying according to G. Rose's examinations between ·16 and 38·74%. It has been sometimes thought that the placer gold was purer (less argentiferous) than that extracted from deposits *in situ*, but G. Rose has shown that such is not the case in the Ural Mountains. He found that the amount of silver was very variable in both cases, although the highest amount of silver was found in gold from veins, which contained even in the same lode very variable quantities."

Mr. Geo. Foord, F.C.S., of Melbourne, could find no difference between the quality of the internal and external portions of nuggets; but in one case he found a vein which was of a greenish-yellow in the centre, from the larger amount of silver present in that part of the gold.—Brough Smyth, *Gold Fields and Mineral Statistics of Victoria*, p. 359 – 60.

Mr. Birkmyre, p. 371 of the same work, points out that the "Welcome" Nugget weighing one hundred and eighty-four pounds nine ounces gave him 23 car. $3\frac{1}{8}$ grs. gold or 99·20%, or it was nearly as rich as the finest gold dust viz., 23 carats $3\frac{3}{8}$ grs.

The following analyses of gold from the North Transvaal, (E. Cohen, Jahr. f. Min. 1889) show a slight difference between the vein and the alluvial gold; but much importance cannot be attached to it:—

	Residue.	Ag.	Au.	Cu.	Fe.	Total.
1. Vein gold ...	·02	5·16	94·48	·25	trace	99·91
2. Alluvial gold	·78	6·49	91·38	·09	,,	98·74
3. ,, ,,	·07	5·64	95·16	...	,,	99·87
4. ,, ,,	·07	4·57	94·87	·11	,,	99·62

1. Vein gold, Button's reef, Marabastad, North Transvaal.
2. Alluvial gold, Button's Creek, derived from above.
3. and 4. Alluvial gold, in flakes and grains.

Experiments.

Freshly fractured pieces of the following sulphides were placed in cylinders of the photographer's gold toning solution (fifteen grains of the double chloride of gold and sodium in fifteen ounces of water) viz., iron pyrites, molybdenite, mispickel, galena, copper pyrites, blende, argentite, &c.

In some cases the sulphide reduced the gold at once and became gilt or coated with the reduced gold, either as a bright coherent deposit or else as a dull ochre-coloured one. Successive quantities of the gold solution were added from day to day as it became colourless, and in this way quite thick and strong deposits of gold were formed on the sulphides.

In the case of the molybdenite, MoS_2, the gold deposit was at first lustrous and metallic, but as time went on it became of a dead brown aspect, although this under the microscope was seen to be made up of brilliant metallic points of light. Blue and white oxides of molybdenum separated out.

The deposit on the mispickel was not compact and coherent like that on the molybdenite, galena, and other minerals, but loose and easily rubbed off.

The deposit on the iron pyrites was also bright and metallic looking at first but as it thickened it became dull and ochre-like in colour.

The deposit on the galena was similar to the above; under the microscope, the surface, as in other cases, is seen to be minutely mammillated, and it is on that account that to the unassisted eye, the gold has a dull brown or ochre colour.

The preceding experiments are not numbered because they are merely qualitative ones, but the next series of experiments were quantitative; weighed pieces of pure sheet gold were put up with various organic reducing substances; sulphides and other naturally occurring substances which I thought might form a galvanic couple, and which would throw down the gold from solution upon the plate as in the electroplating process.

A.—*With a Gold Nucleus and Organic Matter.*

In the following experiments, pure gold specially prepared by the late Dr. Leibius, Senior Assayer of the Sydney Mint, and assaying 1000 was rolled out into fillets of $\frac{1}{200}$ inch thick, so as to expose a large surface and yet be strong enough to handle, these were heated in a cornet crucible to burn off impurities and then boiled with nitric acid, and well washed to get rid of any sulphur or other contaminations from the gas flame. The nuggets and specimens of native gold used as nuclei were also cleaned in the same way. The fillets were next weighed and placed in stoppered glass cylinders with a solution of the sodium chloraurate, supplied for photographic purposes, and made up of the usual strength of a fifteen grain tube of the salt to fifteen ounces of water.

The reducing substances were similar to those used by Wilkinson, but as will be seen with results just the reverse of what he obtained, *i.e.*, the gold foil or other nucleus weighed less instead of more after the experiments.

Experiment 1—A water worn nugget was used as a nucleus the dust of the air was allowed to fall in, and the experiment was continued for one hundred and sixty-eight days, with an occasional addition of gold solution as the liquid in the cylinder became colourless from the reduction of the gold. Although a good deal of gold was precipitated on and around the nugget none of it was adherent, and on reweighing it was found to have lost 0 02 gramme.

Experiments 2 and 3—A plate of pure gold was used as a nucleus in each case, and the solution was exposed to the air as above; one plate lost ·0042 and the other ·0038 gramme.

Experiment 4, with cork.—The gold solution was left in a stoppered cylinder with a slice of clean new cork until the yellow colour of the solution had disappeared, showing that all the gold had been removed from it. Some gold was precipitated at the bottom of the cylinder, some on the sides, and a little floated as films on the top, there was also a small quantity of gold precipitated on the gold plate, but this was non-adherent and came away on washing the plate in a jet of water. This plate underwent no change in weight.

Note.—All of my experiments were carried out in full daylight, and not in the dark like those by Wilkinson, Egleston, and others.

Experiment 5, with Swedish filter paper.—The yellow colour soon disappeared from the solution, and the paper acquired a purple colour. The gold plate lost ·0036 gramme in weight.

Experiment 6, with phosphorus in ether.—The solution soon became colourless, and a black precipitate of gold was thrown down, on the bottom of the cylinder and on the gold plate. Floating films of gold also formed on the surface. On washing the gold plate with a jet of water all the gold deposited on it was washed away, and on drying and weighing it was found to have lost ·0004 gramme.

Experiment 7—In this case a freshly broken jagged fragment of gold in quartz was used as the nucleus instead of a gold plate, but cleaned with the same care. Cuttings from a cedar pencil and some scraps of paper were added, these acted in the same way as the cork and were "mineralized" by the reduced gold; the gold and quartz nucleus lost ·0021 grammes in weight.

Experiment 8—Paper and wood were used as in experiment 7, with a nucleus of jagged gold set free from quartz by means of hydrofluoric acid; the nucleus lost ·0013 gramme.

Experiment 9—Similar to experiment 8 with a nucleus of native gold from Sandhurst (Bendigo). This showed a loss of ·0001 gramme.

On incinerating the cork, cedar, &c., which had been used for reducing the gold, the residue retained the original form, but much shrunken and as has been observed by others, the microscopic structure of a cut section presents the appearance of burnished gold from the pressure of the knife.

No.	Nucleus.	Reducing matter.	Original weight of nucleus.	Weight of nucleus after experiment.	Difference in gms.	Number of days.
1	Nugget ...	dust from air ...	3·4920	3·4900	—·0020	168
2	Gold foil ...	„ „	1·5152	1·5110	—·0042	168
3	„ ...	„ „	1·1713	1·1675	—·0038	168
4	„ ...	with cork ...	1·1410	1·1410	none	273
5	„ ...	with filter paper	·8500	·8464	—·0036	273
6	„ ...	phosphorus in ether ...	·9330	·9326	—·0004	273
7	Gold in quartz	paper and wood	1·7630	1·7609	—·0021	58
8	Gold from „	„ „	2·8487	2·8474	—·0013	58
9	„ „	„ „	·6574	·6573	—·0001	58

The above experiments all show that instead of the nucleus or nugget of gold increasing in weight and size in the presence of organic matter, there is a decrease which is just the reverse of the effects obtained by Wilkinson, Daintree, and others.

The loss in weight of the nucleus may have been due to the removal of small quantities of impurity in the gold used as a nucleus, the native gold would of course contain silver and other impurities, but the gold foil was regarded as particularly pure by the late Dr. Leibius of the Sydney Mint, by whom it had been assayed. This will be the subject of further experiment, the point of chief interest at this stage is that the nuclei did not show any increase in weight.

B.—*With a Gold Nucleus and Inorganic Matter.*

Experiments from Nos. 10 to 49 form the third series, in which a galvanic couple was formed.

Experiment 10, with molybdenite.—No gold was visible on the molybdenite, but on closer examination some was seen between the cleavage planes of the mineral, and this under the microscope had a vermicular and matted structure. On removing the gold plate and cleaning with a brush, it was found to have increased ·0038 grammes in two months.

Experiment 11, with mispickel.—The solution was decolourised in twenty-four hours, and this went on continuously for many successive days. Increase in weight in fifty-nine days ·0006 gram.

Experiment 12, with mispickel.—The gold foil was stained nearly black on both sides, over about two-thirds its area; the black deposit had a blistered or mammillated structure, very marked under the microscope, and readily felt with the finger nail. It increased ·0260 gramme in fifty-nine days. The gold on the mispickel was also dull and mammillated, but in part showed traces of cubes joined in strings, and in one place there were hexagonal plates (microscopic) of bright lustrous gold.

Experiment 13, with mispickel.—The gold deposited on the mispickel was black and pulverulent, and without crystals. The gold on the gold foil was of a bronze-green tint. The plate increased ·0089 gramme in weight in nine days.

Experiment 14, with recent iron pyrites, Loffley's, Taupo.—Contained a very large quantity of ferrous sulphate and sulphuric acid, probably none of the pyrites left unoxidised. It reduced a very large quantity of the gold solution, but none was permanently deposited on the plate, and its weight remained unchanged. On dissolving out with hydrochloric acid, a residue of spongy gold was left together with some particles of a white mineral, probably silica, as the springs at Loffley's deposit this mineral.

Experiment 15.—With cubical iron pyrites. Decolourised in twenty-four hours. The gold foil or plate was dull from the gold which had been deposited upon it. Increase in weight ·0028 gramme in fifty-nine days.

Experiment 16, with pyrites, Joshua's Spa, Lake Taupo, N.Z.—Several charges of gold solution were reduced. The foil was blackened, and a black powder came away on rubbing with the finger, but some permanent brown coloured gold was left on the foil. The foil increased ·0060 g. in weight in fifty-nine days.

A certain amount of loose gold was thrown down with some of the minerals, but no account was taken of this, as the chief object was to ascertain whether a nucleus of gold would have a coherent film of gold deposited upon it when the nucleus formed one element of a couple, and this was found to be the case—the deposit of gold on the foil was usually of a dull reddish-brown colour, felt rough to the nail, and under the microscope was seen to be mammillated, and when rubbed with a hard substance like agate or a glass rod, presented a series of bright points.

Experiment 17, with iron pyrites.—Part of an uncrystallised mass. The coating of gold was dull, with here and there a bright speck, something like the hexagonal plates on the copper pyrites; but the outlines rather irregular; bright gold also along the cracks in the pyrites. The deposit on the plate was of a full copper colour, very rough, and weighed ·0708 g.

Experiment 18, with iron pyrites.—Part of a pentagonal dodecahedron, acquired a dull brown deposit of gold, but no crystals were detected. A similar brown film on the plate increased ·0633 g. in weight.

Experiment 19, with rhombic iron pyrites or *Marcasite.*—Became coated with dull brown gold which gave it the appearance of a coating of rust, there were a few bright specks but no distinct crystals of gold. The gold plates acquired a bronze colour, with a greenish shade, became rough and increased ·0328 g. in weight.

Experiment 20, with brown hæmatite.—Decolourised several charges. Foil became dull and increased ·0003 g. weight in fifty-nine days.

Experiment 21, with limonite.—Decolourised seven ounces of the gold solution. Foil became dull and increased ·00025 g. in weight in fifty-nine days. The deposited gold was dull and mammillated.

Experiment 22, with rust.—A mixture of black and brown oxides from old sheet iron. The gold foil became very dull and dirty looking. Increased ·0011 g. in fifty-nine days. On dissolving the residue in hydrochloric acid, only dark coloured spongy gold was left.

Experiment 23, with yellow copper pyrites.—After fifteen days the gold plate was dull from deposited gold. Increase in weight, ·0059 g. in fifty-nine days.

Experiment 24, with copper pyrites.—Reduced several charges of the gold solution. The foil became deeply stained, and acquired a rough appearance and feel, of the usual brown colour; under the microscope it was seen to be much mammillated; and increased ·0185 g. in weight in fifty-nine days. A large amount of gold was also thrown down on the pyrites, which under the microscope was seen to have a matted vermiform appearance; a certain amount of loose powdery gold was also precipitated.

Experiment 25, with copper pyrites, Walleroo, S.A.—The deposit of gold was almost black but mixed with it were a few very bright microscopic hexagonal plates of gold. The deposit of gold on the plate was very rough and almost black in places, and it had increased in weight ·0666 g.

Experiment 26, with redruthite (copper subsulphide).—The gold was deposited on the sulphide as a black powder, with a little dull yellow in parts. The gold plate became of a dull brown colour near where it had been in contact with the mineral, the upper part was merely stained. Increase = ·0836 g.

Experiment 27, with silver sulphide (argentite).—No change for some time, but between June 28, and November 30, it reduced five ounces of the gold solution and became coated with gold. Some of the gold was crystallised in microscopic imperfect hexagonal scales. The gold plate increased ·0083 g. in one hundred and fifty-five days.

Experiment 28, with fused artificial silver sulphide.—The gold deposited upon it was vermiform, and a thin coating of dead gold formed on the plate, which increased ·0082 g. in weight in nine days only.

Experiment 29, with galena.—The cleavage planes became gilt almost immediately, *i.e.*, in a minute or so; without the gold nucleus the gilding takes an hour or two. As the deposit of gold thickens it loses its brilliancy. After a fifteen days action the gold plate had become dull from the gold deposited upon it; increase ·0049 in fifty-nine days.

Experiment 30, with galena, Broken Hill, N.S.W.—The gold deposited on the galena was black, but brown in places, with a few rectangular specks of bright gold; some lead sulphate had also formed. The gold on the gold plate was of a copper colour. The foil increased ·0281 g. in weight.

Experiment 31, with zinc blende.—Decolourised several charges. The foil was unchanged. On dissolving the blende, much dull spongy gold was left mixed with a few bright crystallised points seated on the gold, one St. Andrew's cross was very distinct, also some with six rays, but all microscopic.

Experiment 32, with zinc blende.—Increase in weight of plate was ·0086 g. Mixed with the dull vermicular gold on the blende were scattered hexagonal crystals of bright gold.

By vermicular or vermiform gold is meant a more or less close net work of worm-like rounded and irregular threads of gold, which eventually coalesce in the thicker deposits and form a mammillated surface.

Experiment 33, with graphitic casing from an auriferous vein.—It decolourised two ounces of the solution in five days and successive quantities afterwards. The surface of the graphitic casing became completely coated with a very thick deposit of dark coloured mammillary gold, but in a few places were some minute crystals of bright gold showing up most brilliantly; they appeared to be hexagonal plates. The gold foil did not show any increase in weight.

In this instance as well as in that of the coal, graphite and charcoal, the gold appeared to be thrown down entirely upon the precipitants, and none came down as a loose powder nor upon the sides of the glass vessel. The miners at Ballaarat and other places attach a good deal of importance to the graphite casing of veins, and speak of it as the "indicator." It usually contains iron pyrites; the carbon and the pyrites together reduce the gold very quickly.

Plates of pure gold, cleaned by ignition and boiling potash, were also placed in photographer's gold solution with the following non-metallic substances; they were shaken daily and refilled with fresh gold and sodium chloride solution as often as the solution became colourless.

Experiment 34, with graphite, Ceylon.—Decolourised several charges of solution. The gold plate was frosted (moiré métallique) on one side, and had increased ·0001 g. in fifty-nine days.

Experiment 35, with charcoal.—Decolourised many successive two ounce charges of gold solution, and the charcoal became thickly coated with dull brown gold, under microscope this was seen to be mammillated. The plate increased ·00005 g. only in fifty-nine days.

Experiment 36, with coal powder.—The gold plate was still bright when removed, on the 31st May 1893, *i.e.*, after thirty-five days, and had lost ·0019 g. On burning off the coal spongy brown gold was left mixed with the coal ash.

Experiment 37, with white sandstone, Sydney.—The gold plate gradually acquired a frosted appearance and became stained of a dull brown colour. Under the microscope the frosting was seen to be due to the gold having crystallised in the same way that zinc crystallises on galvanized iron and tin in the moiré-métallique; the crystals on the gold plate were nearly all square or rectangular in outline and about 1 mm. across. From April 26 to May 31, 1893, the plate increased ·0007 gramme in weight.

Experiment 38, with reddish coloured sandstone, Sydney.—Foil became very dull and acquired a rough incrustation of gold. The foil increased ·0060 g. in weight in fifty-nine days.

Experiment 39, with sand, from April 26 to June 1.—Although one charge of two ounces of the gold chloride was decolourised and another about half decolourised, the plate underwent no change in weight. The solution was doubtless reduced by organic matter present in the sand.

Experiment 40, with gravel, from Bingera Diamond Mines.—Solution not decolourised, but the plate lost ·0008 g. in fifty-nine days.

Experiment 41, with wash dirt, Inverell, N.S. Wales.—Minute flakes of bright gold were found intermingled with the clay from this dirt. Foil increased ·0003 g. Decolourised two charges, *i.e.*, four ounces of the solution.

Experiment 42, with granite, Hartley, N.S.W.—Foil became dull and stained on one side, and had increased ·0006 g. in weight in fifty-nine days.

Experiment 43, with granite, Hartley, N.S.W.—The powder of this granite turned brown like a pale clay; the foil became dull, much stained, and increased ·0002 g. in weight in fifty-nine days.

Experiment 44, with white quartz.—Decolourised two ounces of the solution, and a second two ounces partly; increase in gold plate, ·0002 g. in fifty-nine days.

Experiment 45, with clay, University Paddock.—Decolourised several charges. Foil became dull, and increased ·0019 g. in weight in fifty-nine days.

Experiment 46, with statuary marble.—This decolourised two ounces of the solution before the addition of the gold plate and several successive charges after; the plate darkened in colour and increased ·0002 g. On dissolving the marble in hydrochloric acid a residue of brown mammillated gold was left.

Experiment 47, with apatite, Canada.—As the solution was not decolourised after two hundred days, the gold foil was not reweighed.

Experiment 48, with serpentine, containing a little magnetite.—Decolourised four ounces of gold solution, but the plate only showed an increase of ·0001 g. in fifty nine days.

Experiment 49, with plate glass, in powder.—Before the plate of gold was added the glass reduced two ounces of the solution; and on June 1 it had reduced the second two ounces. The plate increased ·00005 g. in weight in fifty-nine days.

No.	Name of substance placed with the gold plate.	Difference in weight in g.	Length of Experiment
10	Molybdenite	+ ·0038	59 days
11	Mispickel	+ ·0006	59 ,,
12	,, ...	+ ·0260	59 ,,
13	,, ...	+ ·0089	9 ,,
14	Recent iron pyrites, Loffley's	none	59 ,,
15	Cubical iron pyrites	+ ·0028	59 ,,
16	Iron pyrites, Joshua's Spa.	+ ·0060	59 ,,
17	Iron pyrites	+ ·0708	9 ,,
18	Iron pyrites	+ ·0633	9 ,,
19	Rhombic iron pyrites or *Marcasite* ...	+ ·0328	9 ,,
20	Brown hæmatite	+ ·0003	59 ,,
21	Limonite	+ ·00025	59 ,,
22	Rust	+ ·0011	59 ,,
23	Copper pyrites	+ ·0059	59 ,,
24	Copper pyrites	+ ·0185	59 ,,
25	Copper pyrites, Walleroo, S.A.	+ ·0666	9 ,,
26	Redruthite (copper subsulphide) ...	+ ·0836	9 ,,
27	Silver sulphide (argentite)	+ ·0083	155 ,,
28	Fused artificial silver sulphide	+ ·0082	9 ,,
29	Galena	+ ·0049	59 ,,
30	Galena, Broken Hill, N.S.W.	+ ·0281	9 ,,
31	Zinc blende	none	59 ,,
32	Zinc blende	+ ·0086	9 ,,
33	Graphitic casing	none	
34	Graphite, Ceylon...	+ ·0001	59 ,,
35	Charcoal	+ ·00005	59 ,,
36	Coal powder	—·0019	35 ,,
37	White sandstone, Pyrmont	+ ·0007	35 ,,
38	Sandstone, reddish	+ ·0060	59 ,,
39	Sand	none	36 ,,
40	Gravel, Bingera Diamond Fields, N.S.W.	—·0008	59 ,,
41	Wash-dirt, Inverell, N.S.W.	+ ·0003	9 ,,
42	Granite, Hartley, N.S.W.	+ ·0006	59 ,,
43	Granite, Hartley, N.S.W.	+ ·0002	59 ,,
44	Quartz, white	+ ·0002	59 ,,
45	Clay, University Paddock	+ ·0019	59 ,,
46	Statuary marble	+ ·0002	59 ,,
47	Apatite, Canada	none	200 ,,
48	Serpentine	+ ·0001	59 ,,
49	Plate glass	+ ·00005	59 ,,

The above table shows that in forty experiments there was a loss of gold from the nucleus in two cases, in five others there was no change, but in thirty-three there was an increase in weight, this increase varying from ·00005 g. to ·0836 g. The heavier deposits could be separated as a continuous film by bending the gold plate backwards and forwards a few times.

The foregoing experiments show that gold is deposited from solution upon a nucleus of gold in contact not only with metalliferous sulphides and arsenides, which form strong galvanic couples but also with such substances as iron oxides, charcoal, graphite, sandstone, granite, quartz, clay and marble, which form but weak galvanic couples with the gold plate, and as we might expect, the deposition goes on more slowly in the latter cases. In Daintree's experiment the glass of the bottle may have formed a couple with the gold fragment.

Gold in Natural Waters.

Very little is accurately known as to the solution of gold by natural waters, we know, it is true, that gold has been deposited from solution, and we also know that its deposition from such is still going on, and several references are made to its deposition in this paper, but the search for gold in meteoric and mine waters has not met with satisfactory results; the analyses which have been made do not absolutely prove that gold is present in solution, the presence of gold has been detected but it may have been held there mechanically. Accordingly I have thought that it would not be amiss to give a brief resumé of the papers which I have come across upon this matter.

In the case of sea water, however, E. Sonstadt published a communication in the Chemical News, Oct. 4th, 1872, upon the presence of gold in sea water, and stated that he had not determined the amount, but that it was less than one grain per ton. A letter appeared from him upon the same subject in the Chemical News of March 11th, 1892, confirming his previous statement, both as to its presence and to the smallness of the amount, "being far less than one grain to the ton."

The presence of gold (and silver) in sea water as alleged by Sonstadt is confirmed by the presence of gold and silver in the sheathing from old vessels and piles—one specimen which I examined from a vessel which had long traded along the Australian coasts, contained traces of gold and silver, but in much larger proportion than one would expect in Muntz metal, but as none of the unexposed metal could be obtained, the difference or increase if any could not be determined.

The sheathing was dissolved in pure sulphuric acid and the insoluble residue examined for gold and silver; with the lead sulphate was a comparatively large quantity of iodine, the latter evidently derived from the sea water. Lately I have obtained through the kindness of Mr. C. W. Darley, Engineer-in-Chief for Harbours and Rivers, specimens of sheathing from piles in various places along the coasts of New South Wales so that the age and conditions of exposure of the sheathing are known, and he has also been good enough to have plates of Muntz metal attached to piles in the following places, viz:—at Newcastle and on the Richmond, Clarence, Macleay, Shoalhaven and Moruya Rivers; and a section through the plate has been sent to me to determine the silver and gold before immersion in sea water, so that when the immersed plates are analysed after a certain number of years time, any accumulation of gold and silver can be rigidly determined.

One of the earliest writers in Australasia, the Revd. W. B. Clarke, M.A., in his *Southern Gold Fields* (Sydney 1860) in a letter to the *S. M. Herald*, 15th June, 1858, says p. 55, "It, *i.e.*, gold, is elaborated by vegetable growth in soils where there are no pretended geological indications; it is found occasionally in rain water; it may, for anything I know to the contrary, exist in the air, vapourized and afloat, as reguline."

Gustav Bischof, in his *Elements of Chemical and Physical Geology* (Car. Soc. 1859, Vol. III., 534) says: "A silicate of gold may be prepared artificially, and it appears that under certain circumstances it may be dissolved in sensible amount. The . . .

quartz associated with gold certainly originates from the decomposition of silicates in rocks, and it may be conjectured that the gold has the same origin, possibly existing as silicates."

I have verified Bischof's statement by digesting gold leaf with sodium silicate and potassium silicate solutions under a pressure of ninety pounds to the square inch, and found that the solution gave a brown precipitate with oxalic acid, and that this acquired the metallic lustre and colour of gold under a burnisher.

The reduction of gold chloride in solutions of sodium and potassium silicates, also mentioned by Bischof, was verified, but I do not attach much importance to these experiments, for gold chloride is so easily reduced that its reduction is brought about by almost anything; the fact that gold is dissolved by sodium silicate is a matter of much greater importance. The solution in sodium silicate turned blue in about thirty minutes, that in potassium silicate took a longer time, and the separated gold was of a reddish tint.

J. Cosmo Newbery states that an amethystine colour is sometimes seen in quartz reefs and in wash dirt. Aplin, at Beechworth, Victoria, found that such clay, after exposure to light, lost its colour and showed the presence of gold although none was visible before; a successful miner, Clement, observed the same thing at Maldon. This appears to indicate that the clay was moistened with a solution of a gold salt. No chemical examination was, however, made.

Lock (p. 558) quoting from Prof. Hutton *On the Thames Gold Field*, says: "Of the time when the veins were first charged with gold, Hutton can offer no opinion; but there are one or two facts which make it appear probable that gold is still in circulation through the rocks. . . . . In the Niau claim, above the Hokianga, on the Karaka, open quartz veins are seen partly filled with black humus that has filtered down from the vegetable soil above and this humus, on being carefully washed, yields fine gold, which Hutton supposes had been precipitated from solution by the organic matter of the humus."

C. Dölter, *Solubility of Minerals* (Monatsb. II., p. 149), found that gold at 200 C. in a sealed tube with a 5% solution of Na_2CO_3 or Na_2SiO_3 is dissolved to the extent of 1·5% of the weight of the gold taken.

Bischof also found that gold sulphide is slightly soluble in meteoric waters, and still more soluble in a saturated solution of hydrogen sulphide; and that it is also slightly soluble in persalts of iron.

Newbery tested this by dissolving gold sulphide in a weak solution of an alkaline bicarbonate, and found that on introducing a chip of wood and a cube of pyrites that the gold was deposited on the pyrites. (See his paper *On the Formation of Nuggets*, Roy. Society, Victoria, 1868).

I find that gold foil is attacked by a strong solution of sodium sulphide, in nine days a fillet of gold foil exposing about four square inches of surface, and weighing ·6181 gramme, lost ·0021 gramme. Gold leaf treated with sodium sulphide still more readily yielded a solution containing gold.

R. Daintree in his *Geology of the Ballan District, Victoria*, 1866 says:—"I had long come to the conclusion that most, if not all, the gold in the quartz reefs was derived from the rocks in which these reefs occur. That the strata themselves received their supply of gold at the period of their deposition from the ocean in which they were deposited. That the organic matter and the gases generated therefrom on decomposition, sulphuretted hydrogen &c. were the cause of the precipitation; and that the amount of metallic deposit was in proportion to the amount of organic matter deposited with the organic sediment."

Sir. W. Logan says, (quoted by Daintree) "The observations among the gold bearing rocks of the Southern States seem to show that the precious metal was originally deposited in the beds of various sedimentary rocks, such as slates, quartzites and limestones, and that by a subsequent process, it has been, in some instances, accumulated in the veins which intersect these rocks."

An additional proof of the solubility of gold in natural waters is given in *A treatise on Ore Deposits* by Bernhard von Cotta. Translated from the second German Edition, New York, 1870, p. 198, says, "the gold at Eisenberg near Corbach, Rhine, occurs partly in the clefts of the quartz siliceous slate in thin dendritic incrustations; or (and this is the most common occurrence) it encrusts the very small rhombohedrons of spathic iron, which are found on the limestone incrustations of the clefts; these consequently have the appearance of gold crystals."

Orville A. Derby, in a paper on *Peculiar modes of occurrence of Gold in Brazil*, (Am. Jour. Sci., Dec. 1884, p. 440) affords still another example of the recent deposition of gold from solution. In this paper an account is given of a specimen of gold on limonite from Ponte Grande, Sabara, Minas Geraes. The limonite is botryoidal, lustrous, in parts of an iridescent bronzy colour and in others black and brown, and on various parts of the specimen are minute detached films of gold; the author points out that these films of gold have apparently been deposited from solution upon the limonite, which is also a mineral of aqueous origin.

Similar thin films of gold as thin as gold leaf are seen on the limonite at Mount Morgan, Queensland, and upon quartz at Oura near Wagga Wagga, New South Wales.

J. Cosmo Newbery, B.Sc., in a paper *Upon the Mineral Waters of Victoria*, (Trans. Roy. Soc. Vict., 1867, p. 278) gives the analyses of several mineral waters, and amongst them those of certain auriferous quartz mines of Maldon, which are remarkable for the large quantity of potassium chloride present, but gold in solution does not appear to have been met with. He investigated the question of the presence of gold in the waters of gold mines; and found gold in mine timbers, boiler deposits, etc., but stated that it was difficult to make sure that the gold had not found its way in mechanically. Other observers also have failed to prove the presence of gold in solution in mine waters by chemical tests.

Plates of copper connected with a battery were placed in mine waters, but although gold was found on the crust which coated them, the trial could not be relied on as the copper was not tested before the experiment was started.

The following quotation from Sterry Hunt is still another proof that gold does exist in solution in natural waters :—" I have in my possession a portion of a small trunk taken from the mud of a spring in the province of Ontario, in which the yet undecayed wood of the centre is seen to be incrusted by hard and brilliant iron pyrites. In like manner the trees found in the New Jersey sandstone became incrusted with copper sulphide, which, as decay went on, in great part replaced the woody tissue. Similar deposits of sulphides of copper and of iron often took place in basins where the organic matter was present in such a condition or in such quantity as to be entirely decomposed, and to leave no trace of its form, unlike the examples just mentioned. In this way have been formed fahlbands and beds of pyrites and other ores. The fact that such deposits are associated with silver and with gold leads to the conclusion that these metals have obeyed the same laws as iron and copper. It is known that both persalts of iron and soluble sulphides have the power of rendering gold soluble, and its subsequent deposition in the metallic state is then easily understood."—*Chemical and Geological Essays*, 2nd Edition, 1879, p. 232.

J. C. Newbery analysed similar recent tree trunks from the Victorian Gold Fields, converted into pyrites, and found gold present.

In 1876, when in New Zealand, I collected some iron pyrites, from a hot spring at Taupo, which was being deposited upon some twigs and branches of wood, the wood was much decayed, black, and quite rotten, but it still retained its form and character. The iron sulphide was on assay found to contain traces of gold, which must have been in solution in the water.—(Jour. Roy. Soc. N.S. Wales, 1877, p. 264). The waters from the Hot Springs occurring in different parts of New Zealand, have been carefully analysed from time to time by Mr. Skey, F.C.S., Government Analyst, but I think that gold has not been detected in any of them, although we know it must be there, because it is contained in the pyrites deposited from the waters, by decaying organic matter reducing the sulphates in solution.

The following extract from the *Mining and Metallurgy of Gold and Silver*, by J. Arthur Phillips. Foot-note, p.p. 10, 11, is given because it refers to the recent deposition of gold from solution and apparently also by volatilization :—

"The moulds of cubical crystals of iron pyrites are frequently found in the quartz of auriferous veins, and more particularly so near the surface, thus showing that the formation of the pyrites must have been as old as that of the vein itself. In such cases, although the iron has often been entirely removed by chemical action, the cavities left sometimes contain finely divided gold, obviously liberated by the decomposition of pyrites. The gold contained in crystallised pyrites enclosed in quartz, is readily rendered apparent by placing the specimen, for a few hours, in a warm place in nitric acid, by which the pyrites is dissolved, and finely powdered or filiform gold will partially occupy the resulting cavities. With regard to the age of auriferous quartz veins, it has been already shown that many of them must evidently be of comparatively recent date, but in some cases the deposition of gold bearing quartz would appear to be taking place even at the present time. At Steamboat Springs, near Virginia, in the State of Nevada, and in other localities on the Pacific Coast, numerous parallel deposits of quartz, assuming the form of veins, are taking place along a line of boiling springs now in a state of great activity. The quartz from this locality exactly resembles that of the ordinary auriferous quartz veins of California, and besides small quantities of iron and copper pyrites, contains oxide of iron and traces of manganese. On making an examination of this quartz for gold and silver, we were unable to find an appreciable quantity of either of these metals ; but Mr. Laur, who made a similar investigation of this quartz, succeeded in finding specimens containing small quantities of gold.—(Annales des Mines, Sixiéme Série, iii. p. 421.) These facts would, therefore, not only tend to lead to the conclusion that auriferous veins are under certain conditions deposited from siliceous solutions, but also to explain the action by which many of the slates of the auriferous period may have become metamorphosed and silicified."

"We are indebted to Dr. Oxland, formerly manager of the works belonging to the Borax Lake Company, Lake County, California, for the following note on the occurrence of gold and silver in that locality:—"In the Sulphur Bank at Borax Lake, sulphur is constantly in course of formation, with the evolution of aqueous vapour, carbonic acid, and boracic acid, but without any sulphuretted hydrogen, which might have been expected to be present. The smell of carbonic acid is remarkably pungent. The gaseous matters issuing from the "Soffioni" in gentle blowers are usually at the temperature of about ninety-five degrees Fahr. They appear to be the agency by which gold, silver, mercury, and iron are brought up from below and deposited in cavities near the surface. Sulphur is deposited on the sides of the cavities, either in groups of crystals or in highly translucent amorphous masses of a beautiful light lemon-yellow colour. Sometimes the sulphur is intermixed with cinnabar, but more frequently with very fine crystals of iron pyrites, and with pulverulent silica in masses blackened by some hydro-carbon which is difficult to isolate. The iron pyrites may be separated by dissolving off the sulphur with bisulphide of carbon, and washing off the silica with water. It is found associated with silver and a trace of gold.

"On the sides of the cavities of the blowers, gelatinous silica is sometimes found coating opalised silica in varying degrees of induration, according to its depth from the surface, presenting examples of opal or hydrated silica in its various stages of formation, from gelatinous silica up to the hardest opal. The indurated silica is sometimes colourless, but is more frequently permeated with cinnabar or iron pyrites, and blackened by the tarry matter before alluded to. Sometimes from a diffusion of cinnabar throughout the mass in minute quantity, it is delicately tinted of a pinkish colour. The cinnabar is also found in striæ, and occasionally even in veins and concretionary masses of some thickness. Where the bituminous matter occurs in the largest quantity, and the mass is quite black and friable, cinnabar is replaced by metallic mercury.

"In another locality of similar character, about ten miles distant, gold has been found with cinnabar in crystalline masses of some size. In the same place, a vein of apparently compact quartz, about ten inches in thickness, was found to be so friable that it could be easily taken out with the hand in small conchoidal fragments, most of which rapidly fell into fine powder. From its great resemblance to a vein occurring in the Mexican Mine, Virginia City, which is many feet in thickness, and contains $20 to $30 of gold and silver to the ton, attention was drawn to it, and it proved on being assayed, to contain with a trace of gold, to the value of $15 per ton.

"These phenomena present indubitable evidences of the volatility of gold, silver, mercury, and iron, in presence of aqueous vapour associated with sulphuretted hydrogen, carbonic acid, and boracic acid. Whether the contemporaneous association of these substances may produce a definite compound possessing peculiar powers of solution and volatilization under the influence of elevated temperature, although probable, yet remains to be proved."

Conclusion.

When the metallic sulphides and arsenides are used to reduce the gold solution, there is no real necessity for the gold plate or nucleus, since the film of gold which immediately forms on the mineral acts as the negative element of the couple ; but it is convenient to use the gold nucleus, inasmuch as the gold is deposited more quickly, and in a form convenient for weighing, as it is free from admixture with other substances, the nucleus merely requires to be washed, dried and weighed. When substances like powdered granite, glass, clay, sandstone, etc. are used, the gold plate or nucleus is necessary to form the galvanic couple, (although a weak one) and to collect the gold.

The gold reduced by means of phosphorus in ether from very dilute solutions has quite a different appearance to that reduced by the sulphides and other substances given in the preceding experiments, the gold is reduced in such a finely divided state that it imparts a blue or purple tint to the water, and may take many years to completely precipitate and yield a clear solution. Some which I precipitated as far back as 1884 still have the gold in suspension. (A. Liversidge—*On the Removal of Gold from Suspension and Solution by Fungoid Growths.*—Report of the Aust. Assoc. Advt. of Science, 1890, p. 399, *et seq.*)

When the solution of gold is stronger, the gold comes down more quickly, and after a time becomes more or less crystallised, as in the following case :—The gold reduced from a one per cent. solution of the chloride of gold and sodium by phosphorus in ether, and which had been standing from September 1889 to April 28, 1893, or three and a-half years, was seen under the microscope to be made up of a mass of narrow ribbons of gold—more or less matted together. The ribbons were of bright, lustrous, metallic gold, and fairly uniform in size ; mixed with them were a few rounded particles or beads of gold and some octohedral crystals.

In another and weaker solution (fifteen gn. of the double sodium and gold chloride to fifteen ounces water) which was also allowed to stand for three and a-half years, from October 1889 to April 1893, the gold was deposited in the form of masses of octohedrons, more or less well formed and large enough to be seen with an ordinary pocket lens.

In the preceding experiments only the difference in the weight of the nucleus is taken into account, the amount of gold reduced and deposited upon the sulphide or other reducing agent is neglected; in some cases the quantity was very large, but no attempt was made to ascertain the amount as the results were not required in this investigation. The question to be answered by the experiments was merely whether a nucleus of gold immersed in a solution of gold and in the presence of, or in contact with, a substance (such as might be met with under natural circumstances) would increase in weight, this has been answered in the affirmative, and I think we can safely say that a nucleus of gold in an alluvial deposit or in a vein in contact with any of the foregoing substances or other similar bodies, would tend to increase in size so long as the supply of gold in solution was maintained, and that masses as large as the largest known nuggets, or indefinitely larger, might be so formed. My own opinion, however, in spite of this is that the large nuggets have not been so formed, but have been set free from veins, and have acquired their rounded and mammillated surfaces by attrition; the main outline being due to the original form of the mass when liberated from its matrix. Nuggets may have also received deposits of gold from solution, but such deposits have I think made no material alteration in the size of the larger nuggets.

The advocates of the hypothesis is that the large nuggets have been formed *in situ*, support it by the following amongst other arguments :—

1. That the large nuggets have been found to have a different chemical composition to the vein gold.

Undue weight seems to have been attached to this, the dissimilarity in composition between nuggets and vein gold is usually but small and immaterial, and sometimes the vein gold is even richer than the alluvial. The variations certainly do not show that the nuggets have necessarily had a different origin.

With finely divided alluvial gold there is a greater difference in composition, this may be due to the silver and other impurities having been partly removed by solution, the greater surface exposed by the gold dust and grains would of course facilitate their elimination.

2. That the large nuggets have all been found far removed from the nearest vein. This is an argument of no great importance; and it is already answered in the preceding pages; the reef from which they have been derived may have been entirely denuded away or so covered with other material as to be inaccessible.

3. It is urged that if nuggets had been derived from veins that their forms would be different, and especially that they would retain traces of crystalline form and roughness within the cavities, and would not possess mammillated surfaces.

As I have pointed out in another paper, (*On the Condition of Gold in Quartz Veins*, p. 301) it is very unusual to find any trace of crystalline structure in the gold set free from veins. Roughness of course, we do meet with in vein gold, but when the gold weathers out from the reef this is gradually lost by abrasion; the projecting points of soft malleable gold are flattened down and rounded off rather than ground away in powder, as in the case of hard and brittle substances, and the nuggets would necessarily acquire a mammillated appearance.

It is quite true that heavy nuggets would not be so easily carried by currents as ordinary pebbles and boulders, still they would be moved and rolled occasionally, by masses of rock forced against them, also by being undermined and falling over; further, although perhaps not moving much themselves, they would be subjected to nearly as much abrasion by the constant attrition of other and lighter pebbles grinding over them. The cavities in such nuggets would also be smoothed off and rounded out by the constant stream of water-borne sand and pebbles searching every crevice, acting much like the sand blast, but less quickly; as the nugget fell over from time to time all parts of its surface would be abraded in turn.

To bring this about, I do not think it is necessary to assume with Sir Roderick Murchison and Prof. Egleston, that the violence of the old currents was greater than that of those of the present day; when in flood, streams of the present day are quite powerful enough to shift, in the manner described, the largest nugget which has yet been found; even in their normal condition existing streams would eventually bring about the form and general appearance possessed by nuggets.

4. It is stated that large nuggets are much more common than large masses of gold in veins. As I have already shown, large

masses, nearly equal in weight to the largest nuggets, have been met with in veins, and probably will again; the gold found in alluvial deposits may represent the contents of hundreds of feet (in height) of vein stuff which has been removed by denudation.

The vein-stuff removed by the miner is infinitesimal in comparison with the amount which has been removed by geological agencies, and if we could by any means make a fair comparison between the two, we should probably find that the proportion of large masses met with in veins is not unequal to that found in alluvial deposits.

After answering the arguments brought forward to show that nuggets have had a different origin to vein gold, many reasons may be brought forward to show that nuggets have been derived from veins. It has already been pointed out that all the large nuggets have had more or less quartz attached to them, which shows that they have either been set free from quartz veins or else that the two substances had been deposited together in the alluvial, and as we have no proof of quartz, *i.e.*, of the particular kind associated with gold nuggets, being deposited otherwise than in reefs, the latter explanation is hardly tenable.

Many of the water worn quartz boulders, pebbles, and sand found with gold are admitted to have come from gold bearing rocks and reefs, that being so, why should we seek for another origin for the associated water worn pebbles of gold?

Further if it be contended that all the large nuggets have been formed *in situ*, from gold in solution, then we may ask, what has become of the large masses of gold which must have been set free from the veins by denudation? Masses, which we know must have been comparable to the largest nuggets, for several such have been mined, and as Prof. Whitney has pointed out,—why is alluvial gold not found as plates and strings if it has been deposited *in situ?*

There is no doubt in my mind, first that gold is present in meteoric waters, although, as already stated, no absolute chemical proof of its presence has been brought forward (except in the case of sea water), for it is found in recently formed pyrites and other deposits, and could only have got there from solution. In sea water it is thought to be held in solution by iodine, but its condition in land waters is uncertain, it may be as chloride, sulphide, silicate, or other compound.

The recently formed pyrites containing but a trace of gold might, in theory, eventually be wholly replaced by a mass of gold possessing a mammillated structure and the appearance of a nugget, but practically I do not think this has occurred.

Artificial nuggets of quite large size, I am sure, could be made in a few years by almost any of the methods followed for obtaining thin films of gold on sulphides, plates and particles of gold as detailed in this paper, and I think that in places gold is being so deposited at the present day, but I feel sure that the large nuggets have not thus been formed *in situ;* they have been set free from reefs, and any small addition of gold that they may have derived from meteoric water has been quite immaterial, and may be neglected. In the case of gold grains and dust it may be different, for such expose a much greater surface, and the "electroplating" may have had an appreciable effect in increasing the amount of such gold.

On the CRYSTALLIZATION of GOLD in HEXAGONAL FORMS.

By A. Liversidge, M.A., F.R.S.
Professor of Chemistry in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

While experimenting upon the reduction of gold, from a solution of the double chloride of gold and sodium in water, by various metallic sulphides, (On the Formation of Gold Nuggets, Jour. Roy. Soc. N. S. Wales, 1893, p. 303), I found that in certain cases the gold was deposited on the sulphides in the form of minute prisms and six rayed stars.

The solution used was the ordinary one employed in toning photographs, *i.e.*, fifteen grains of the $AuCl_3, NaCl, 2H_2O$ to fifteen ounces water ; freshly fractured fragments of the sulphides were immersed in this and left until a sufficient amount of gold had been reduced and deposited upon them, as stated in the paper referred to; the gold was usually deposited in ochre coloured lustreless mammillated films, but when copper pyrites was used, the gold was in some cases, also deposited in minute prisms, beautifully sharp and well defined; many of the prisms were grouped in tufts, and in the form of exquisitely arranged six rayed stars or in groups of three fan-like rays, the rays in both forms meeting at angles of 60° and resembling snow crystals in miniature, but of a most brilliant metallic lustre and of the colour of the purest gold. In other instances the gold was in the form of six sided plates.

When a "graphitic casing" from an auriferous vein was used, as the reducing agent, the gold was in part deposited in the form of minute very brilliant hexagonal plates.

With zinc blende in one instance, a few bright apparently crystallised points of gold were intermingled with the dull mammillary gold, also a few well defined six rayed stars and one very distinct St. Andrew's Cross, *i.e.*, a six rayed star with one transverse pair of rays left out, these may have been broken off or never formed.

Microscopic hexagonal stars of brilliant gold were also deposited on mispickel and on native silver sulphide associated with mammillary gold.

On marcasite a few bright specks were deposited, probably incipient crystals, but no recognisable forms.

In no case were there any traces of gold in forms belonging to the cubical system, although these are so readily obtained by reducing gold with ether, phosphorus in ether, oxalic acid, ferrous sulphate etc.

The occurrence of gold in prismatic and hexagonal forms has been observed by others : Prof. W. P. Blake describes *Crystallised Gold in prismatic forms*—(Am. Jour. Sci., Vol. XXVIII., 1884.) From near Clancy, Clancy Creek, Jefferson County, Montana, were obtained prismatic crystals of gold terminated by an octohedral head or knob, the whole having a comet-like appearance. The total length is about 3 m.m. or $\frac{1}{8}$ inch, the prism portion is hexagonal in section. (Figures are given in the paper). They are extremely brittle, and appear to cleave or break at right angles to their length. Hence probably an alloy or amalgam.

Small brilliant hexagonal crystals of gold, terminated at each end by pyramids, were found at Sonora, in Tuolumne County, California, and they resemble the artificial prismatic gold crystals obtained by Prof. Chester (Am. Jour. Sci., July 1878). It is possible that these crystals are also artificial, although similar crystals obtained at Angel's Camp in the same district were said to have been obtained from a cavity in quartz, but Prof. E. S. Dana in a paper on the *Crystallisation of Gold* from White Bull Mine—(Am. Jour. Sci., Vol. XXXII., p. 132), points out that the rhombohedral and hexagonal pyramid forms are due to planes of the 303 which are elongated in the direction of the octohedral axis.

In another paper *On the Crystallisation of Gold*—(Am. Jour. Sci., August 1886, p. 138.) Prof. E. S. Dana refers to hexagonal depressions in gold crystals and of crystalline ribs meeting at 60° and 120°, which are also quite consistent with the cubical system.

Prof. vom Rath in Groth's Zeitschrift für Krystallographie und Mineralogie 1877, describes some crystals of gold from Transylvania, and amongst them a star like formation from Felsö-banya, each ray being a twin of the four faced cube (∞ O 2) round a trigonal axis and extended along the diagonal of a face of the octohedron. He states that the acicular and capillary forms are usually rhombic in section, and consist of elongated cubes terminated by faces of the tetrakis hexadron (∞ On), the striations of the prisms being due to oscillatory combinations of the cube (∞ O∞) and four faced cube (∞ On).

A hexagonal prism of gold closed at both ends by a hexagonal pyramid is said to have been found at New Bendigo; this may have been a pseudomorph after quartz.—(Selwyn and Ulrich, Phys. Geog. Geology and Mineralogy of Victoria, Melbourne 1866).

Prof. Chester described some hexagonal crystals of gold (Am. Journ. Sci. 3rd Series xvi., p. 32), but as they consisted of an amalgam containing 6% of mercury, they can hardly be cited in support of the apparent hexagonal nature of the crystals obtained on the sulphides by reduction.

Prof. Egleston states that petroleum throws down hexagonal crystals of gold from gold chloride.

The crystals obtained by me up to the present are unfortunately very small and require further investigation, it may also prove to be that the hexagonal plates and stars are incipient cubical forms or even gold containing sufficient foreign matter to affect its crystallisation.

I hope to have an opportunity to lay before the Society the results of some further experiments upon the formation of these hexagonal crystals as soon as they are completed.

GOLD MOIRÉ-MÉTALLIQUE.

By A. Liversidge, M.A., F.R.S.,
Professor of Chemistry, University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

In experimenting upon the reduction of gold from solution, to test the theories of the formation of gold nuggets, I found that the pure gold plates and foil which I used (as described in another paper, see p. 327), in many cases presented a moiré-métallique appearance, such as is so familiar to us in tin plate and galvanized iron. The whole surface of the plate became dotted over with more or less regular crystals like those often seen on tin plate, they are however, much more regular and rectangular in outline and very small, the majority being less than 1 mm. square.

Afterwards I found that this crystallisation could be brought about by merely boiling the pure gold foil or plate in hydrochloric acid. The acid, although free from nitric acid, dissolved traces of the gold, probably due to a little free chlorine.

This moiré-métallique gold may have been observed before, but I have not come across any reference to it. Advantage might be taken of it for decorative purposes on jewellery and other articles made of gold plate.

A COMBINATION LABORATORY LAMP, RETORT, AND FILTER STAND.

By A. Liversidge, M.A., F.R.S.,

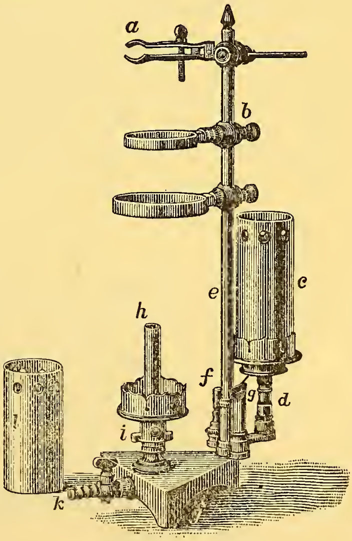
Professor of Chemistry in the University of Sydney.

[*Exhibited before the Royal Society of N. S. Wales, September 6, 1893.*]

The stand, as will be seen from the figure, is fitted with :—

A brass screw clamp (*a*)

Two or more adjustable brass retort or filter rings, which can be placed on the rod by the lateral slit at (*b*).



An Argand burner (*c*), on its peg (*a*), with regulator and copper chimney or shade, this is perforated so as to allow of its being used as a support for dishes, watch glasses, or crucibles. With a glass chimney the Argand can be used for illumination purposes.

A support or peg for the Argand or bunsen burner when not in use (*d*).

Retort and filter ring rod (*e*), this is attached to the foot (*j*) of the lamp by a bayonet joint not shown in the woodcut.

An ordinary fish tail jet (*f*), on its peg, for glass bending or illumination.

A blowpipe jet (*g*) on its peg.

A bunsen burner (*h*), provided with an air regulator at (*i*), and a gallery for the support of the draught shade or chimney (*l*).

The foot (*j*) is made of lead instead of iron for the sake of increased stability and to prevent rusting; it also is made to rest on three points for greater steadiness and to keep it out of liquids which may happen to be spilt on the bench.

A more convenient position for the supply tap (*k*) is at the side at (*j*).

There is also a rose burner, not shown in figure, to drop over the bunsen burner.

All the parts are interchangeable and are provided with ground joints so as to avoid the inconvenience of their becoming fixed as often happens with screw joints.

When the Argand or other jet is required for use, the bunsen burner is placed on the peg at the back, from which the former burner or jet has been removed, so that there is no need for any of the parts to get astray when not in use.

RESULTS OF OBSERVATIONS OF COMET VI. (BROOKS) 1892, AT WINDSOR, NEW SOUTH WALES.

By JOHN TEBBUTT, F.R.A.S., &c.

[*Read before the Royal Society of N. S. Wales, September 6, 1893.*]

THE comet was discovered at Geneva, New York, by Mr. W. R. Brooks, on August 28, 1892, and was well observed in the Northern Hemisphere down to the close of November. Observations of it were commenced at my observatory on the morning of November 29, civil time, and were continued, with interruptions from strong moonlight and cloudy weather, to June 19. The comparisons of the comet were made throughout by means of a square bar-micrometer in a dark field, the four and a half inch equatorial being employed on the first two dates, and the eight inch instrument on all subsequent dates. In November and December the comet had a fairly bright condensation in its centre, but this gradually grew fainter and smaller. The gradual diminution of the condensation facilitated its observation at the edges of the micrometer-bars. A faint tail was seen in the telescope during November, December and January. In consequence of cloud or haze, observations were unsatisfactory on December 20, 21, January 7, 25, February 28, March 13, 20, 24, 26, April 19, 21, 23. The observations of February 14, March 20, April 17, in consequence of the proximity of small stars, were made with difficulty. In the first seven comparisons of April 17, the comet gradually approached a star of the eighth magnitude, and in the last three comparisons both objects were observed as one. After March the comet was reduced to a very small hazy speck without the usual coma, and in May was observed with difficulty in consequence of its projection on a bright branch of the Milky Way. In June the comet was, notwithstanding its increased distance from the sun and earth, quite as conspicuous as in the month of May. This circumstance was due to the fact that the comet was now projected on a comparatively dark sky. After the withdrawal of the moon an attempt was made to re-observe the comet in July but without success, as it was again projected on one of the branches of the Milky Way. I may add that the parallax corrections furnished in this paper are based on an equatorial horizontal parallax of the sun = 8·85″ and on the ephemerides published in the *Astronomische Nachrichten*, Nos. 3127, 3131, 3155, 3162, by Dr. F. Ristenpart of Carlsruhe, whose parabolic elements closely represent the comet's movements down to the close of my observations.

COMET VI. (BROOKS) 1892.

Date.	Windsor Mean Time.	Comet—Star.		Comparisons.	Comet's Apparent.		Parallax Corrections in		Reductions of Star Places.		Comp. Star.
		Δ α	Δ δ		α	δ	α	δ	α	δ	
1892.	h. m. s.	m. s.	′ ″		h. m. s.	° ′ ″	s.	″	s.	″	
Nov. 28	15 49 38	+0 59·09	—0 27·5	6	11 16 44·00	—13 30 2·2	—0·40	—4·0	+1·74	—4·6	1
,, 29	15 24 8	+7 45·24	—18 23·9	8	11 21 43·44	—14 30 7·1	—0·45	—4·0	+1·77	—4·5	2
Dec. 8	14 38 20	—0 52·62	—3 21·5	10	12 9 1·10	—23 14 28·7	—0·55	—3·7	+1·70	—5·5	3
,, 8	15 17 40	—1 7·75	—1 24·5	10	12 9 9·59	—23 16 2·8	—0·50	—3 2	+1·70	—5·5	4
,, 8	15 44 36	—3 5 55	+7 47·5	4	12 9 15·86	—23 17 5·5	—0·45	—2·9	+1·69	—5·5	5
,, 9	15 7 25	—2 50·23	+6 40·7	15	12 14 34·40	—24 9 48·9	—0·51	—3·2	+1 69	—5·6	6
,, 9	15 7 25	—3 11·33	+4 44·2	15	12 14 34·36	—24 9 49·1	—0·51	—3·2	+1·69	—5·7	7
,, 12	14 33 26	—1 2·02	—11 27 5	12	12 30 58·17	—26 44 2·1	—0·57	—3·4	+1·72	—5 9	8
,, 12	15 34 25	+0 36·22	+3 53·2	10	12 31 11·93	—26 46 9·6	—0·49	—2·6	+1·72	—5·8	9
,, 13	15 12 43	—1 7·29	+0 52·1	20	12 36 40·83	—27 34 44·2	—0·52	—2·8	+1·72	—6·0	10
,, 13	15 12 43	—1 35·82	+9 9·9	20	12 36 41·05	—27 34 47·0	—0 52	—2·8	+1·71	—5·9	11
,, 14	15 27 49	+1 13·03	+0 27·2	12	12 42 19·50	—28 23 18·9	—0·50	—2·5	+1·73	—6·0	12
,, 15	15 30 54	+6 18·80	—9 54·7	6	12 47 56·15	—29 10 4·6	—0·50	—2·4	+1·76	—6·0	13
,, 15	15 30 54	+6 0·13	+2 21·3	6	12 47 55·80	—29 10 4·2	—0·50	—2·4	+1·76	—5·9	14
,, 20	14 59 26	—1 4·04	—3 13·1	10	13 16 2·63	—32 40 49·4	—0·56	—2·5	+1·78	—6·6	15
,, 21	14 50 33	+1 17·98	+8 6·8	14	13 21 40·30	—33 18 30·6	—0·57	—2·6	+1·80	—6·6	16
,, 23	14 46 14	+1 34·80	+0 1·6	20	13 32 59·42	—34 29 55·4	—0·58	—2·6	+1·83	—6·7	17
,, 23	14 46 14	+1 21·07	+0 58·7	20	13 32 59·47	—34 29 54·5	—0·58	—2·6	+1·83	—6·7	18
,, 24	14 46 29	—4 4·58	+6 18·9	10	13 38 40·09	—35 3 21·4	—0·58	—2·6	+1·83	—6·9	19
,, 24	14 46 29	—8 36·58	+4 31·7	10	13 38 39·47	—35 3 25·0	—0·58	—2·6	+1·82	—7·0	20
,, 28	14 23 6	+1 35·20	+10 23·5	5	14 1 5·73	—37 2 25·8	—0·60	—2·9	+1·92	—7·1	21
,, 29	15 17 48	+2 13·84	—5 58·2	5	...	...	—0·55	—1·9	+1·94	—7·2	22
,, 29	15 17 48	—7 6·84	—6 20·8	5	14 6 54·50	—37 29 46·4	—0·55	—1·9	+1·92	—7·3	23
1893.											
Jan. 2	14 13 49	—0 54·54	+8 59·8	4	14 28 46·80	—38 58 35·8	—0·60	—3·0	—1·71	+8·6	24
,, 7	15 19 43	—1 53·05	—0 28·4	12	14 55 52·09	—40 26 48·9	—0·55	—1·7	—1·72	+6·9	25
,, 9	14 53 35	+3 45·73	—7 32·1	16	...	...	—0·57	—2·1	—1·67	+6·6	26
,, 9	14 53 35	+3 12·07	—6 45·6	16	...	...	—0·57	—2·1	—1·68	+6·6	27
,, 13	15 22 2	+3 19·75	—0 22·3	20	15 26 30·61	—41 33 12·4	—0·54	—1·6	—1·66	+5·3	28
,, 15	14 51 58	—3 46·07	+4 22·4	7	15 36 9·59	—41 47 30·5	—0·56	—2·1	—1·68	+4·3	29
,, 16	15 7 5	+1 4·19	—1 39·5	20	15 40 59·89	—41 53 32·4	—0·54	—1·8	—1·64	+4·3	29
,, 17	15 17 35	+5 49·37	—6 51·7	12	15 45 45·11	—41 58 44·7	—0·53	—1·6	—1·60	+4·2	29
,, 17	15 17 35	+1 36·56	—0 17·8	12	...	...	—0·53	—1·6	—1·62	+4·0	30
,, 18	14 48 22	+6 10·40	—4 32·5	2	...	...	—0·55	—2·1	—1·58	+4·0	30
,, 18	14 48 22	+4 10·46	—6 23·7	2	...	...	—0·55	—2·1	—1·59	+3·8	31
,, 19	15 39 29	+7 8·45	+10 24·7	8	15 55 4·03	—42 6 45·5	—0·51	—1·3	—1·57	+3·8	32
,, 20	15 20 26	+4 9·30	+2 37·1	10	...	...	—0 52	—1·6	—1·57	+3·3	33
,, 20	15 20 26	+3 4·23	+1 54·7	10	...	...	—0·52	—1·6	—1·57	+3·2	34
,, 25	15 8 48	+9 15·97	+10 19·0	2	16 21 5·36	—42 14 18·7	—0·52	—1·7	—1·46	+2·3	35
,, 25	15 8 48	+1 23·68	—0 53·2	2	...	...	—0·52	—1·7	—1·49	+1·8	36
,, 26	15 35 29	+5 34·70	—0 8·2	10	...	...	—0·49	—1·3	—1·45	+1·8	36
,, 27	15 45 42	+9 38·74	+1 13·9	6	...	...	—0·48	—1·1	—1·41	+1·8	36
,, 28	14 43 33	—13 17·01	+0 36·7	2	16 33 8·34	—42 10 23·5	—0·52	—2·1	—1·50	+0·4	37
,, 28	14 43 33	—13 43·72	+7 40·9	2	16 33 8·25	—42 10 22·9	—0·52	—2·1	—1·51	+0·4	38
Feb. 3	16 7 17	+2 11·02	+4 8·1	10	16 55 42·99	—41 50 29·2	—0·43	—0·8	—1·29	—0·1	39
,, 8	15 41 20	+6 6·32	+8 46·5	4	...	...	—0·44	—1·1	—1·14	—0·8	40
,, 8	15 41 20	—1 12·35	+2 14·6	4	...	...	—0·44	—1·1	—1·17	—1·1	41
,, 8	15 41 20	—4 51·06	—0 33·6	4	...	...	—0·44	—1·1	—1·19	—1·3	42
,, 9	15 56 14	—1 39·47	+5 32·6	10	...	...	—0·43	—0·9	—1·15	—1·3	42
,, 13	15 7 31	+3 18·61	+4 49·3	10	17 27 28·29	—40 52 35·2	—0·46	—1·6	—1·01	—1·6	43
,, 13	15 7 31	+0 45·49	+4 23·6	10	17 27 28·46	—40 52 34·2	—0·46	—1·6	—1·02	—1·7	44
,, 14	15 21 50	+6 10·60	+11 52·6	11	17 30 20·32	—40 45 31·9	—0·44	—1·3	—0·97	—1·6	43
,, 14	15 21 50	+3 37 43	+11 26·5	11	17 30 20·43	—40 45 31·3	—0·44	—1·3	—0·99	—1·7	44
,, 21	15 23 43	+7 12·91	—0 53·9	10	17 48 26·85	—39 52 30 2	—0·42	—1·2	—0·76	—2·5	45
,, 21	15 23 43	+5 45·48	+10 51·9	10	17 48 26·80	—39 52 28·8	—0·42	—1·2	—0·77	—2·5	46
,, 21	15 23 43	—0 54·83	+2 25·9	10	...	...	—0·42	—1·2	—0·80	—2·7	47
,, 25	15 26 42	+4 35 96	—5 38·7	11	17 57 28·43	—39 19 55·5	—0·40	—1·1	—0·65	—2·9	48
,, 25	15 26 42	—7 34·13	+1 59·6	11	17 57 28·30	—39 19 56·7	—0·40	—1·1	—0·71	—3·2	49
,, 27	15 43 7	+11 24·80	+2 0·4	8	18 1 40·22	—39 3 9·5	—0·38	—0·9	—0·56	—2·9	50
,, 27	15 43 7	+9 7·48	+0 2·2	8	...	...	—0·38	—0·9	—0·57	—3·0	51
,, 27	15 43 7	—3 52·87	+7 46·1	8	18 1 40·12	—39 3 8·8	—0·38	—0·9	—0·63	—3 2	52
,, 28	15 52 43	—10 7·86	+9 20·8	7	18 3 41·50	—38 54 42·2	—0·36	—0·8	—0·63	—3·3	53
,, 28	15 59 56	—12 30·23	—0 18·2	6	...	...	—0·35	—0·7	—0·64	—3·4	54

COMET VI. (BROOKS) 1892.—*continued.*

Date.	Windsor Mean Time.	Comet—Star. Δα	Δδ	Comparisons.	Comet's Apparent. α	δ	Parallax Corrections in α	δ	Reductions of Star Places. α	δ	Comp. Star.
1893.	h. m. s.	m. s.	′ ″		h. m. s.	° ′ ″	s.	″	s.	″	
Mar. 13	14 41 36	+0 51·40	—10 54·6	4	18 24 46·97	—37 3 49·8	—0·39	—1·4	—0·18	—3·8	55
,, 14	15 35 6	+2 9·67	—2 4·6	23	18 26 5·28	—36 54 59·8	—0·33	—0·7	—0·14	—3·8	55
,, 18	15 38 8	+3 55·48	+6 45·0	10	18 30 37·94	—36 20 31·6	—0·31	—0·6	0·00	—3·8	56
,, 18	15 38 8	—1 28·74	—1 32·9	10	18 30 38·08	—36 20 49·3	—0·31	—0·6	—0·03	—3·9	57
,, 20	15 15 37	—5 31·52	—6 18·8	6	18 32 36·50	—36 4 9·9	—0·33	—0·8	+0·02	—3·9	58
,, 21	14 27 7	—4 39·42	+1 52·1	10	18 33 28·63	—35 55 59·0	—0·37	—1·3	+0·05	—3·9	58
,, 21	14 27 7	—3 40·52	...	10	18 33 28·94	...	—0·37	—1·3	+0·06	...	59
,, 23	14 46 1	—1 59·09	+5 45·2	20	18 35 10·44	—35 39 5·0	—0·35	—1·1	+0·13	—3·9	59
,, 24	15 10 36	+10 32·78	—5 7·2	10	18 35 56·62	—35 30 39·5	—0·32	—0·8	+0·23	—4·0	60
,, 24	15 10 36	+6 40·11	+1 18·5	10	18 35 56·54	—35 30 37·3	—0·32	—0·8	+0·21	—4·0	61
,, 24	15 10 36	+3 25·31	—7 27·1	10	18 35 56·46	—35 30 40·0	—0·32	—0·8	+0·19	—4·0	62
,, 26	15 46 35	+4 49·00	+9 22·6	5	18 37 20·23	—35 13 50·2	—0·26	—0·4	+0·27	—3·9	62
,, 26	15 46 35	+4 10·28	+1 28·0	5	...	...	—0·26	—0·4	+0·27	—4·0	63
,, 26	15 47 21	+1 57·71	+1 33·8	4	...	...	—0·26	—0·4	+0·25	—4·0	64
Apr. 13	14 53 17	+0 26·35	—8 56·3	15	18 41 7·00	—32 49 32·1	—0·23	—0·6	+0·87	—4·3	65
,, 13	14 53 17	—0 57·78	+0 11·2	15	18 41 7·19	—32 49 35·0	—0·23	—0·6	+0·87	—4·2	66
,, 17	14 24 50	—6 51·27	—11 0·2	10	18 39 54·27	—32 18 18·7	—0·25	—0·7	+0·98	—4·1	67
,, 19	14 30 39	—0 38·75	—1 18·1	4	...	...	—0·23	—0·6	+1·08	—4·4	68
,, 19	14 30 39	—2 26·16	...	4	18 39 0·97	...	—0·23	—0·6	+1·08	...	69
,, 19	14 30 39	—7 44·71	+4 51·2	4	18 39 0·90	—32 2 27·3	—0·23	—0·6	+1·05	—4·1	67
,, 20	13 58 26	—1 7·87	+6 16·1	11	...	...	—0·26	—0·8	+1·12	—4·3	68
,, 20	13 58 26	—2 55·51	+3 59·9	11	18 38 31·65	—31 54 54·4	—0·26	—0·8	+1·11	—4·3	69
,, 21	14 53 14	+1 35·61	—2 16·1	2	...	...	—0·18	—0·5	+1·17	—4·5	70
,, 21	14 53 14	—2 19·50	+4 32·6	2	18 37 57·62	—31 46 41·9	—0·18	—0·5	+1·15	—4·3	71
,, 22	15 37 31	+2 17·06	—4 1·8	9	18 37 19·73	—31 38 45·7	—0·10	—0·3	+1·21	—4·6	72
,, 22	15 37 31	+0 58·20	+5 42·3	9	18 37 19·89	—31 38 44·0	—0·10	—0·3	+1·20	—4·5	73
,, 23	11 5 21	+1 42·31	+3 29·6	18	18 36 45·01	—31 31 14·3	—0·24	—0·7	+1·24	—4·6	72
,, 23	14 5 21	—0 58·74	—0 47·3	18	18 36 45·27	—31 31 17·6	—0·24	—0·7	+1·23	—4·5	74
May 8	10 29 51	+0 25·00	—6 6·2	10	18 22 49·90	—29 31 1·4	—0·37	—2·1	+1·75	—5·6	75
,, 8	11 2 31	+0 23·04	—11 18·8	10	18 22 48·13	—29 30 51·6	—0·35	—1·8	+1·74	—5·6	76
,, 9	11 8 57	—0 49·58	—2 51·0	2	18 21 35·55	—29 22 23·8	—0·34	—1·7	+1·78	—5·6	76
,, 11	10 49 51	+5 28·14	+0 59·2	8	18 19 7·08	—29 5 42·6	—0·34	—1·8	+1·86	—6·1	77
,, 11	10 49 51	—6 20·27	+10 15·7	8	18 19 7·22	—29 5 43·1	—0·34	—1·8	+1·83	—5·4	78
,, 13	11 19 7	—5 12·85	+2 16·1	10	18 16 30·10	—28 48 29·8	—0·31	—1·4	+1·89	—5·7	79
,, 13	11 19 7	—7 15·68	+3 30·6	10	18 16 30·21	—28 48 29·6	—0·31	—1·4	+1·89	—5·6	80
,, 16	10 52 21	+1 49·53	—3 16·9	14	18 12 28·06	—28 22 31·6	—0·31	—1·6	+2·00	—6·4	81
,, 16	10 52 21	—2 47·42	+6 10·1	14	18 12 28·46	—28 22 37·6	—0·31	—1·6	+1·99	—6·1	82
,, 18	11 4 55	+3 46·38	+10 34·7	10	18 9 40·39	—28 5 8·6	—0·29	—1·4	+2·07	—6·7	83
,, 18	11 4 55	+0 44·41	+1 39·2	10	18 9 40·43	—28 5 8·8	—0·29	—1·4	+2·06	—6·6	84
,, 19	10 7 55	—1 56·40	—11 29·9	10	18 8 19·26	—27 56 25·8	—0·33	—1·8	+2·07	—6·6	85
,, 19	10 7 55	—2 33·68	—2 15·0	10	18 8 19·79	—27 56 29·3	—0·33	—1·8	+2·07	—6·5	86
June 15	9 37 55	+4 57·75	—1 58·9	10	17 29 53·54	—23 54 53·4	—0·18	—1·2	+2·57	—9·8	87
,, 18	8 37 37	+1 30·29	+4 36·8	10	17 26 15·08	—23 30 0·5	—0·22	—1·4	+2·60	—9·9	88
,, 18	9 34 25	+1 27·61	+5 0·0	10	17 26 12·40	—23 29 37·3	—0·16	—1·1	+2·60	—9·9	88
,, 19	10 30 43	+2 33·99	+0 6·4	10	17 24 58·74	—23 21 6·6	—0·08	—0·9	+2·60	—10·0	89

MEAN PLACES OF THE COMPARISON STARS FOR THE BEGINNING OF THE YEAR OF OBSERVATION.

Star.	α	δ	Authorities.
	h. m. s.	° ′ ″	
1	11 15 43·17	—13 29 30·1	Lalande, 21639.
2	11 13 56·43	—14 11 38·7	Greenwich Nautical Almanac, 1892.
3	12 9 52·02	—23 11 1·7	Arg-Oeltzen 12024.
4	12 10 15·64	—23 14 32·8	Arg-Oeltzen 12034.
5	12 12 19·72	—23 24 47·5	Lalande 23027; Arg-Oeltzen 12058-9.
6	12 17 22·94	—24 16 24·0	Yarnall$_3$ 5255; Stone 6880.

Mean places of the Comparison Stars for the beginning of the Year of Observation—*continued.*

Star.	α	δ	Authorities.
	h. m. s.	° ′ ″	
7	12 17 44·00	—24 14 27·6	Cape Cat. 1850, 2221; Yarnall$_3$ 5260; Stone 6885.
8	12 31 58·47	—26 32 28·7	Arg-Oeltzen 12289-90; Yarnall$_3$ 5365; Quetelet 5169; Stone 7000; Greenwich Cat. 1880, 1971.
9	12 30 33·99	—26 49 57·0	Arg-Oeltzen 12270; Wash. Mural Cir. Zone 112, 21.
10	12 37 46·40	—27 35 30·3	Arg-Oeltzen 12368; Wash. Merid. Tr. Zone 234, 2; Wash. Mural Cir. Zone 105, 123.
11	12 38 15·16	—27 43 51·0	Cape Cat. 1850, 2276; Arg-Oeltzen 12377; Wash. Merid. Tr. Zone 234, 3; Wash. Mural Cir. Zone 105, 124; Yarnall$_3$ 5413; Greenwich Cat. 1880, 1988; Stone 7043.
12	12 41 4·74	—28 23 40·1	Wash. Merid. Cir. Zone 92, 66; Wash. Mural. Cir. Zone 164, 9.
13	12 41 35·59	—29 0 3·9	Wash. Merid. Cir. Zone 91, 91.
14	12 41 53·91	—29 12 19·6	Arg-Oeltzen 12420; Wash. Merid. Tr. Zone 116, 22; Wash. Merid. Cir. Zone 91, 92.
15	13 17 4·89	—32 37 29·7	Stone 7332.
16	13 20 20·52	—33 26 30·8	Stone 7359.
17	13 31 22·79	—34 29 50·3	Yarnall$_3$ 5713; Stone 7462.
18	13 31 36.57	—34 30 46·5	Yarnall$_3$ 5714; Stone 7466.
19	13 42 42·84	—35 9 33·4	Yarnall$_3$ 5782; Stone 7556.
20	13 47 14·23	—35 7 49·7	Cape Cat. 1850, 2471; Yarnall$_3$ 5829; Stone 7604.
21	13 59 28·61	—37 12 42·2	Yarnall$_3$ 5916; Stone 7711.
22	14 4 39	—37 24	Equatorial.
23	14 13 59·42	—37 23 18·3	Yarnall$_3$ 6016; Stone 7821.
24	14 29 43·05	—39 7 44·2	Yarnall$_3$ 6119; Stone 7945.
25	14 57 46·86	—40 26 27·4	Stone 8189.
26	15 2 28	—40 46	Equatorial.
27	15 3 2	—40 47	Equatorial.
28	15 23 12·52	—41 32 55·4	Stone 8421. Brighter component employed.
29	15 39 57·34	—41 51 57·2	Stone 8564.
30	15 44 10	—41 59	Equatorial.
31	15 46 10	—41 57	Equatorial.
32	15 47 57·15	—42 17 14·0	Stone 8635.
33	15 55 24	—42 12	Equatorial.
34	15 56 29	—42 11	Equatorial.
35	16 11 50·85	—42 24 40·0	Stone 8860.
36	16 19 43	—42 13	Equatorial.
37	16 46 26·85	—42 11 0·6	Cape Cat. 1850, 3129; Stone 9160.
38	16 46 53·48	—42 18 4·2	Cape Cat. 1850, 3135; Stone 9169.
39	16 53 33·26	—41 54 37·2	Stone 9242.
40	17 6 15	—41 34	Equatorial.
41	17 13 34	—41 27	Equatorial.
42	17 17 12	—41 24	Equatorial.
43	17 24 10·69	—40 57 22·9	Stone 9537.
44	17 26 43·99	—40 56 56·1	Stone 9565.
45	17 41 14·70	—39 51 33·8	Stone 9683.
46	17 42 42·09	—40 3 18·2	Cape Cat. 1850, 3388; Stone 9707.
47	17 49 22	—39 55	Equatorial.
48	17 52 53·12	—39 14 13·9	Stone 9798.
49	18 5 3·14	—39 21 53·1	Stone 9904.
50	17 50 15·98	—39 5 7·0	Stone 9772.
51	17 52 33	—39 3	Equatorial.
52	18 5 33·62	—39 10 51·7	Stone 9908.
53	18 13 49·99	—39 3 59·7	Stone 9990.
54	18 16 13	—38 54	Equatorial.
55	18 23 55 75	—36 52 51·4	Yarnall$_3$ 7982; Stone 10078.
56	18 26 42·46	—36 27 12·8	Wash. Mural Cir. Zone 49, 3.
57	18 32 6·85	—36 19 12·5	Wash. Mural Cir. Zone 49, 5.
58	18 38 8·00	—35 57 47·2	Yarnall$_3$ 8087; Stone 10194.
59	18 37 9·40	—35 44 46·3	Sydney Obs. 1859; Stone 10183; Melbourne$_2$ 934.
60	18 25 23·61	—35 25 28·3	Wash. Merid. Tr. Zone 44, 47; Yarnall$_3$ 7993; Stone 10086.
61	18 29 16·22	—35 31 51·8	Wash. Merid. Tr. Zone 44, 48.
62	18 32 30 96	—35 23 8·9	Wash. Merid. Tr. Zone 44, 49.
63	18 33 9	—35 15	Equatorial.
64	18 35 22	—35 15	Equatorial.
65	18 40 39·78	—32 40 31·5	Wash. Mural Cir. Zone 25, 77.
66	18 42 4·10	—32 49 42·0	Wash. Mural Cir. Zone 25, 78; Cape Cat. 1850, 3668; Stone 10228.

Mean Places of the Comparison Stars for the beginning of the Year of Observation—*continued.*

Star.	α	δ	Authorities.
	h. m. s.	° ′ ″	
67	18 46 44·56	—32 7 14·4	Cape Cat. 1850, 3692; Wash. Mural Cir. Zone 25, 79; Stone 10275.
68	18 39 38	—32 1	Equatorial.
69	18 41 26·05	—31 58 50·0	Wash. Merid. Tr. Zone 30, 79.
70	18 36 21	—31 44	Equatorial.
71	18 40 15·97	—31 51 10·2	Wash. Merid. Tr. Zone 30, 78.
72	18 35 1·46	—31 34 39·3	Wash. Mural Cir. Zone 39, 24; Yarnall_3 8063.
73	18 36 20·49	—31 44 21·8	Yarnall_3 8072.
74	18 37 42·78	—31 33 25·8	Wash. Mural Cir. Zone 39, 26.
75	18 22 23·15	—29 24 49·6	Wash. Mural Cir. Zone 261, 18; Wash. Merid. Cir. Zone 97, 167.
76	18 22 23·35	—29 19 27·2	Wash. Mural Cir. Zone 261, 19; Wash. Merid. Cir. Zone 97, 168; Yarnall_3 7972; Quetelet 7504; Stone 10061.
77	18 13 37·08	—29 6 35·7	Wash. Mural Cir. Zone 27, 62: 261, 11; Wash. Merid. Cir. Zone 97, 162; Arg-Oeltzen 18045.
78	18 25 25·66	—29 15 53·4	Arg-Oeltzen 18329; Wash. Mural Cir. Zone 261, 22; Wash. Merid. Cir. Zone 97, 170; Yarnall_3 7997; Quetelet 7540; Stone 10088.
79	18 21 41·06	—28 50 40·2	Wash. Mural Cir. Zone 47, 9; Yarnall_3 7962.
80	18 23 44·00	—28 51 54·6	Cape Cat. 1850, 3582; Arg-Oeltzen 18291-2; Wash. Mural Cir. Zone 47, 10: 182, 25; Yarnall_3 7981; Stone 10076.
81	18 10 36·53	—28 19 8·3	Cape Cat. 1850, 3517; Wash. Merid. Tr. Zone 51, 33; Wash. Merid. Cir. Zone 117, 134; Yarnall_3 7880; Stone 9965. Declinations very discordant; probable proper motion in declination.
82	18 15 13·89	—28 28 41·6	Cape Cat. 1850, 3540; Wash. Mural. Cir. Zone 27, 63: 117, 138; Wash. Merid. Cir. Zone 94, 90; Wash. Merid. Tr. Zone 51, 36; Yarnall_3 7914; Stone 10002.
83	18 5 51·94	—28 15 36·6	Cape Cat. 1850, 3493; Arg-Oeltzen 17803; Wash. Mural Cir. Zone 117, 130; Wash. Merid. Tr. Zone 51, 29; Yarnall_3 7826; Stone 9913. Wash. Mural Cir. Zone Declin. rejected.
84	18 8 53 96	—28 6 41·4	Arg-Oeltzen 17896; Wash. Mural Cir. Zone 117, 132; Wash. Merid. Tr. Zone 51, 32.
85	18 10 13·59	—27 44 49·3	Cape Cat. 1850, 3513; Yarnall_3 7870; Stone 9960.
86	18 10 51·40	—27 54 7·8	Arg-Oeltzen 17964; Wash. Mural Cir. Zone 45, 13.
87	17 24 53·22	—23 52 44·7	Cape Cat. 1850, 3313; Arg-Oeltzen 16877-8; Yarnall_3 7407; Stone 9544.
88	17 24 42·19	—23 34 27·4	Arg-Oeltzen 16873-4.
89	17 22 22·15	—23 21 3·0	Arg-Oeltzen 16826.

ROCK PAINTINGS BY THE ABORIGINES IN CAVES ON BULGAR CREEK, NEAR SINGLETON.

By R. H. MATHEWS, Licensed Surveyor.

[With Plates XVIII. - XX.]

[*Read before the Royal Society of N. S. Wales, October 4, 1893.*]

ABOUT eighteen months ago I was engaged on some extensive surveys under the Real Property Act in the Parishes of Whybrow and Milbrodale, about fifteen miles from Singleton, and whilst so employed my attention was drawn to the existence of some caves in the vicinity, containing aboriginal drawings. Being anxious to obtain all the information I could on the subject, I got some of the residents to act as guides, and visited two of the most interesting of these caves. Thinking that the result of my inspection may be of some interest to the members of this Society, I have prepared a few notes, with illustrative diagrams, which I will now place before you.

I will first deal with the cave shown on Plate 19. This cave or rock-shelter, is a large overhanging ledge of Hawkesbury Sandstone on the west side of Bulgar Creek, a tributary of the Wollombi Brook, and is situated within Portion No. 2 of six hundred and forty acres, in the Parish of Milbrodale, County of Northumberland, about a quarter of a mile southerly from the old road from Sydney, over the Bulgar Mountains, to Singleton, and is about fifteen miles south-westerly from the latter town.

The cave or shelter, is in one of the ordinary low rocky escarpments of the Hawkesbury Sandstone which are very numerous in this part of the district; the direction of the escarpment being north-westerly, and the dip north easterly. The cave is about eighty feet above the adjacent valley, and faces the north-east, consequently the sun shines into it, on fine days, all the year round. There is also a good drainage from the front of the cave, which keeps it dry and free from moisture. The shelter is about fifty-eight feet long, and is twenty-three feet high from the ground to the top of the ledge, the depth from the front to the back of the interior being twenty-two feet at the widest part. The thickness of the overhanging rock at the front is about three feet, gradually getting thicker as it goes back. The floor of the cave is, in places, sandstone, *in situ;* in others, disintegrated sand, but too shallow for burials to have taken place. There is no trace of any hearth-rubbish, leading to the belief that the recess has not been used to any great extent as one of residence.

I will now proceed to briefly describe the figures. Standing in front of the cave with the face towards it, the most prominent object is the grotesque figure of a man about eight feet high, with the arms and legs extended, and out of all proportion to the rest of the body. It is generally supposed by old colonists who have been a good deal among the aborigines in the early days of the Colony that the figure of a man represents either a good or evil spirit, and generally were those who presided over the ceremony of the *Bora.* The figure in this cave, having the legs and arms fully extended, seems to represent a man lying on the ground. It is known that, at the ceremonies of the *Bora* some of the aboriginal tribes were in the habit of making a colossal figure of a man on the ground with sticks, and covering them over with earth, so as to show the outline distinctly. Such a figure represented *Baiamai*, or the Great Spirit. In front of this cave there is a large level valley, timbered with large and lofty trees, well suited for a *Bora* ground, and I think it more than probable that *Boras* were held here, and that the figures in the cave are connected with the ceremonies which took place on such occasions. There was plenty of good water in the Bulgar Creek close by, and good hunting grounds all around.

But to proceed with our description of the figures. On either side of the body, just below the arms, there are perpendicular lines about eight or nine inches long, three being on the right hand side, and four on the left. It is not clear what these lines are supposed to represent, but I think a very feasible theory is that they are intended to show the upper ends of spears, the lower ends being on the ground, with their tops resting against the rock. Close to the body on the right hand side is a native tomahawk with handle, and on the left, a boomerang, with another boomerang a little further to the left. A short distance below the right hand there is another tomahawk with handle, and what appears to be intended for a waddy. There are four impressions of hands in the immediate vicinity of the figure of the man, and one hand and a boomerang at some distance, in the upper left hand corner of the cave. It will thus be seen that all the figures in this cave consist of one rude drawing of a man, seven spear heads, three boomerangs, two tomahawks, and a waddy. The plate shows all these drawings exactly as they are in the cave, being accurately drawn to scale from actual measurements, and in the proper colours.

The figure of *Baiamai*, or Devil Devil, or whatever the image represents, is drawn in red, by a number of strokes drawn in the direction of the different limbs, not one mass of red colour, and appears to have been done with some red substance held in the hand. The apple tree, and also the grass tree of Australia, yield a red gum or resin, which has the property of staining anything with which it comes in contact when in a wet state. The eyes, and the lower part of the body of the man, are drawn in white.

The seven perpendicular marks, which we have supposed to be the upper ends of spears resting against the rock, are drawn in a whitish grey colour, probably with a white stone held in the hand. All the rest of the figures are drawn in what has been called the "stencil" or "splash-work" method. These drawings appear to have been made by placing the extended hand, or other object, flat on the rock, and then squirting a whitish colour over it by means of the mouth, or in some other manner. It will be observed that three of the hands in this cave are right hands, which is rather unusual in these rock drawings, the impression being generally that of the left hand.

After the "splash-work" drawing was completed, some dark substance appears to have been applied to the rock within its margin, because all the splash work figures in this cave are darker than the surrounding sandstone. The height of the lowest of these figures above the floor of the cave is about four feet, and that of the highest about twelve feet.

I was informed by Mr. W. G. McAlpin, who is now eighty-four years of age, and has resided in the neighbourhood for the last fifty years, that the figures in this cave were there when he first came to the district; and even at that time the drawings were beyond the knowledge of the local blacks. Mr. McAlpin further states that the figures on the rock are now in about the same state of preservation as when he first saw them upwards of fifty years ago, having suffered very little in that time. It may be mentioned that the Hawkesbury Sandstone is not very durable, even under the most favourable circumstances, and when located in damp situations, and subjected to much moisture, it crumbles away rapidly. It is owing to the very favourable situation of this cave, pointed out in the early part of this paper, that its walls are now apparently in very nearly the same state as when the drawings were made upon them.

Going on now to describe the drawings shown on Plate 20, which is drawn to the same scale as Plate 19, it will be observed that they are not so interesting as those we have first noticed; the cave is not so large, and the drawings are confined to impressions of the hand. This cave is situated on Crown land, in the Parish of Whybrow, County of Hunter, on the south side of Bulgar Inlet, a tributary of the Wollombi Brook, about a mile south-westerly from Thomas Hayes' forty acres, being Portion 34 in the Parish just named. The cave is on the side of a hill facing the north-east, about one hundred and fifty feet above the level of the creek, and about one hundred yards back from it. It is in one of a number of large rocks a little way above the sandstone escarpment which bounds the creek, which bears at this place nearly east and west. There is good natural drainage, and the sun shines into the cave from sunrise till past mid-day, thus keeping it very dry. The cave is about sixteen feet long, and extends back into the rock about nine feet; it is about five feet high inside, but on account of its dome shaped interior, is only about four feet at the entrance. The formation of the rock containing the cave is sandstone conglomerate. The figures are drawn on the back wall of the cave, near the roof, and are in an excellent state of preservation. There are ten hands altogether, all being left hands, with the exception of one. Each hand is of the dirty yellowish-brown colour of the surrounding sandstone, but the surface of the rock, outside the margin of the figures, is smeared with a whitish or ash-coloured substance after the manner of "splash-work," which causes the figures to stand out in relief.

As a rule, very little more than the hand is ever depicted in the native drawings, and the hand with part of the arm attached is considered very rare. It will be observed that two of the figures in this cave show the arm as far as the elbow, which makes them unusually interesting.

Mr. W. G. McAlpin who resides on the Wollombi Brook about three miles from these caves, told me that he used to know of another cave with aboriginal drawings on its walls, similar to those which I have been describing, some miles further to the westward, but of late years the rock in which the cave was situated, has fallen over on its face covering the entrance to the recess in which the drawings appeared.

The practice of rock painting by the aborigines has been observed from the time of the earliest explorers and is universally distributed over Australia, having been observed in different parts of New South Wales, in Queensland, and in Western Australia, but there appears to have been very little attention paid to it.

I have confined myself as much as possible to descriptions only of these drawings, and have not attempted to connect them with the myths and superstitions of the Australian aborigines; neither have I speculated on their supposed totemic or symbolical meanings. I have left these researches for those better qualified to follow them out than I am, or have more time at their disposal.

I have prepared a plan (see Plate 18) drawn to scale, which shows the correct position of the caves with regard to the nearest purchased lands, with the names of the Parish and County in which each is situated, so that anyone wishing to visit them can do so with facility.

On the PROBABILITY of EXTRAORDINARILY HIGH SPRING-TIDES about the DECEMBER SOLSTICE of 1893.

By John Tebbutt, F.R.A.S., &c.

[*Read before the Royal Society of N. S. Wales, November 1, 1893*]

A brief paper by me on the High Tides of June 15 – 17th 1889, was read before the Royal Society on July 3rd of that year, and published in the twenty-third volume of the Society's Journal. It treated of the extraordinary tides which occurred at and near Sydney, at the period referred to, and of the astronomical conditions which combined to produce them. It also referred to another instance of the registration of a very high tide by the Fort Denison gauge on May 26, 1880, and stated the astronomical conditions to which that tide was also due. During a few moments of leisure from my ordinary observatory work, my attention was drawn to a consideration of this interesting subject, and as a result, I found that the approaching summer solstice would present conditions much more favourable for the production of high tides than even those referred to in my former paper.

It is well known that there are two astronomical conditions which are especially favourable for the production of high tides, namely, the conjunction or opposition of the moon and her passage through her perigee. Speaking of the earth generally, we expect that if the new or full moon occur simultaneously or nearly so with her perigeal passage, there will be an unusually high tide. But if we speak of Sydney in particular, there is another condition which sometimes coincides with those just mentioned, and which has a very marked effect on the magnitude of the tide wave. I refer to the moon's maximum declination. When I treated of the conditions which combined to produce the tidal phenomena that formed the subject of my former paper, I showed the close coincidence of the moon's opposition with her passage through her perigee. In addition to these general conditions, I further pointed out that the moon nearly at the same time attained her greatest declination, namely twenty-four and a-half and twenty-three degrees in May 1880 and June 1889 respectively, and that the vertex or crest of the tide-wave therefore approached more than ordinarily near to the latitude of Sydney. But decisive as these maxima of declination were in producing the high tides of May 1880, and June 1889, they were not so potent as will be the corresponding condition at the next summer solstice. A little consideration will show that if at the time of the moon's opposition at the summer solstice the longitude of her ascending node be approximately that of the vernal equinox, the moon's north declination will be its greatest possible, and that as a consequence the crest of the tide-wave will also make its nearest possible approach to the latitude of Sydney.

In order that the members may understand at a glance the eminently favourable conditions which will obtain for a very high tide at next December full moon, I give them in the following table in juxtaposition with the similar conditions for the full moons of May 1880 and June 1889 :—

	1880.	1889.	1893.
	d. h. m.	d. h. m.	d. h. m.
Full moon, Sydney mean time	May 24 4 44	June 13 12 3	Dec. 23 2 41
Perigee " "	May 24 16 0	June 13 14 0	Dec. 23 1 0
Moon's opposition declination	—23° 39′	—21° 30′	+28° 17′
Sun's declination at opposition	+20 51	+23 15	—23 27
Moon's distance at perigee in equatorial radii of the earth	56·05	55·99	55·89

I may add that the diurnal inequality of the high tides about the approaching solstice will be very great, and that it is the day spring-tide or that which occurs when the moon is below the horizon that we must look forward to as the extraordinary one.

In the course of this paper I have referred to those conditions only which may be regarded as strictly astronomical, but there are causes which are more strictly meteorological that have to do with the magnitude of the ordinary tides. Winds and atmospheric pressure have much to do in modifying them. If in addition to the astronomical conditions announced for the December full moon, a strong easterly gale prevail with a very low barometer the expected high tides will be increased, but if on the other hand strong westerly winds prevail with a very high barometer they will be diminished. In conclusion, I shall myself look forward to the records of the Fort Denison tide gauge with much interest, and I trust that the remarks which I have written down during a few leisure moments, may not be without interest to the members generally.

On METEORITE No. 2 from GILGOIN STATION.

By H. C. Russell, B.A., C.M.G., F.R.S.

[*Read before the Royal Society of N. S. Wales, November 1, 1893.*]

It will be remembered that at the June 1889 meeting of the Society, I exhibited a meteorite weighing sixty-seven and a-half pounds, sent to me by J. F. Yeomans Esq., of Gilgoin Station, situated forty miles towards east-south-east from Brewarrina. This meteorite had been long exposed to the weather, and the chemical action of air and rain had broken up its surface to such an extent that pieces fell off each time it was handled.

On the 8th February this year, Mr. Yeomans again wrote to me, and said, "we have in our possession an aerolite, found a short time since, about two miles south of the one we sent you some time ago, I can have it sent to you by train from Byrock." Various delays occurred and I did not get it until September 5th. The meteorite had been very carefully packed, and had not suffered much loss on the journey, although like the previous one from this locality it is much cracked, and many parts of the surface are ready to crumble away. All the parts together weigh seventy-four pounds five ounces, and its specific gravity as a whole is 3·757. The No. 1 Gilgoin meteorite weighs sixty-seven pounds five ounces, and its specific gravity is 3·857. It seems probable from the fact that they were found so close together, that they originally formed parts of the same meteorite, and this view is strengthened by the similarity in outward appearance and in specific gravity. It is but right, however, to add that if so, they must have travelled through the atmosphere together a sufficient distance to cause the usual melted surface, which, although in parts lost by subsequent slow effect of oxidation, is yet too extensive to admit the alternative that they divided as they fell.

This recently found No. 2 Gilgoin meteorite is roughly double convex, and measures seven inches through the thickest part, and fourteen by fifteen inches diameter. The surface has been melted but is not so smooth nor glassy as others I have seen. When a part of it that has not been oxidized is broken, it is dark grey in colour, and shows a great abundance of fine bright white metallic particles. No analysis has yet been made.

PICTORIAL RAIN MAPS.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Plate XXI.]

[*Read before the Royal Society of N. S. Wales, November 1, 1893.*]

Rain maps made with the object of presenting to the eye in a shape easily received, the results of volumes of figures, may be divided into three kinds. First, those in which varying shades or intensities of colour convey to the mind's eye the amount of the rainfall in different parts of a country, or it may be of the whole world. For example we have the rain maps published by the Meteorological Department of India, in which nine shades of the same colour (blue) are used to indicate districts in which different quantities of rain fall, the amount varying from 0 to 100 inches. The same method with variations has been adopted in America, Canada, Victoria, South Australia, France, Germany and other countries, and the same method was used by Professor Elias Loomis in picturing on a map of the world the amount of rainfall in every place where it is known.

This method undoubtedly is invaluable to the student who is looking at the question of general distribution of rain over large areas, but it does not give the practical and easily read details wanted by the agriculturalist and others. The jump from one shade to another is sometimes as much as ten inches, and it must be admitted that this method of picturing the rainfall fails to give that fullness of information which other methods afford, and I think I shall be able to show you to-night a rain map, which, gives the rainfall to within a quarter of an inch for each part of the country; it at the same time shows the areas of equal rainfall.

Second, we have the diagram form of rain map. One of the earliest of these was our own spot map as it is familiarly called, in which a round spot indicates the locality of each observer, and the quantity of rain recorded. This avoids shading in, on the assumption that rain has extended over districts where no measures have been taken. A similar method is followed in Queensland and Tasmania, and for some years was in use in South Australia. In Java a spot is used, but all are the same size, and the quantity of rain is shown by the number of rings in a spot not by the diameter of the spot, and it does not convey to the eye the relative quantity of rain so well as that in which the size of the spots is in proportion to the amount of rain.

In 1880 Mr. G. J. Symons the well known author of "British Rainfall," adopted a diagram form in which a simple spot indicates an average quantity of rain. The signs + and — show excess or defect of rainfall from ten to twenty-five per cent., either sign enclosed by a ring quantities over twenty-five per cent. The same author in 1884 made a diagram in which the length of a vertical line shows the quantity of rain in each month, and twelve such lines placed side by side show the rainfall for the year for each district in which they are placed. The Meteorological Office of the United States draws on some rain maps lines of equal rainfall in addition to the shading, which define more clearly the limit over which the same quantity has fallen.

Third, those in which the quantity of rain is shown by actual figures located so that they indicate the rainfall for the district in which they are placed. One of the first of these, if not the first, forms part of the report on the Meteorology of the Bombay Presidency for 1878, and shows the rainfall there for 1874 and previous years. In this the country is divided by red lines into small areas, in which each individual record is given in black ink, and the mean of all is given in red ink, but the effect is not pleasing and the information not rapidly assimilated. In New South Wales we first used this method in 1883 to indicate the mean rainfall over this colony. The figures were large and can be read at a distance of six or eight feet, the object being to make it possible to see the quantities easily, and they are so conspicuous that they remain as a mental picture not easily forgotten. At that time observers were not so numerous as they are to-day, and for considerable areas there were no observers, the number has gradually increased and is now more than twelve hundred ; and in the new edition of the 1883 map, which I have brought to exhibit to-night, we have been able to get several stations in each square degree of the Colony, save one exception in the extreme north-west. The mean of the records in each square degree has been taken as the average rainfall for that area, and this quantity is shown to the nearest quarter of an inch in large figures on the degree, while other smaller figures show the number of years over which the observations have extended, and the number of stations used to find the mean.

This rain map gives the most complete information about the average rainfall of a country of any that I have seen, at the same time it shows in a conspicuous manner lines of equal rainfall and outlines of large areas of heavier rainfall like the shaded rain map, but it gives at the same time what the shaded map cannot give, viz., the variations in the rainfall of these areas of heavier rain. It was specially prepared to meet the wants of the pastoralist and agriculturalist, but now that it is made it serves also the wants of the student better than any other form of rain map with which I am acquainted.

It will be noted that the amount of rain increases with remarkable regularity in each latitude from west to east, save here and there a slight irregularity due to differences of elevation, and in one or two instances to the records not having extended over a sufficient number of years to eliminate the effect of dry periods. There are however one or two places where the variation from this regularity cannot be explained in this way, notably the head of the Hunter River valley, where proximity to the sea and the mountainous character of the country would lead us to expect a greater rainfall than that shown. There are ten stations there, and records extend over twenty-one years, so that there must be some local condition affecting the rainfall of which I am not aware, but hope soon to find out.

It will be observed that the lowest average annual rainfall in the whole Colony is found in the extreme west, and is nine and a-half inches. Along the valley of the Darling it is from ten to eighteen inches, and along the valley of the Murray it is from twelve to twenty-six inches, while our heaviest average rainfall (seventy-three and three-quarter inches), is found on the Tweed River, which runs at the foot of a range of mountains, some of which rise to a height of five thousand feet, and cause this heavy rainfall by intercepting the east and south-easterly winds.

This average rainfall map includes all the rainfall records up to the end of 1892. It has been published by the Government Printer in a convenient form, and will I hope serve the purpose for which it was designed. See reduced copy of the map, Plate 21.

NOTE ON THE OCCURRENCE OF A NEW MINERAL AT BROKEN HILL.

By Edward F. Pittman, A.R.S.M., Government Geologist.

[*Read before the Royal Society of N. S. Wales, November 1, 1893.*]

It is only a few months since Professor Liversidge read a paper (by Mr. C. W. Marsh), before this Society, describing a new mineral which he named "marshite." The composition of the mineral was iodide of copper, and it was discovered by Mr. Marsh in the celebrated Aldridge Collection at Broken Hill. I have now much pleasure in recording the occurrence of another interesting mineral from the same district, viz., from the Australian Broken Hill Consols Mine. The composition of this mineral is sulph-antimonide of cobalt and nickel. The credit of discovering the mineral is due to Mr. George Smith, M.A.I.M.E., Sub-Manager of the Broken Hill Consols Mine, and it is at his request that I am bringing the mineral under the notice of this Society.

I propose to name the mineral Willyamite (pronounced Willy-ah'-mite) after Willyama the official name of the Broken Hill township, and the aboriginal word meaning a hill with a broken contour. Complete analyses in duplicate of the mineral have been made by Mr. J. C. H. Mingaye, F.C.S., Analyst and Assayer to the Department of Mines, and the results are as follow :—

	No. 1.	No. 2.
Sb ...	56·85	56·71
Co ...	13·92	13·84
Ni ...	13·38	13·44
Fe ...	trace	trace
Cu ...	minute trace	minute trace
Pb ...	minute trace	minute trace
S ...	15·64	15·92
	99·79	99·91

These analyses correspond almost exactly with the formula CoS_2, NiS_2, $CoSb_2$, $NiSb_2$, or a sulph-antimonide of nickel and cobalt. When first discovered the mineral was supposed to be a sulph-antimonide of cobalt, but Mr. Mingaye's analysis shows it to contain equal quantities of cobalt and nickel, although it is of course just possible that future discoveries may show that these two metals may replace one another in varying proportions. The mineral which agrees most closely with willyamite is ulmannite, a sulph-antimonide of nickel NiS_2, $NiSb_2$. In the last edition of Dana's "System of Mineralogy," several analyses of ulmannite are quoted which show that mineral to contain a trace of cobalt, and one specimen is quoted as containing 1·06 per cent. of cobalt in connection with twenty-six per cent. of nickel. The presence of equal quantities however of cobalt and nickel in willyamite appears to justify its recognition as a new mineral. Mr. Smith informs me that a small quantity of the new mineral only was found associated with a lump of dyscrasite in a gangue of calcite and siderite at a depth of one hundred and fifty feet (vertical).

I have tested the physical and pyrognostic characters of the mineral, and they are as follow:—System of crystallisation, isometric. Cleavage, cubic, perfect. Fracture uneven, brittle. Hardness, about 5·5. Specific gravity (mean of a number of experiments) 6·87. Lustre metallic. Colour between tin-white and steel-grey. Streak greyish-black. In the closed tube and next to the assay yields a dark red sublimate, which is orange coloured on cooling, and this is surmounted by a faint white sublimate. In the open tube decrepitates, yields antimonial and sulphurous fumes; near the assay the white sublimate shows in fern-like forms. Before the blowpipe on charcoal, fuses readily to a globule, which boils and emits sulphurous and antimonial fumes. With borax glass gives at first the cobalt blue colour, but after oxidising all the cobalt, the nickel reaction is subsequently obtained. Decomposed by nitric acid with separation of antimony trioxide.

The Australian Broken Hill Consols Lode in which this mineral was found, differs materially from the other lodes on the field, and has more the appearance of a true fissure lode. It has an east and west course, and the working shaft is situated about three-quarters of a mile in an east-south-east direction from that part of the main Broken Hill Lode known as the British Mine. The width of the Consols Lode varies from a few inches up to ten feet and it dips to the south at an angle varying from 24° near the surface to 60° at a depth of five hundred and fifty feet. The lode traverses gneisses and schists and an intrusive (?) basic rock, which has been examined by Mr. J. B Jaquet, Geological Surveyor, and found to consist essentially of hornblende, triclinic felspar and bronzite. According to Mr. George Smith, the lode is productive only where it intersects this hornblende rock. The gangue or veinstuff consists chiefly of limonite down to a depth of one hundred and thirty feet, which appears to be about the limit of the zone of oxidation, below that depth the gangue consists of chalybite and calcite.

Mr. George Smith, who is an enthusiastic mineralogist, has dentified a considerable number of rare minerals occurring in this mine, and I am indebted to him for the following notes upon their occurrence, and also for specimens illustrating a number of the minerals :—

NOTES BY GEORGE SMITH, M.A.I.M.E., Sub-Manager,
Upon the minerals occurring in the Australian Broken Hill Consols Mine.

Dyscrasite or antimonial silver has been found in slugs or masses at all depths. Photographs are exhibited of two of these masses known respectively as the Turtle and the Flitch of Bacon. The former weighed sixteen hundredweight, and contained eighty per cent. of pure silver. The latter weighed eighty-seven pounds and contained eighty-three per cent. of silver. A piece still larger than the Turtle was found weighing twenty-three hundredweight, but was not photographed. The proportions of silver and antimony have been found to vary considerably in different specimens of dyscrasite from the mine. The formulæ of the most common varieties were found to be Ag_3Sb, Ag_4Sb, Ag_6Sb, $Ag_{12}Sb$.

Argentite—Silver Sulphide (Ag_2S).—Very rare, only small specimens met with, contained generally in dyscrasite, sometimes in small crystalline masses, showing a well marked cubical structure; rarely in cubes possessing the peculiar shrivelled appearance reported by Cox and Ratte *(Mines and Minerals).* The purest specimens were never tested; a typical piece gave seventy-eight per cent. silver, the impurity being probably lead sulphide. Very soft, sectile, but not perfectly so. Depth about one hundred and twenty feet (vertical); lode-gangue principally limonite.

Stephanite—Antimonial Silver glance (Ag_5SbS_4).—Found in one part of the mine only in small quantity, in soft puggy ground between two veins of mixed calcite and siderite. Specimens detached and small, all crystallised. Rhombic six sided prisms and tables; macles frequent. Specific gravity 6·23. Contains 67·1 per cent. silver; no silver compounds associated. Depth between three hundred and eighty and four hundred feet (vertical); lode-gangue calcite and siderite.

Pyrargyrite—Ruby silver ore, (Ag_3SbS_3). Also found in small quantity only; very rarely crystallised in hexagonal prisms. Small amorphous pieces apparently very pure, translucent on edges, gave 56·3 per cent. silver. Mostly in films in cleavages of siderite, rarely dendritic in calcite, the latter very dark in colour, rather sectile with the characteristic streak. Always with or near tetrahedrite, rarely with pyrite and pyrrhotite. Various depths; lode-gangue siderite and calcite.

Sternbergite—Sulphides of silver and iron ($AgFe_2S_3$).—Very rare, found encrusting a piece of dyscrasite weighing over fifty pounds, at a depth of one hundred and fifty feet. Several lumps (detached slugs) of dyscrasite were found in close proximity, but only with one was this rare ore associated. Amorphous and more or less impure through admixture with pyrargyrite. The purest piece tested gave silver 33·94 per cent., iron 30·76 per cent., and contained a little antimony, quantity not determined. Fused B.B. to metallic globule; marked paper slightly; streak black;

colour bronze tarnishing blue. Rather brittle, but some pieces almost sectile in places. S.G. 4·34, H. about three. Associated minerals dyscrasite and pyrargyrite. Lode-gangue siderite and calcite.

Stromeyerite—Sulphide of silver and copper ($Ag_2S.\ Cu_2S.$)—The principal ore of the mine and the most uninteresting mineralogically. Never crystalline, but very uniform in appearance, and fairly consistent in silver value, viz., about thirty per cent. Colour bluish- and greenish-black to black. Tough; often antimonial. So common in the past that no special tests were made of it. Depth (where it occurred in large quantities) one hundred to one hundred and forty feet (vertical); associated minerals principally azurite, malachite, volgerite and galena. Lode-gangue limonite and rarely siderite.

Argentiferous Tetrahedrite.—Sulphide of copper and antimony. This and stromeyerite are the only silver ores found in quantity (excepting the antimonial chloride mentioned later). The others are so rare as to be considered curiosities. The bulk of this ore contained about twenty per cent. of silver, though small deposits have been found at various parts of the mine giving about thirteen and a-half per cent. At our deepest level however some of this class of ore has been found containing the same amount as the bulk, viz., twenty per cent. Large quantities have been found in siderite, but the richest and largest masses have always been found enclosed in calcite. The rich varieties have a lighter colour and brighter lustre than the poorer kinds. An isolated imperfect tetrahedron was found, but this was the only appearance of crystalline form observed up to the present. Depth, various, Associated minerals galena, pyrargyrite, chalcopyrite, bournonite and dyscrasite. Lode-gangue siderite and calcite.

Brongniardite—Sulphide of lead, silver and antimony ($PbS.\ Ag_2S.Sb_2S_3$).—Very rare; only met with associated with the upper portion of a large deposit of stromeyerite. Gave very distinctive reactions before the blowpipe, but contained a large quantity of silver—thirty-four and a-half per cent. Encrusted with a grey carbonate of lead into which it was being changed. Purest specimens crypto-crystalline, structure somewhat resembling argentite but very indistinct. Depth about one hundred feet; associated mineral stromeyerite ; lode-gangue limonite.

Antimonial Silver Chloride—Silver chloride (or chloro-bromide) is of comparatively rare occurrence, considering the quantities found elsewhere on this field. A silver chloride has been found in large masses which differs from the ordinary chloride of the other mines, and in fact from any yet reported. This ore is always massive and antimonial ; of a uniform grey colour and fairly constant value of about fifty-five per cent. silver. Some lumps enclosed veins of the ordinary chloride, and others patches of dyscrasite ; some of the latter showed that it had undoubtedly, in my opinion, been altered from the dyscrasite. A specimen in my collection shows the antimonial chloride enclosing a kernel of unaltered dyscrasite, round the edge of which can be seen the chloride in the granular form of the other. A very interesting mineral deserving further attention and analysis. Associated minerals stromeyerite, bindheimite, azurite and volgerite ; lode-gangue limonite. Depth one hundred to one hundred and forty feet (vertical). A round lump (detached slug) of this mineral was found in a soft formation, and was coated with small crystals of ordinary chloride. A large slug was unearthed before I came to the mine, and which I did not see, weighing four hundred and seventy-five pounds. These pieces were shipped to London intact and were presumably homogeneous.

Bournonite—Antimonial lead and copper ore. Entered here on account of its high silver value. Occurs in limited quantity in upper portion of vein forming small bonanzas in limonite, often perfectly isolated from other ores ; always impure containing from about five to seven per cent. silver. Generally associated with various lead ores and malachite ; sometimes showing mechanical mixture with tetrahedrite from which the silver has doubtless been derived. An analysis gave a friend who kindly undertook to determine a specimen of this ore, the following :—

Pb.	29·0
Cu.	8·9
Sb.	25·0
Fe.	3·0
Ag.	5·7
S.	22·5
	94·1
Insoluble	3·0
Moisture by difference ...	2·9
	100·0

Always amorphous ; too impure to be interesting. Associated minerals galena, anglesite, cerussite, bindheimite, tetrahedrite, malachite, and rarely brochantite ; lode-gangue limonite. Depth about eighty to ninety feet, vertical.

Kerargyrite—Silver chloride—Comparatively scarce. Some very pure specimens were found with the antimonial chloride, which were colourless, and in thin pieces quite translucent. Assayed 73·1 per cent. Depth various ; lode-gangue limonite.

Iodyrite—Silver iodide—Fairly plentiful in various parts of the mine. Always with limonite. Some found at shallow depth was associated with a bright red mineral readily tarnishing on exposure to sunlight, which was found to be sulphide of mercury. No special tests made. Various depths.

Galena including Anglesite—Almost all grades of granular form have been met with, from the finest grain—very like chalcocite—to cubes six inches across, but contrary to the general opinion, comparatively little assistance in discrimination was afforded by the differences in crystalline structure. Some samples very rich in silver were exactly similar in appearance to many of the poor ores, occurring sometimes within a short distance of each other in the same matrices. As an instance of their similarity might be mentioned two classes of galena which were being stoped simultaneously within a short distance of each other, and which could not be separated by any difference in their appearance, and yet their respective assays were (bulk samples) one thousand and forty-five ounces and forty ounces, the richer ore in silver strangely enough containing about seventy-five per cent. of lead as compared with sixty-five per cent. in the other ore. Some fine crystals were found, principally cubo-octahedrons, the finest specimens occurring in calcite. Pseudomorphs of anglesite, after galena, were found rather plentifully in the upper portion of the vein, some specimens showing a kernel of unaltered galena when broken, the sulphate often containing a crust of carbonate into which it was being altered. A few assays show the great range in silver value :—

Coarse grain—	Ag.	10 ozs.	fairly plentiful ...	Pb.	83%
„	„	40 „	plentiful	„	65 „
„	„	389 „	rare	„	77 „
Fine grain	„	40 „	plentiful	„	65 „
„	„	720 „	found in fair quantity,	„	80 „
„	„	900 „	„ „	„	80 „
„	„	1080 „	„ „	„	76 „
Very fine grain	„	690 „	very rare	„	79 „

Cerussite—Carbonate of lead ($PbCO_3$)—Very little found. Few crystals in upper levels. Grey variety resulting from the alteration of other ores was found near the rich ore assaying over one thousand five hundred ounces silver, and about sixty per cent. lead.

Phosgenite—Chloro-carbonate of lead ($PbCO_3 PbCl_2$)—Very rare ; amorphous. No special trials made. Contains little silver, about five ounces. Found in upper levels.

Bindheimite—Hydrous antimonate of lead.—Found in good quantity ; generally earthy ; always amorphous ; sometimes very rich in silver. No special tests made of any specimens from this mine. Found in upper levels associated with all the silver ores.

Caledonite—Cupreous sulpho-carbonate of lead.—Very rare and impure, mixed with carbonate and sulphate of lead ; amorphous. No special tests made.

Vanadinite—Vanadate of lead.—Occurs as an incrustation on the crystals (pseudomorphs after siderite) of limonite, not plentiful.

A qualitative determination showed presence of phosphoric acid, chlorine, a little sulphuric acid, and antimony.

Johnstonite ?—Variety of galena—Some peculiar pieces of galena were found from which some of the lead had been eliminated leaving the sulphur free. This variety is possibly identical with the "Johnstonite" reported by Dana.

Stibnite—Antimony trisulphide (Sb_2S_3)—Rare, in fine capillary crystals on siderite associated with mispickel.

Volgerite—Hydrous antimonic acid.—A white earthy oxide of antimony, occurring in small quantities with stromeyerite and sometimes chloride of silver; earthy. Quantity too small to test thoroughly. Contains nine or ten per cent. water. Rather a doubtful species; insoluble or nearly so in HCl. The only sample assayed for silver gave one hundred and seventy-four ounces.

Stibiconite—($Sb_2O_4H_2O$.)—Very rare, earthy. Found enclosed in one lump of silver chloride.

Mispickel—Arsenical pryites.—Rather rare, found scattered in small amorphous lumps through siderite.

Cobaltite—Sulph-arsenide of cobalt (CoS_2CoAs_2)—Rarely in crystals. Amorphous variety common; generally argentiferous through admixture with dyscrasite and sometimes fahlerz. Occurs at various depths in calcite. On exposure soon oxidises to the arsenate (erythrite).

Erythrite—Hydrous cobalt arsenate.—One specimen found only *in situ*, crystallised in stellate form on siderite.

Copper ores—None interesting; only small quantities found. Varieties consist of malachite, azurite, chenevixite, brochantite, bornite and chalcopyrite, the latter most plentifully.

Aurichalcite—Basic carbonate of zinc and copper.—Rare; very handsome specimens were found forming stalactite shaped masses in a vugh near the deposit of rich ore. The inside of these specimens was filled with dyscrasite, iodide of silver and gossan.

Calamine—Carbonate of zinc.—Rare; in small globules on limonite.

Willyamite—Curiously enough this mineral was found associated with one lump of dyscrasite only, about forty pounds. This lump was found near the piece which contained the sternbergite, although other lumps were found in the near vicinity, none of this mineral was found with them, a remarkable coincidence, seeing that the lumps were so close *in situ*. Associated mineral dyscrasite; depth one hundred and fifty feet vertical. Lode-gangue calcite and siderite.

Calcite, Siderite, Limonite—Vein material, often well crystallised. The limonite being of course pseudomorphous after siderite; the change taking place at about one hundred and thirty feet, which may be considered the water level.

Aragonite—In well developed crystals; rare. The best specimens being found at about three hundred feet in a cleft of the enclosing country, viz., amphibolite. All the above minerals were found enclosed by this rock in which the whole shoot of ore exists.

Mercury—Sulphide.—Found as a red hard mineral associated with iodide of silver in limonite in one locality, in upper levels; also three hundred feet lower, coating dyscrasite of a brownish-red colour. All varieties readily tarnish on exposure to sunlight.

Manganese—Manganese dioxide, pyrolusite and wad ?—Rather plentiful in upper levels. The former sometimes in stalactitic and branch-like forms, making good cabinet specimens.

Quartz—Small perfect crystals with double terminations; rather rare. Agate and amethyst, both well coloured; the former was common in upper workings.

Native Sulphur—In small crystals associated with cerussite in vughs in galena, from the decomposition of which it has no doubt been derived.

ARTESIAN BORES ON BUNDA STATION IN QUEENSLAND.

By the Hon. W. H. Suttor, M.L.C.

[*Read before the Royal Society of N. S. Wales, November 1, 1893.*]

With reference to No. 1 Bore on this station I find that boring operations were first commenced on 4th November 1892, and it was completed by the 19th December following. Some delay was caused from want of cable, the estimated quantity is 1,500,000 gallons per twenty-four hours, which gives, as well as I am able to calculate, about 1,040 gallons per minute.

No. 1 Bore cost as follows :—	£	s.	d.
By drilling 682 feet at 15/- per foot	511	10	0
Stewart's well joints, 267 feet at 7/4 per foot...	97	18	0
Seventy-two eight inch conductor at 11/2 ...	40	15	2
Four hundred weight of coal	2	19	6
Twenty cords firewood	10	0	0
Men's wages account	70	13	4
Ration account	33	15	0
	£767	11	0

Completed on 19th December, 1892.

No. 2 Bore.	£	s.	d.
By drilling 613 feet at 15/- per foot	459	15	0
Stewarts well joints, 294 ft. 6 in. at 7/4 per foot	107	7	8
Ninety-four conductors at 11/2	52	9	8
Three hundred weight of coal	1	9	8
Men's wages	34	10	8
Rations	31	0	0
	£732	12	0

Telegram sent on 8th February *re* this bore.

No. 1 Bore is in the creek in Nimro paddock, after running some five to six miles through it, it runs about a mile and a-half through the corner of Britchy paddock, and then some six miles through Black Bull paddock, and going through the fence across the road into the unfenced country, which will make a large area available to the cattle. The water has been helped along by ploughing and deepening the drains from one water hole to another. The outflow from this bore is estimated at 1,500,000 gallons. Where the water flows the grass is growing quite green along the banks of the creek, and the same at the other two bores. The water is clear and sparkling as distilled water, and does not contain much mineral of any kind.

No. 3 Bore is well up in the south end of Black Bull paddock, and runs some ten or twelve miles through it, as yet the water has not passed into the outside country, but it is expected to do so shortly. The outflow from this bore is estimated at 1,500,000 gallons per day, the same as No. 1 Bore, and is seven hundred and forty-two feet in depth and was completed some time in the end of March, 1893. No. 2 Bore is on the north-east side of the Saxby River and is on what is now used as the cattle country about eight miles from the head station up the Saxby and some four miles out from the river. The outflow from this bore is estimated at 1,000,000 gallons per twenty-four hours. Owing to their being no well-defined creek channel to carry the water, and very little fall in the country, this water does not run more than three miles; the water spreading itself out into swamps. As soon as possible drains will be made to bring this water a longer distance for the benefit of the cattle and stock generally. The finding of such a good supply of water at such a shallow sinking has put a value on the run of many thousands, and has reduced future operations and the watering of the place to a certainty.

Mr. Leslie J. de Gruchy, informs me that Richmond Downs Township is seven hundred and ten, decimal fifteen (710·15) feet above sea level.

Bunda Bunda is about eighty miles from Richmond Downs Station, probable fall in the Flinders River four to six inches per mile.

ON THE OCCURRENCE OF TRIASSIC PLANT REMAINS IN A SHALE BED NEAR MANLY.

By B. DUNSTAN, F.G.S.

[With Plate XXII.]

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

FOR sometime past the fossil fern *Tæniopteris*, to which is allied *Oleandridium*, has been known to occur in the beds both above and below the Hawkesbury Sandstones, but as far as I know, there has been no record made of its occurrence in these particular beds.

Professor David has noted the presence of *Macrotæniopteris* in the Narrabeen Shales, and Mr. R. Etheridge, Junr., the Government Palæontologist, has informed me he found traces of *Tæniopteris* and *Macrotæniopteris* in some of the many lenticular patches of shale occurring in the sandstones around Sydney.

Oleandridium, however, until now has not been found anywhere in our sedimentary rocks, and judging from the number of impressions which may be seen on single blocks of stone, the deposits which I have discovered, when opened out, would prove to be immensely rich in these plant remains. All the fossils obtained by me were from exposed places, and probably, by further excavating much better preserved specimens would be found.

The locality in which the deposits of these plant remains occur is about a mile and a quarter north of Manly, and is known as Freshwater, being the second point on the coast line north of Manly Ocean Beach. (See accompanying sketch plan.)

The outcrop of the fossiliferous bed, which is shale and shaly-sandstone of about twenty-five feet in thickness, is very conspicuous on the south side of the point, where a good natural section is exposed to view. The sketch section on the accompanying plan will show its relation to the beds above and below it.

With regard to the horizontal extension of the shale bed, I find the rocks at Freshwater Point have decidedly a dip of 4° in the direction W. 40° S., that the rocks at Curl Curl Head to the south have a dip in the direction slightly north of west, and that the rocks at Deewhy Head have a dip almost the same as those at Freshwater, both in direction and inclination. Consequently the shales should outcrop on Deewhy Head but not at Curl Curl Head, and this I find to be the case. At Deewhy they are somewhat altered in character, being much more arenaceous than those at Freshwater.

At Curl Curl Head, although the shale bed is not to be seen yet traces of plant remains are to be found, and probably *Oleandridium* and other forms may occur above the geological horizon of the shale beds at Freshwater Point.

Between Freshwater Point and Deewhy Head occurs a large lagoon, and when visiting the locality I was struck with the idea that perhaps the existence of this lagoon may in some measure be due to the presence of these soft shales. On studying the question I am convinced that not only does the lagoon owe its existence to the shale bed, but that also the contour of the coast line in this locality has been influenced by it. A visit to the spot will show that both marine and subaerial denudation has taken place —that the sea in the past has made encroachments where the soft shales dip below sea level south of Freshwater Point, and that streams have eaten away the shales to just below sea level, between the Point and Deewhy Head, and that the wide channel formed has been closed, and is now being gradually filled up by the accumulation of deposits of blown sand and alluvial.

Mr. Etheridge has kindly undertaken to work out and describe the plant remains, and his results will be published subsequently. Provisionally his classification of the different forms is as follows:

Macrotæniopteris wianamattæ (Feist.)
Oleandridium, sp. nov.
Phyllotheca, sp. non det.
(?) *Podozamites*.

(?) Seed vessels.

(?) Seed scales.

In conclusion I must tender my thanks to Mr. W. W. Froggatt of the Technological Museum and to Mr. E. Avdall, a geological student of the Sydney Technical College, for assistance kindly rendered.

THE ORBIT OF THE DOUBLE STAR ♄ 5014.

By R. P. Sellors, B.A., Sydney Observatory.

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

This double star, which was discovered by Herschel at the Cape of Good Hope in 1836, has now described about half its apparent orbit, so I thought I would try if a set of elements could be found which would represent fairly well the observations. I accordingly collected all the measures to which I had access, and think the accompanying list is complete. It will be seen that the observations from 1836 to 1886 are very few and unsatisfactory; this is no doubt to be accounted for by the closeness of the pair at that time; Herschel describes it as "excessively close and difficult," and Jacob compares it to "a dumpy egg." It is to be regretted that more attention has not been devoted to this star, as it is an interesting binary, and with more measures to work from, a tolerably good orbit might now be obtained. The elements which I have the honour to submit to the Society are, of course, only provisional, but seem as satisfactory as can be expected from such data. The distance measures are so scanty that I had to draw the apparent ellipse from the position angles alone, after the method devised by Herschel. Mr. Burnham has pointed out that by thus rejecting the distance measures one may be misled by an apparent agreement between the observed and calculated positions, and conclude that the result must be the best that is obtainable from the given measures when really it is not so. In the present instance no other course is open, there being no distance measures at all over a great part of the arc described. The elements were deduced from the apparent ellipse by the formulæ given by Prof. Glasenapp in Vol. XLIX. of the Monthly Notices of the Royal Astronomical Society.

The Right Ascension and South Declination for 1900 are, 18 h. 0 m. and 43° 24′, and the components are equal and of 6·5 magnitude.

Elements.

Ω = 37° 39′	a = 0″·91
ι = 37 13	T = 1839·00
λ = 199 36	P = 141·69 years
ϵ = 0·499	μ = —2°·5408

The following is the comparison between the observed and calculated positions :—

Epoch.	Observer.	θ_o Observed Pos. Angle.	θ_c Calculated Pos. Angle.	$\theta_o-\theta_c$	No. of Nights.	ρ_o Observed Distance.	ρ_c Calculated Distance.	$\rho_o-\rho_c$	No. of Nights.
		°	°	°		″	″	″	
1836-73.	Herschel	249·2	251·2	—2·0	4	0·67	0·43	+0·24	1
57·28	Jacob	135·1	133·8	+1·3	2	0·55e	0·63		
80·46	Russell	79·3	82·5	—3·2	1	0·81	1·05	—0·24	1
80·53	Cruls	84·4	82·4	+2·0	2	0·6e	1·05		
86·57	Pollock	74·8	75·0	—0·2	1	1·27	1·14	+0·13	1
87·75	Pollock	73·0	73·8	—0·8	3	1·38	1·16	+0·22	2
90·61	Sellors	71·4	70·7	+0·7	2	1·21	1·19	+0·02	2
91·63	Sellors	69·9	69·7	+0·2	2	1·10	1·20	—0·10	2
93·64	Sellors	68·1	67·7	+0·4	3	1·02	1·23	—0·21	3

OCCURRENCE OF EVANSITE IN TASMANIA.

By Henry G. Smith,
Laboratory Assistant, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

The Sydney Technological Museum having come into possession of a small collection of minerals from the mines of Zeehan and district, in Tasmania, I found when investigating them for the purpose of classification, that this specimen gave different reactions than those expected. It came from the Mount Zeehan Company's Mine, and was stated to be known locally as "soda crystals."

The small globular excrescences covering the surface, somewhat botryoidal in appearance, are entirely amorphous and without a trace of crystallization, colourless, and these have a vitreous lustre resembling glass, or milky-white and slightly opalescent, often translucent, very brittle, streak white, hardness near 4, specific gravity 1·842 at 60° F.

Heated in a closed tube it decrepitates and gives off much water which has an alkaline reaction. When heated with nitrate of cobalt solution, gives an intense blue colour. Heated before the blowpipe, gives a greenish flame. Soluble in sulphuric, nitric, and hydrochloric acids. These properties only differ slightly in some respects from the original Evansite from Zsetcznik, Hungary; examined and described by David Forbes, F.R.S.*

The specific gravity of the Tasmanian specimen is a little lower than the original, given as 1·939, although two of Mr. Forbes' determinations gave 1·872 and 1·822. The water given off in the present specimen is alkaline, while that of the original specimen was neutral.

In all the determinations and analysis only the perfectly glassy beads were taken. No fluorine, silica, or iron were detected in these. The mineral is a basic aluminium phosphate.

* Phil. Mag., IV., XXVIII., p. 341, 1864.

The phosphoric acid determined by molybdate of ammonia gave 17·996 per cent. By citric acid and precipitating with sulphate of magnesia 18·232 per cent., mean 18·114 per cent. The amount of water present was 41·266 per cent., the greatest precaution being taken to prevent loss by decrepitation. The loss equalled ·434 per cent., this may be considered principally as alkalis; all attempts to detect ammonia, as indicated by the alkaline water, failed. On evaporating the filtrate from which the phosphoric acid and the alumina had been removed, the minute quantity left gave a strong sodium flame. The white opaque cellular portions of the specimen are very siliceous. The rock appears to be a slaty one, and a few particles of galena are present.

The formula $Al_3P_2O_{14} + 18H_2O$ gives

Theoretically :—	Alumina ...	39·8%,	Found:—	40·186%.
,,	Phosphoric acid	18·35%,	,,	18·114%.
,,	Water... ...	41·85%,	,,	41·266%.
			loss	·434%.
		100·00		100·000

Since the above paper was read, my attention has been directed to a "Catalogue of the Minerals of Tasmania" by Mr. W. F. Petterd, published during the present year. On page 27, under Evansite from Zeehan is the following :—"A rare species, occurring as botryoidal incrustations which are often almost colourless but sometimes milky-white, at all times having an attractive pearly lustre. It appears to differ from the typical form in having a proportion of silica chemically combined. The examples were obtained in a silver-lead lode, with galena and sphalerite."

From a courteous communication since received from Mr. Petterd, it appears that the above is all the information published in regard to the Tasmanian mineral, so that my analysis and observations will prove acceptable.

THE PROGRESS AND POSITION OF IRRIGATION IN NEW SOUTH WALES.

By H. G. McKinney, M.E., M. Inst. C.E.,
Chief Engineer for Water Conservation.

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

It is not generally realised that notwithstanding the remarkable succession of good seasons which this Colony has enjoyed since 1888, irrigation is being more widely adopted every year, and its benefits are becoming better understood. The wet seasons have in a number of cases, led to a diminution of the irrigated areas in the Eastern and Central Divisions in recent years, but the number of irrigation plants has increased, and there are strong indications of a more rapid increase in the near future. The importance of developing the export trade is beginning to be generally understood, and as a natural consequence every means of increasing the productiveness of the land is receiving increased attention. Irrigation is, however, still in its infancy here, so that it is not necessary to go far back in tracing its development.

When, as a visitor from India, I first travelled over the plains in the southern and south-western districts, about seventeen and a half years ago, the miserable appearance of the herbage where any was to be seen, and the numerous skeletons of sheep and cattle to be seen in all directions, showed much better than any words could do, the necessity for providing means for sustaining the live stock in dry years. When I ventured to suggest to some enterprising and successful pastoralists, that it would be well worth while to try irrigation of fodder crops at suitable places in their runs, these pastoralists, with all the assurance of superior knowledge informed me that such a suggestion coming from an Anglo-Indian who did not understand the conditions of labour in Australia was not surprising; but that in reality it was absurd to entertain the idea of carrying on irrigation with profit in these colonies. A second visit to the south-western plains showed that these same pastoralists had come to the conclusion that the absurdity was all on their side. In fact some of those who in 1876 had ridiculed the idea that irrigation might prove profitable in the western districts of this Colony had themselves adopted that means of reducing the losses occasioned by lack of rainfall. This change of ideas had occurred without any appreciable alteration in the conditions of labour.

Doubtless, questions connected with the tenure of the land had an important effect in curbing enterprise and preventing the adoption of any course which would tend to show the value and productiveness of the land. There was certainly abundant evidence in 1876 that the pastoralists in the Murrumbidgee and Murray Districts were not wanting in enterprise in regard to providing water for their stock. The Burrabogie run near Hay, now the property of Mr. Wentworth, but then the property of Messrs. McGaw & Co., was perhaps as good an instance as could then be found in the Colony of the extent to which the stock-carrying capacity of the land could be increased by the adoption of suitable means for conserving and utilising the available supply of water. Dams, tanks, and wells were extensively used, and with them a remarkable variety of water-lifting appliances from the centrifugal pump to an ingenious adaptation of the balance lever worked by horse power. In short, throughout the districts adjoining the Murrumbidgee and the Murray, a very creditable amount of enterprise and ingenuity was shown in providing water for stock requirements; but the idea that irrigation was financially feasible, even with the drought then prevailing, was universally scouted.

A settler from one of the Western States of America would scarcely credit the statement that men of intelligence and enterprise under such conditions, would hold such opinions. The explanation is, however, not difficult to find. The policy adopted in the Western States of America was to sell the land at a price little more than nominal, and to grant to the purchasers extensive rights to river waters free of charge. In New South Wales, immense areas of land were sold to pastoralists above their true market value, the purchasers being practically compelled to buy to prevent their runs from being ruined by selection. Where the land was not sold to the pastoralists, the conditions of tenure were not such as to encourage the runholders to develop the capabilities of the soil. While charging a higher price for the land or letting it on terms which did not encourage its development, the Government of this Colony conceded no rights whatever in regard to river waters. The results of these widely different policies in this Colony and in the Western States of America are such as might have been anticipated from the commencement thus made. The landowners in the Western States soon understood what a valuable property they had in the waters of their rivers, and they lost no time in turning this property to account. Having obtained their land at a very moderate cost, they were the better able to proceed with works for increasing its productiveness. Not having a Government which they could look to for assistance with any hope of obtaining it, they quickly learned how to help themselves. Thus in Wyoming, which became a State only in 1891, and which has a population of only 65,000, the sum of ten million dollars, or say two millions sterling, has been expended on the construction of channels for diverting water from the rivers. In 1889, before this Territory was constituted a State the area of irrigation was nearly 230,000 acres of crops, without reckoning irrigated pasture land. The total area of crops irrigated in the year mentioned in what is termed the Arid Region in the Western States of America amounted to over three and a half million acres. In this Colony the landowners, by constructing tanks, dams, and wells have made provision—in some cases sufficient, in others not so—for watering their live stock; but as they cannot obtain any legal authority for increasing the stock-carrying capacity of their holdings, by irrigation, comparatively few are willing to incur the necessary risk and expense.

What the landholders of New South Wales and the Colony at large, lose by this backward state of irrigation may to some extent be inferred from the returns of the United States Census Office. In a report of that office, dated 20th August, 1892, the following passage occurs :—"The average value of the land irrigated in 1889 with the improvements thereon, is found to be $83·28 per acre, and the average value of products for the year stated $14·89 per acre. By correspondence with over 20,000 irrigators, fairly distributed throughout the arid and subhumid regions, it has been ascertained that the average first cost of irrigation is $8·15 per acre and the average value placed upon the water rights, where separable from the land, $26·00 per acre, or over three times their original cost. The average annual expenditure for water, as distinguished from the purchase of water rights, is $1·07 per acre, and the average cost of the original preparation of the ground for cultivation, including the purchase of the land at the Government rate of $1·25 per acre, is $12·12 per acre. By applying, with necessary modifications, to the enumerator's returns, the averages obtained for each separate State and Territory, it has been found that in round numbers the total investment in productive irrigation systems utilized in 1889, in whole or in part, was up to June 1st, 1890, $29,611,000. Their value at that date was $94,412,000 showing an apparent profit of $64,801,000, or 218·84 per cent. In the same manner the aggregate first cost of the irrigated areas with their water rights, not including the farms of the subhumid states, has been ascertained to be $77,490,000, and the value of the same on June 1st, 1890, $296,850,000, showing an increase in the value of land and water rights of $219,360,000, or 283·08 per cent. In other words, the land irrigated in 1889 was worth nearly four times what it cost, no allowance evidently being made for failures. The total expenditure for water, including the maintenance and repairs of ditches, in the arid states in 1889 was $3,794,000 and the total value of products $53,057,000."

It is quite beyond question that the development of this Colony and especially of the fertile plains west of the Dividing Range, is and has been seriously retarded through want of suitable legislation on the subject of water rights and the utilisation of our rivers. On the other hand, it is equally beyond question that legislation or legalised customs of a somewhat reckless character have given an unhealthy stimulus to the construction of channels for diverting water from the rivers of the Western States of America. The ill-considered design and wasteful working of many of the channels was referred to in Mr. Deakin's interesting and instructive report on American Irrigation. These faults are doubtless due in a large measure to the haste involved in acting on the principle "first come, first served." The working of this principle in Colorado, and of the useful modification of it adopted in Wyoming, has been described as follows :—" In Colorado, A taps a stream and runs his ditches as far as he pleases. Then B taps the stream above A and runs his ditches in the same or another valley or locality. Farming is carried on along both sets of ditches ; but when there exists a scarcity of water, A appeals for his priority rights and gets all the water his ditches will carry. B has his ditches closed, and the orchards and gardens and grain fields along his ditches must die of drought, even though A's territory may not be all under cultivation, or though he may have twice the water he needs. Under the Wyoming system, priority rights prevail, but only water that is actually benefiting land is at any man's disposal." I may here remark parenthetically, that I have never been able to discover on what grounds the Americans apply the term "ditch" to an irrigation canal or distributary. If this term were used regarding American irrigation channels by a hostile critic, the meaning would be obvious, though in many cases the application would be unfair, as there are many American irrigation canals which certainly do not deserve to be called "ditches."

The wholesale waste, both in water and the cost of construction of works, arising from such a system as that described is at once apparent. With reference to this, an American might very pertinently ask us whether such a state of affairs is not preferable to the backward condition of this Colony through want of suitable legislation. On the one hand we have in Western America wholesale waste and extravagance, due chiefly to the haste with which settlers naturally avail themselves of their water rights; but to counterbalance this waste, there is the great progress of agriculture and of horticulture. On the other hand in New South Wales the development of agriculture and horticulture has been greatly retarded, owing to the fact that no person has any right to use the river waters for irrigation. The free use of the river waters in Western America has led to remarkable progress in the cultivation of the land, but it has created objectionable monopolies, has caused much useless expenditure through ill-considered design and faulty construction of works, and has laid the foundation for endless disputes and litigation. Mr. Deakin has described how in California and Colorado, canals were constructed without engineers and even without surveys. Under such circumstances it is not surprising to find a more recent writer on the same subject, stating that he saw on a map of one of the counties in Wyoming a place where, to use his own words, "one hundred and fifty ditches, paralleled and duplicated one another in land which two ditches would have served thoroughly well." A comparison of Mr. Deakin's report on Irrigation in America with his recent admirable work on Irrigated India is very instructive on this and kindred points.

Notwithstanding the exceptionally favourable seasons which this Colony has lately experienced, and the absence of any legal right to irrigate from our rivers, the spread of irrigation since 1884 has been much greater than is generally supposed. In that year the Royal Commission on the Conservation of Water was appointed under the presidency of the present Minister of Works, Mr. Lyne. Up till that time, with a very few exceptions, irrigation in New South Wales was practised only by Chinamen, who in this respect may, and very possibly do, claim to have been the pioneers of civilisation. Now there are pumping appliances for irrigation purposes to be found on every important river, and on a number of creeks and lagoons west of the Dividing Range; and not only so, but even in the coast district, irrigation, particularly of orchards, is regularly carried out. This is highly encouraging progress, especially when it is borne in mind that since records of the rainfall and of the river levels began to be kept no such succession of wet seasons as we have lately been favoured with was ever experienced. In a number of cases in which irrigation of fodder crops was carried on in dry or ordinary seasons, such irrigation has in recent years been wholly or partially suspended ; but this is more than counterbalanced by the increase in the number of cases in which pumping machinery for this purpose has been brought into use and by the extension of knowledge of the subject and its importance.

During three years, from 1889 till 1892, prizes were awarded by the Government for the best irrigated farms and orchards. Having had the honour of being one of three judges in the first of these years, and sole judge in the other two, I had excellent opportunities of observing the progress which is being made. The competitors west of the Dividing Range represented properties on the Namoi, Lachlan, and Murrumbidgee Rivers and the Gilmore Creek, a tributary of the Tumut River. Those east of the Dividing Range represented the Hawkesbury, the Parramatta, and the Bega districts. From some cause or other a number of irrigators, particularly on the western rivers, did not compete, although their properties would have attracted favourable notice if they had been entered. The properties which were entered showed in a number of instances a highly creditable class of work, and showed also that the irrigators had the ability and judgment to select the methods best adapted to their circumstances.

The properties entered, though not numerous, embraced orchards, mixed farms, and farms specially intended for providing fodder on pastoral estates. In some cases the conditions were all in favour of the irrigators, but in others it was surprising that irrigation was ever attempted. The most remarkable case of irrigation under difficult circumstances which I have seen, was that successfully carried out by Mr. Wren, Manager of the Kameruka Estate near Bega. As a considerable quantity of fodder was required on that property, and a stock of it had to be maintained, Mr. Wren went into the question whether he could produce lucerne hay in a central position in the estate. He came to the conclusion that he could do so with advantage, notwithstanding the serious difficulties to be overcome. Owing in a great measure to the high cost of carriage, lucerne hay could seldom be obtained for less than £6 per ton, and had cost as much as £8 per ton. The problem to be solved was how to produce lucerne hay at a lower cost than this on land which consisted of low but steep hills without any intervening valleys. A good supply of water was available, but the soil on these hills was only from five to nine inches deep, underlaid by disintegrated granite, the depth of which was seldom less than two to three feet, and as a rule was considerably more. Under these unpromising circumstances not only were good crops of lucerne of a high quality obtained, but on account of the admirable manner in which the water was distributed, the crop was more even than almost any crop of lucerne I have ever seen on the plains. The secret of this uniform distribution of the water lay in the fact that the channels were skilfully marked out with the aid of a simple but effective water level, which was made by Mr. Wren's engineer, and were constructed in a proper manner. As a rule, in the construction of distribution channels in these colonies and America, economy in first cost is attained with considerable sacrifice of efficiency and economy in the subsequent working. At Kameruka, the channels were neatly cut with the Hornsby draining plough, and very little hand dressing was required. The water had to be raised two hundred and forty-six feet, and the pumping plant was guaranteed to deliver 30,000 gallons per hour at that height. The circumstances here were most exceptional, and though the experiment was successful and satisfactory, it is unlikely that irrigation will be attempted in many other cases where like difficulties exist.

Another irrigated property in which I found features of a somewhat unusual character was the farm in the pastoral estate of Mr. Wills Allen at Gunnible, near Gunnedah. Here also the chief crop irrigated was lucerne, but maize and other grain crops were grown successfully. This is a class of irrigation which deserves to be widely imitated, as on it will depend, in an important degree the increase of production and settlement on our western rivers. The source of supply in this case is the river Namoi, and the water is raised by a centrifugal pump to a maximum height of slightly over thirty feet. This is one of those cases in which economy in the construction of distributary channels has been carefully considered, while economy in water has been left out of account. The style in which the irrigation is done would not be allowed on any canal in Upper India—in fact it is just such a case as would be deemed to require the application of the penal clause in the Canal Act relating to waste of water. Yet the result is highly successful and no one is at present injured by the extravagant use of the water. The soil is of a very porous character and is underlaid by drift and shingle, so that the natural drainage leaves nothing to be desired, and no damage is done by over-watering. On the contrary, as the water contains certain fertilizing properties, the land is really manured as well as watered by the copious floodings. All this has been taken into account, and there is no doubt that the results obtained amply justify the practice adopted. Not only is the supply of water actually used with the crops unusually large, but there is extensive loss of water in the distributary channels. Like the case of the pumping, this also was a matter which was carefully considered by Mr. Wills Allen, who came to the conclusion that the broad and shallow channels while wasteful of water, were, as compared with channels constructed on more scientific principles, a source of convenience and economy in working his irrigation paddocks. Viewed in this light, the position was a perfectly sound one. The results of the irrigation are highly satisfactory, and the system followed is undoubtedly warranted by the circumstances, though there are many places in which such watering would kill the crops, and others in which it would turn the land into a marsh.

In the Central and Western Divisions, wherever a supply of water is available, irrigated gardens and orchards are to be seen beside the homesteads of a large proportion of the landowners. But in addition to this, irrigation has been in many places successfully adopted by professional fruitgrowers. In the western districts it may be stated that as a rule fruit cannot be grown except by this means, but it is somewhat surprising that the best managed irrigated orchards which I have seen are in the coast district. It is improbable, however, that this supremacy will be long maintained. When the owner of an orchard ten acres in extent spends nearly £200 on a steam boiler, pump, and piping for irrigation, and finds that his outlay gives a highly profitable return, there is clearly a good field for such enterprise and a fair margin to allow for mistakes. Such outlay under such circumstances has actually been incurred in several instances in the coast district and with the result stated.

In connection with irrigation of orchards it may be here mentioned that great advantages to intending irrigators are likely to be obtained in the Irrigation Trusts at Hay, Balranald, and Wentworth. The Municipal Council of each of these towns has been constituted an Irrigation Trust by special Act of Parliament and in each case a highly valuable grant of land has been given free by Government for subdivision among intending settlers. The Trusts have to obtain the necessary pumping plant for raising the water, and have to construct the works for its distribution. The settlers will be required to fulfil certain reasonable conditions as to residence and cultivation and to pay interest, working expenses, and sinking fund. The present time is very unfavourable for starting new enterprises like these, but there is a strong probability that notwithstanding this fact two of these Trusts will soon be in a position to commence operations.

The question of utilising for irrigation the surplus water from artesian bores, is one with which I had to deal when it first attracted attention, three or four years ago. I then suggested the advisability of using the available supply of water at every artesian bore for the purpose of raising crops—fodder by preference—which might be required in a time of drought. The district beyond the River Darling, in which nearly all the successful artesian bores are situated, is not likely to be used to any considerable extent for other than pastoral purposes. This being so the object to be aimed at here is the increase of the stock-carrying capacity of the land. The attainment of this object depends mainly on the provision of an ample supply of water for the stock and of reserves of fodder for assisting in tiding over dry seasons. Throughout a large portion of the north-western district, these requirements can be met in part by artesian supplies of water. There is therefore, strong reason for drawing on these supplies to their fullest extent, and making use of them to the greatest advantage.

As already mentioned, irrigation in connection with pastoral properties has in some cases, particularly in the Central Division, diminished in recent years owing to the exceptional rainfall. Since 1886 the record of maximum annual rainfall has been twice broken, namely in 1887 and 1890; not only so, but, with the exception of 1888, every year since the beginning of 1887 has been above the previous average in regard to rainfall and to floods in the rivers. A resident of the Gwydir district of twenty-seven years' standing, lately informed me that during the whole of that period there was no such succession of floods as that experienced in the last few years. The most sanguine will scarcely expect this state of affairs to last much longer. Since the last severe drought the number of sheep in this Colony has nearly doubled, other live stock have increased very largely in number, and the importance of agriculture, dairying, and fruit growing have advanced in at least a corresponding degree. Under these circumstances the question suggests itself, "How are we now prepared for a drought"? This is a question of the first importance and one which requires to be examined from several points of view.

In the last ten years the number of sheep in this Colony has increased from 36,115,000 to 58,080,000, and other live stock have also increased largely, though not in the same proportion. Selectors in the Central Division and homestead lessees in the Western Division constitute an important increase in the number of settlers. While the seasons have, on the whole, been unusually favourable, the low prices for wool and for live stock and produce generally, and the loss and expense caused by rabbits, have, in many cases, more than counterbalanced the benefits which might have been expected from increased rainfall. Bearing these facts in mind, and also taking into account the present state of the money market, there is no doubt that regarded from the purely financial point of view, the Central and Western Divisions are not so well prepared for a drought as they were ten years ago.

There is another point in regard to which the Western Division particularly has deteriorated; namely the quantity of edible scrub. When grass was not to be had, the rabbits quickly discovered all the most useful and nutritious kinds of edible bushes and scrub, and they sustained themselves on the bark of these and as much of the leaves as they could reach. In this way the edible scrub was killed over very extensive areas, and in a number of instances the resumed areas of pastoral holdings were abandoned by the lessees, largely on this account. As a striking instance of depreciation of the value of pastoral holdings owing to the presence of rabbits, and to the destruction caused by them, it may be mentioned that in March 1892, a station in the south-western part of the Colony, comprising about 1,200 square miles of country and including 5,000 acres of freehold land with a good woolshed, home-station and garden, and 10,000 sheep, fifty horses, and fifty head of cattle was sold for £3,250.

Thus, as compared with the position ten years ago, we have a largely increased number of live stock, diminished carrying capacity of large areas of country, and a much more stringent money market. But on the other hand, railway communications have increased largely during that period, and the facilities for transferring live stock from one part of the Colony to another have increased in a corresponding degree. This is a very important matter, as it rarely happens that there is not some part of the country which escapes a drought, and to which stock in large numbers can be transferred. Another important redeeming feature in the present position is the large number of pumping engines on the rivers and the increased knowledge of the capabilities of irrigation. There is no doubt that as soon as the pinch of drought begins to be felt, the irrigation plants in the Central and Westrn Divisions will be worked to their full capacity, and a great stimulus will be given to irrigation enterprise. It is to be regretted that the favourable seasons have had the effect of making very many of our landholders forget what a drought is like, and of lulling them into a feeling of security which the statistics of the rainfall do not warrant. In each of the three classes of country landholders—pastoralists, farmers, and fruit growers—there are men to be found who stand in the front rank in the knowledge and practice of their business, but they constitute only a small minority. Landholders as a rule are the most conservative portion of a community, and the slowest to adopt altered methods or new expedients. Still it is not likely to happen again that on rich alluvial land fronting on a permanent river, mattresses will be ripped up for the fodder which they contain, or flour used in the absence of other available food to keep horses alive, as has actually happened in times past; but it may be confidently expected that when a drought does come, many of the landholders will be badly provided with reserves of fodder to meet it. While many have neglected excellent opportunities of collecting large supplies of bush hay—that is, hay made from the natural grasses—it is not surprising that those who have pumping engines have frequently contented themselves with producing lucerne and other fodder crops in quantities very little above current requirements.

Respecting this question of irrigation for pastoral purposes, it is worth while to examine how it is dealt with in the Western States of America. In the references to American irrigation which have appeared in the press in this Colony, the fruit growing industry is so frequently referred to as to create an impression that irrigation there is confined chiefly to orchards. As a matter of fact, with the exception of California and New Mexico, all the States in which irrigation is practised have a larger area in fodder crops than in all others combined. Not only so, but in some at least of the States, in addition to these crops, extensive areas of grass land are watered merely for pasture. In this country, though we are beyond the stage at which intelligent persons will be found to make the bald statement that irrigation will not pay, there are still many who will state that irrigation of grass land or of cereals will not pay. Such a statement is really absurd and meaningless, unless the rainfall is so abundant that further watering would not be beneficial. If by supplementing the rainfall an increased growth of grass or an increased crop of cereals resulted, clearly there would be appreciable benefit from this watering. If the value of this benefit exceeded the cost of the watering it would be clear that it did pay to have the watering. For instance, if by irrigating wheat the average yield were increased by five bushels per acre, while the cost per acre of applying the water was equivalent to the value of two bushels, there would be no question as to the watering being remunerative. It is extraordinary that so much misapprehension exists in regard to a point which seems so obvious. As a matter of fact there are places in this Colony in which irrigation of grass land is practised with great advantage, and there are others which present nearly equal facilities for it. In short where water is available or can be made available, what the landholder has to ascertain before he can come to a conclusion on the subject of irrigation is in the first place the most suitable crop to produce, in the second place the cost per acre of irrigating that crop, and in the third place the value of the increase of crop owing to watering. If this method of taking up the subject were generally adopted, there would be no doubt as to the results. I have not met with or heard of a single person in this Colony who has tried irrigation in a rational and business-like manner, who has not been thoroughly satisfied with the experiment.

When the railway system of India was much less extensive than it is now, the importance, in times of famine, of what were termed "protected areas," was recognised, and as far as possible the principle of providing for such areas was acted on. A district was protected against famine when there was a sufficient area of irrigated land to supply food for the population within its bounds. Notwithstanding the rapid increase in the population of India, famines are becoming less frequent and less severe. This is due almost entirely to the extension of irrigation and of railway construction. The same system is wanted here, not in our case for the protection of human life, but chiefly for the protection of live stock. If the western districts were dotted over with irrigation farms, wherever water is available, and pastoralists would adopt the principle of having at least one acre of irrigation to every five hundred acres of land in its natural state, the position of the country in time of drought would be immensely improved. In land which in its natural condition cannot be depended on to feed more than one sheep to every ten acres, the importance of patches of lucerne, every acre of which will supply feed for twenty sheep is at once apparent. This is the class of irrigation which is likely to prevail throughout a large part of the colony; but on some of our rivers, and particularly on the Murrumbidgee, Murray, and Macquarie, there is scope for projects which in point of magnitude will take rank with the more important irrigation systems of the Western States of America.

I was glad to find that there is a paper by an expert in agricultural chemistry to follow this one, the subject being Irrigation from Artesian Wells. The same branch of the irrigation question was dealt with last year in a valuable paper read before this Society by Mr. Mingaye, the Chemical Analyst attached to the Department of Mines. While it would be out of place for me to attempt to deal in any way with questions which belong to experts in chemistry, it is only right that I should refer to the saline efflorescence found in many places in India, and attributed by some to irrigation. Having had the advantage of living for years in districts largely affected by the efflorescence, which is known in Upper India by the various names, "reh," "usur," "shōr," and "kullur," and having been in immediate charge of irrigation works in these districts, I am in a position to speak from actual knowledge of the facts. The subject is one which received much attention, both from the irrigation engineers and from the land settlement officers. For many years it has been well known in India that irrigation should not be allowed in places where the soil is much impregnated with salts or where the subsoil drainage is defective. So long ago as 1862, General Strachey of the Royal Engineers, lucidly stated the case as follows:—"The salts known as "reh" are contained in the soil. If canal percolation takes place, it may at length proceed to such an extent as to saturate the subsoil with water. The surface being at the same time exposed to sun and air, becomes heated, and continual evaporation goes on. The water lost by the surface evaporation is replaced by moisture drawn up from below by capillary action. The water coming from below contains a certain quantity of the soluble salts of the soil which it has taken up on its way: as the water evaporates at the surface the salts must be left behind, and a constant accumulation of the salt takes place on the evaporating surface. Where such efflorescence takes place at a distance from a canal, and where no free percolation takes place, it may possibly be explained by the action of an impervious stratum of clay (or kunkur) at some depth below the surface, which arrests the descent of water derived from the fall of rain (or irrigation), and accumulated from a large area into some natural depression, and held, as it were, in a basin, though of course diffused in the subsoil from which the great summer heats at length extract the whole of it with the same result as before suggested."

This theory may not meet all cases, but it is recognised that it has very wide application. Hence, when it fell to my lot to take charge of the first irrigation which was started on the Lower Ganges Canal, I had special instructions in accordance with the principles here laid down. In the early days of the large irrigation works in India, and before this question was understood, there is little doubt that in some instances the saline efflorescence was spread by injudicious irrigation; but precautionary measures were subsequently instituted, and more recently the Indian

Government, not content with preventing the spread of the *reh*, has been conducting experiments with a view to its extirpation.

The river waters of this country, like those of India are highly suitable for purposes of irrigation, and all that is required in utilising them is to make certain that they are used only on suitable land. The waters from some of our artesian bores contain such proportions of salts that caution will be required in making use of them for irrigation. In some cases in India where the rainfall was insufficient to produce crops with any degree of certainty, while the only water available was more or less brackish, I have seen such water used to a limited extent for irrigation, the salt being in sufficient quantity to form a deposit in the small distributaries. This irrigation was adopted as the best of a choice of evils—possible privation on the one hand and probable injury to the land on the other. A similar choice of evils may have to be met sometimes in the western districts in this Colony.

In conclusion, I may point out that in regard to irrigation we have only passed the period of experiment, and have yet to deal with it on a scale commensurate with our opportunities and requirements, this fact contains much ground for consolation and encouragement in such a time of depression as we are now passing through. The immense resources of this Colony, and particularly of its soil, are altogether undeveloped. The necessity for increased production is now apparent to all, and the means to that end are therefore certain to receive more attention. As one of the most potent aids to production, irrigation will command its share of consideration ; but while our settlers are held back by the curb of antiquated and unsuitable laws, they cannot be expected to show their capabilities to advantage.

PRELIMINARY NOTE ON THE OCCURRENCE OF A CHROMITE-BEARING ROCK IN THE BASALT AT THE PENNANT HILLS QUARRY NEAR PARRAMATTA.

By Professor DAVID, B.A., F.G.S., W. F. SMEETH, M.A., B.E., Assoc. R.S.M., and J. ALEXANDER WATT, M.A.

[*Read before the Royal Society of N. S. Wales, August 2, 1893.*]

THE basalt quarry at the Pennant Hills has been described by Mr. C. S. Wilkinson, F.G.S., the late Government Geologist.* With reference to this quarry Mr. Wilkinson states *(loc. cit.)*:—"It is an immense excavation from which the road metal is said to have been taken for over fifty years. The rock consists of a dense but jointed basalt, containing small fragments of other rocks and some large masses of coaly shale, from which it would appear that this spot is the site of an ancient volcanic point of eruption." Subsequent examination of this quarry by ourselves, inclines us to confirm Mr. Wilkinson's opinion as to its having probably at one time formed part of a volcano, or at any rate having been definitely related to some volcanic outburst.

General Geological Features.

The Pennant Hills Quarry is distant about three miles north-easterly, from Parramatta, and about one and a-half miles westerly from Eastwood Railway Station on the Northern Line. The quarry has been worked intermittently for road metal, for which purpose the rock there is well adapted, for about sixty-three years, during which time an excavation has been formed about three hundred feet long, one hundred and fifty feet wide and seventy feet deep, which affords an excellent geological section.

The rock quarried is seen to be an eruptive mass of basalt apparently of elongated oval shape, and more or less surrounded

* Annual Report of the Department of Mines for 1879, page 218, Appendix A.

by the sedimentary rocks, which it has intruded. No distinct evidence however was obtained to prove that the eruptive rock was shut off in every direction by sedimentary rock, and it is probable that it is prolonged in the form of tongue-like apophyses or as dykes, in one or more directions. This supposition is confirmed by the statement made to us by a local observer to the effect that at a distance of about one and a-half miles from the Pennant Hills Quarry a rock occurred, which he considered similar to the chromite-bearing rock, which forms the subject of this paper. The sedimentary rocks seen at the quarry belong to the Wianamatta Shales, the uppermost division of the Hawkesbury Series, and are admitted to be probably of Triassic Age. The junction line however of the under surface of the Wianamatta Shale with the top of the underlying Hawkesbury Sandstone cannot be far below the level of the bottom of the quarry, as a comparison of the latter level with that of the junction line between these two formations, as seen in the neighbouring road cuttings proves. It is possible that the deepest portion of this quarry is already below the junction line of the Wianamatta Shale with the Hawkesbury Sandstone, but as this portion of the quarry is situated wholly in the eruptive rock, this question cannot be settled at present. The section on the east side of the quarry shows that the eruptive mass of basalt has distinctly intruded the Wianamatta Shales, the line of junction between the two rocks being almost invariably characterised by the presence of a "crush-breccia," composed of angular fragments of Wianamatta Shale, bleached to a light grey colour, and otherwise altered by the dark grey to black eruptive rock, in which they are imbedded.

In addition to the angular fragments of Wianamatta Shale, forming the crush-breccias, there are numerous enclosures in the basalt (upon the eastern and south-eastern faces of the quarry), of other rocks, including lumps of clay shale, pieces of Hawkesbury Sandstone converted into quartzite, and two varieties of eruptive rocks, both of which are foreign to the district, and one of which at least is not known to occur elsewhere in New South

Wales. The last mentioned rock, which contains chromite, occurs in the form of irregularly rounded blocks, the rounded character of which is probably not due to the mechanical action of water, but rather to a partial fusion of the rock in the magma of the originally molten basalt, which by corroding the edges and angles more than the other portions would rapidly convert angular fragments into rounded, just as mineral splinters become rounded during the process of fusion in a borax head before the blowpipe. These blocks vary in diameter from a few inches up to about twenty inches. As they decompose less readily than the basalt they weather out from it, and can be readily separated from the matrix, when the latter is much decomposed, but less decomposed portions of the matrix are found to adhere very tightly to the blocks, and in such cases small fragments of the partially fused blocks appear to be present in the basalt near its contact with the enclosed blocks.

Macroscopic Characters.

At first sight there appear to be two distinct varieties of chrome-bearing rock present, the one a hard dense grey rock, like a very fine grained granite or felstone, which on freshly broken surfaces shows small particles of a jet-black mineral, with minute crystals of pyrites, and what appears to be small greenish stains, the other a greenish-grey rock, showing on freshly fractured surfaces patches of a green mineral, at first presumed to be malachite, intermixed with grey to brownish-grey material. A detailed examination however of these two varieties of rock shows that they probably belong to one and the same type, the difference in their general appearance being due partly to the relative amount of decomposition, which they have respectively undergone, and partly to the comparative variety or abundance of the mineral which has yielded the greenish decomposition products, and which was probably a chrome-bearing diallage, similar to that about to be described.

One block of the chromite-bearing diallage and felspar with chromite passes gradually at the periphery into an external zone about three inches in thickness composed of the greenish-brown rock. In some cases the central portions of the blocks are more decomposed than the external, and exhibit very clearly the granular structure of the rock.

Some of the chromite-bearing fragments, which are much decomposed, are rusty-brown in colour mottled with green, the former tint being due to the conversion of the iron pyrites into hydrated ferric oxide.

In one fragment, the black particles of chromite appear to be aggregated in parallel bands. Some of the fragments are coated with a thin layer of calcite, and the same mineral is found traversing the rock in the form of minute veins formed by segregation or infiltration.

Hardness.—The undecomposed portions of the rock, which are chifly felspar, can be scratched with a steel penknife only with great difficulty, and the hardness must be nearly 7. The chromite has a hardness of between 5 and 6, and the green mineral a hardness of about 3.

Specific Gravity.—The specific gravity of the less decomposed fragments comparatively free from the green mineral and from diallage, but comparatively rich in chromite, was found to be 2·92, while that of a more decomposed fragment containing less chromite and more of the green mineral was found to be 2·76. The specific gravity, therefore, decreases in proportion to the extent of the decomposition. The specific gravity of the felspar approaches that of anorthite, being about 2·7, and that of the green mineral is slightly less, while the specific gravity of the diallage is about 3.

In structure the rock is crystalline granular, felspar predominating and forming the grey coloured areas. The chromite occurs in grains from $\frac{1}{40}$ of an inch up to as much as $\frac{1}{6}$ of an inch in diameter. The diallage crystals are about half an inch in longest diameter, and the green patches representing the decomposed diallage are approximately of the same size, but show a tendency to become blended with one another owing to the spreading of the colouring ingredient. The iron pyrites for the most part is of microscopic dimensions.

Blowpipe characters.—The diallage is slightly fusible and reacts strongly for chromium in the borax head. The green mineral also reacts strongly for chromium. The chromite was found to be almost infusible except at the ends of very thin splinters. The felspar is slightly fusible, and tested by Szabo's method did not give any potash reaction. From this circumstance, taken in conjunction with the fact that the rock effervesces somewhat briskly in hydrochloric acid, and that the specific gravity of the mineral approaches that of anorthite, it is probable that the felspar belongs to the lime or lime-soda series.

Microscopic Structure.

Thin sections of this rock when viewed under the microscope have shown it to be a holocrystalline granular aggregate of felspar and chromite, with iron pyrites and a greenish mineral, the green colouration of which is due to the presence of chromium.

Constituents.—The felspar, which is greyish-white to colourless, and belongs probably to the lime-soda series, is present in the form of granular particles with polygonal outline, which are either traversed by numerous irregular cracks, such as are common in the felspars of troctolite, or show a zig-zag banding probably produced later than the formation of the felspar. The felspars especially those which exhibit the zig-zag banded structure, include a fine dust of iron pyrites, which is frequently disposed in layers following the banding. In some cases curious dendritic forms, resembling cabbage-stalks, of iron pyrites bisect the angles of the folds.

The chromite appears in thin sections as more or less translucent reddish-brown grains of irregular outline, having a very high index of refraction. These seem to occupy a central position from which radiate out in all directions lines which represent the edges of the felspar granules. The crystals are traversed by irregular cracks, no true cleavage planes being present.

The green particles, which seem to represent some decomposition mineral containing chromium, are of a dull pale green colour, and in places show a fibrous structure. The green mineral appears to be an altered diallage. The evidence upon which this statement is based, has been derived from one of the sections, which shows the transition from a diallage to that of the green mineral under consideration.

Diallage.

This mineral occurs in grains of irregular outline having a well marked parallel structure due to prismatic intergrowth, which in the coarseness of its structure resembles that of bronzite rather than that of typical diallage. The colour by transmitted light is a pale yellowish-green. The granules show cleavage cracks and microscopic inclusions, and a well-marked parting parallel to the orthopinacoid. Cleavage flakes taken parallel to this parting have straight exstinction, and exhibit the excentric emergence of an optic axis in convergent polarised light, a feature specially characteristic of diallage, and this admits of the determination of the optical sign of the mineral as positive. The double refraction is high, as indicated by the polarization colours, and the index of refraction is also high. The majority of the sections give oblique exstinction up to angles of 39°.

Note on the Occurrence of a CALCAREOUS SANDSTONE Allied to FONTAINEBLEAU SANDSTONE at ROCK LILY, near NARRABEEN.

By Professor David, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, August 2, 1893.*]

Calcareous Sandstone has previously been recorded as occurring in the Tomago Series of East Maitland, the calcite being crystallised out in the mass of the sandstone, and also in rocks of the

Narrabeen Series, as evidenced by the cores from the Holt Sutherland Diamond Drill Bore.

At Rock Lily at the first headland to the north of the sandy beach there are several beds of a very calcareous sandstone, in which the calcite is crystallised out in the mass of the sandstone in isolated crystals. These crystals exhibit the characteristic cleavage of calcite, and in freshly fractured specimens the cleavage surfaces reflect the light uniformly over areas an inch or so in diameter, showing that the optical orientation of the calcite is not interrupted by the large number of enclosed sand grains. The origin of the calcite in this rock has not yet been determined. Possibly it has been derived from dissolving up of the valves of ostracods.

NOTE ON THE OCCURRENCE OF BARYTES AT FIVE-DOCK, AND ALSO AT THE PENNANT HILLS QUARRY NEAR PARRAMATTA, WITH A SUGGESTION AS TO THE POSSIBLE ORIGIN OF BARYTES IN THE HAWKESBURY SANDSTONE.

By Professor DAVID, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, August 2, 1893.*]

THE first reference made to the occurrence of barytes in the Hawkesbury Sandstone is that made by Mr. H. G. Smith, F.C.S., the Mineralogist to the Technological Museum, who recorded its occurrence at Cook's River.

At a recent excursion to Five Dock held by myself for my second year geological students, some of the quarrymen presented to us specimens taken from the quarry, showing small crystals of barytes associated with quartzite, and in close proximity to the eruptive rock, which there occurs in the form of a dyke of decomposed basalt about twenty feet in width. This barytes has probably been derived from the basalt.

At Pyrmont Sandstone Quarries barytes occurs under similar circumstances, and at the Pennant Hills Quarries it occurs in thin segregated veins in the basalt itself, at a depth of over fifty feet below the surface.

Notes on ARTESIAN WATER in NEW SOUTH WALES AND QUEENSLAND.

(Part II.)

By Professor T. W. E. David, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, October 4, 1893.*]

In some previous notes communicated to this Society on November 4th, 1891, the author referred specially to natural artesian water in the form of mud or mound springs. On the present occasion it is his intention to read a few short notes explanatory of the lantern views exhibited to-night illustrative of artificial artesian water, and the principal artesian bores of New South Wales. The photographs from which the lantern slides have been prepared, were taken by Mr. Kerry during a recent tour in the artesian water district. A working model is also exhibited illustrative of the convexity of the curve of the hydraulic grade in the artesian basin of the Darling River.

I. Artesian Wells of the Sahara.

In the first place attention might be called to the experience lately gained by the French engineers in artesian boring in the Sahara. According to an official report,* the geological forma-

* Rapport a Monsieur le Governeur Général de l' Algerie sur les Forages artésiens exécutés dans la Division de Constantin, de 1860 à 1864.

tions represented between the Atlas Mountains and the Sahara are Cretaceous, Miocene, Pliocene and Quarternary. With the exception of the Lower Cretaceous, none of the members of the Cretaceous system appear to be thoroughly pervious. The Cretaceous rocks under a large area of the Sahara are covered under too great a depth of Post-Cretaceous deposits to be readily accessible to artesian bores. The Miocene system, divided into the (1) *Pecten numidus Beds* (Lower) and *Ostrea crassissima Beds* (Upper) are water-bearing in places, and not too deep to be accessible, but by far the greater portion of the artesian water in the Sahara is obtained from the Pliocene Formation.

The Pliocene strata of the Sahara are formed of white, grey, red, and yellow sand with clay beds and gypsum. The last is in places, as at Bard'Ad in the Oued Rir District, over eighty feet in thickness. Beds of hard limestone over a yard in thickness are met with occasionally. Immediately overlying the water-bearing sands and gravel is a very hard band of rock, a siliceous cement a foot or more in thickness. These Pliocene strata are of lacustrine origin, and lie in a broad basin, which through earth movements has been thrown into a succession of folds.

Mr. G. Rolland, in a paper read before the Geological Society of France, 14th of September 1885, entitled "Ou et comment s' alimentent les eaux artésiennes du bassin de l' Oued Rir?" states that these strata derive their supplies of water partly from direct percolation of rain, partly from rivers, especially from those which take their rise in the Atlas Mountains on the north. Part of this water percolates into the permeable soil and finds its way into the deep alluvial deposits, which dip towards the interior of the basin. The Pliocene strata are also partly supplied with water by springs rising from the Cretaceous strata, as for example the beautiful springs of Western and Central Zab and those of the Djerid. The massifs of the Cretaceous Formation attain an altitude in Aurés of over 7,500 feet, and the porous beds of the Cretaceous Formation which outcrop in these ranges are fed by the rain and melting snow on the higher ranges, and the under sheets of water derived from this source drain towards the south, and give rise to numerous springs along the whole length of the northern edge of the low lying Sahara.

The waters from the Cretaceous springs disappear in the alluvial deposits of the Pliocene Formation and form small underground rivers, which flow towards the south and become united at a depth to form a main stream draining towards the south-south-east, under the lacustrine basin of the Pliocene Formation. The Cretaceous beds being continuous under the Pliocene basin and dipping towards the Sahara, some of the springs derived from their porous strata break out considerably below the surface, and these of course assist the superficial springs in supplying water to the permeable beds of the Pliocene. The underground streams of the Pliocene basin flow in a number of reticulated underground channels like meshes of a net. These have been distinctly traced by means of bores for a length of one hundred and twenty kilometers (about seventy-four and a half miles) and a width of from four to eight kilometers.

That the water circulates in distinct channels has been proved not only by the distribution of the successful bores, but also by the fact that small fish possessing perfect eyes, river crabs, and freshwater mollusca are brought up in considerable quantities at some of the bores. These have been caught in netting placed for the purpose over the discharge pipes at the bores.

The presence of artesian water in the Pliocene strata of the Sahara has manifested itself in the form of "behour," natural springs corresponding to the mound springs or mud springs of Australia. There is a tradition that artesian wells were first sunk in the Oued Rir District of the Sahara by the Arabs as far back as 1341. These native wells seldom exceeded two hundred feet in depth, many being not more than one hundred feet deep. They were timbered with logs cut from the date palm, and owing to the decay of the timber the native wells usually fall in and become completely choked up in from twelve to twenty years.

The Pliocene basin, as already stated, has been found to be traversed by a number of anticlinal folds, and these folds have in places been subjected to a considerable amount of denudation, so that in some cases all the impervious beds overlying the water-bearing strata have been removed, springs of course breaking out along such areas. In other cases after the tops of the anticlines have been denuded down to the water-bearing strata the water in these strata has been sealed up and its escape prevented by a subsequent deposit of quarternary clay. Now the French engineers have taken advantage of these partially denuded anticlines, or of those which are completely denuded down to the horizon of the water-bearing strata but covered with quarternary clay beds, and have sunk their artesian wells on the top of such anticlines with the result that by this means supplies of artesian water have been obtained at a far shallower depth than would have been possible had the wells been sunk in the depressed areas representing synclinal troughs. This is a feature in artesian boring which should specially commend itself to the consideration of Australian hydraulic engineers, inasmuch as the Cretaceous strata of Australia have been considerably tilted in places, and although they have not been sharply folded, still there is evidence to show that as illustrated on Mr. J. B. Henderson's section from Thargomindah to Warwick in Queensland,* there exist some broad and gentle anticlinal curves and synclinal troughs.

The depth of the French wells varies from about one hundred and fifty feet up to about eight hundred feet, the average depth being about two hundred and fifty feet. The highest recorded temperature of the water flowing from these artesian wells is 77° Fah.

The French artesian bores are provided with iron casing, where requisite, and some had been flowing continuously from 1856

* Water Supply Report of the Hydraulic Engineer to the Colonial Treasurer—Government Printer, Brisbane, 1893. Section at foot of first plate at end of report.

until the date of Mr. H. Jus' Report in 1890,* and were still flowing at that time without showing any evidence of diminution in yield of water. It is stated however (*loc. cit.* p. 10) that the artesian wells of the Sahara had almost attained their maximum in 1890, and that if the supply were drawn upon any further the outflow at the individual wells would probably be diminished. The distance of the furthest artesian wells in Algeria from their chief source of supply, the Atlas Mountains, is over three hundred and fifty miles.

The water in the Pliocene is evidently in circulation, and its pressure is therefore hydraulic not hydrostatic ; but what natural outlet there may be for the water from these reticulated subterranean undersheets is not at present known, as far as the author is aware, but the principal direction of the circulation appears to be from north to south. Possibly the circulation is partly maintained through the "*behour*," just as in the Australian Cretaceous strata it was partly maintained through the mud springs, previous to the sinking of the artesian bores. One of the largest artesian wells, the Fontaine de la Paix yields 1,278,720 gallons per twenty-four hours.

The total quantity of water obtained from artesian and sub-artesian wells in Algeria in 1890 was 317,414 litres per minute = 70,452 gallons per minute = 101,450,880 gallons per twenty-four hours. This quantity is almost exactly equal to the total capacity of outflow of the Queensland artesian bores as estimated by Mr. J. B. Henderson in his report for 1893, already referred to.

II. Artesian Basin of New South Wales and Queensland.

All the artesian bores of New South Wales, with the exception perhaps of the Coonamble Bores and those near Gunnedah, derive their supplies of water from the sands and fine gravels of the Lower Cretaceous Formation, the equivalent of which in Queens-

* Résumé Graphique des Soudages Exécutés dans la Provence de Constantine, De 1er Juin 1856 au 1er Janvier 1890. Suiveè d' une Notice sur la Region de l' Oued Rir—Par H. Jus, Constantin 1890.

land is known as the Rolling Downs Formation. This formation covers about 62,000 square miles in New South Wales, as estimated by Mr. E. F. Pittman, A.R.S.M., the Government Geologist, and the enormous area of 376,832 square miles in Queensland, equal to over fifty-six per cent. of its total superficial area, as calculated by Mr. R. L. Jack, F.G.S., the Government Geologist. Out of this area of Rolling Downs Formation in Queensland 88,300 square were considered by Mr. Henderson in 1893 to have been proved to contain artesian water, and in New South Wales artesian water has been proved to exist at intervals over an area of about 20,000 square miles.

In Queensland the estimated total capacity of outflow of all the wells was quoted by Mr. Henderson in 1893 as 105,000,000 gallons daily; amounting to 38,325,000,000 gallons per annum.* In order to replenish this volume of water an amount of rainfall would need to percolate equal to twenty-nine inches per annum over an area of ninety-one square miles.

Mr. Henderson estimates that the aggregate breadth of the outcropping edges of the water-bearing beds of the Lower Cretaceous are not likely to be more than a few chains, and on the assumption that the average width is ten chains, and the length 1,600 miles (measured from the boundary between New South Wales and Queensland to the northern limit of the beds in about Lat. 18° South, and including the western edges of the Rolling Downs Beds on the flanks of the McKinlay Ranges) Mr. Henderson estimates that the total superficial area of the porous beds of the Cretaceous Formation in Queensland available for intake does not exceed perhaps two hundred square miles. He adds (*loc. cit.* p. 5), "If the basis of this simple computation is correct; if the supply is not greatly supplemented by water percolating through the surface strata on the hill sides immediately above the several outcrops and by streams that cross them, and if the number of wells

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* Queensland Water Supply—Report of the Hydraulic Engineer to the Honourable the Colonial Treasurer, Brisbane, 25th January, 1893.

is largely increased, and the practice of allowing a large proportion of them to continuously flow at their full capacity is persevered in, it is probable that the demand will soon overtake the supply, and that there will be a diminution of flow. Indeed it may be—but I do not advance what I am about to say as probable but merely as a possibility—that now the output of the wells equals, nay exceeds, the inflow, and that the output is maintained by accumulations of water stored in the porous beds. Supposing either of these possibilities to exist, it is only a question of time when the higher wells will, one by one, cease to flow with the lowering water-level, until there is an approach to an adjustment between the supply and demand. At all events, whether either of these probabilities exist or not, there seems to me to be a strong element of danger, and as there does not appear to me to be any sound reason why injudicious and wasteful use of the water should be allowed, I venture to submit the matter for serious consideration before such a calamity as the failure of the supplies should happen."

The above passage has been quoted at length as being of grave importance to those who are interested in the artesian water supply of New South Wales. Mr. R. L. Jack substantially agrees with the views expressed by Mr. Henderson, as to the comparatively limited extent of the artesian water supply of Queensland, and if these statements are applicable to Queensland, it would be interesting to consider how far they may be applicable to New South Wales.

Mr. Henderson cautiously states that it is impossible to measure at present with any degree of accuracy the superficial area of the outcropping edges of the porous beds of the Rolling Downs Formation, owing to their being to a great extent overlapped by newer formations. In order to form an accurate estimate of this superficial area it is obviously necessary to know (1) the thickness, (2) the angle of dip, and (3) the angle of slope of the surface of the outcrop of the porous beds, (4) the actual area available for intake, *i.e.*, not covered by newer and impervious beds.

As regards (1) the strata of the Rolling Downs Formation are chiefly clayey, as far as proved at present by the artesian bores. The basal beds however, are sandy, and even gravelly in places. Few data are available for estimating the thickness of these basal beds, for the following reason :—as soon as the top of the basal beds are struck the artesian or sub-artesian water in them rises in the bore to about its maximum height, and the object of the bore having been attained, the bore is discontinued and is not carried down through the whole thickness of the basal beds to the bed-rock. In a few cases however, the water-bearing drifts have been penetrated, and their thickness has been proved, as far as the author is aware, not to exceed from fifty to one hundred feet. No bores to his knowledge have been sunk in the basal-beds of the Rolling Downs Formation, where they abut against the Lower Mesozoic and Palæozoic Rocks of the Main Dividing Range. The approximate thickness therefore of the porous beds along their outcrops can at present, until more data are available, be merely a matter of inference based on certain broad facts. The Rolling Downs Formation is of vast superficial extent and of considerable thickness.

At Malvern Hills 3,926 feet of strata of this age had been been proved in an artesian bore up to February 20th, 1894 (as the Hydraulic Engineer kindly informed the author while this paper was being revised up to date for press), the bore being still in progress, and the high temperature of the water at some of the bores proves that some portions of the Cretaceous Basin must be considerably thicker. For example, at No. 3 Bore, Darr River, Queensland, the temperature of the water is 172° Fah. If the mean surface temperature at the Darr River be 70° Fah. there is an increase of 102° Fah. in the temperature of the water flowing from this bore, as compared with the surface temperature. If the downward rate of increase be 1° Fah. for every sixty-three feet in depth, the depth below the surface of the locality where the water acquires this high temperature would be over 6,400 feet. It is extremely improbable that so vast a formation where it rests with strong unconformability on Palæozoic Rocks, or even where resting conformably on Lower Mesozoic Rocks, should not consist largely of gravel and coarse sand. In many parts of Queensland, and possibly in portions also of New South Wales, there is a conformable upward passage from the strata of the Trias-Jura to the Rolling Downs Formation, and in such cases the sand and gravel beds will as a general rule be found to be very much thinner than in the case of the unconformable junction just mentioned.

During the whole of the Rolling Downs Period large rivers, flowing from east to west, must have entered the margins of the Cretaceous Ocean, and must have spread their gravels over extensive areas, and these rivers, in New South Wales at all events, continued to flow down to the present time, their channels of course being subject to oscillations of position and various modifications, as one geological period succeeded another. It cannot of course be affirmed that such rivers as the Dumaresq, the Gwydir, the Namoi, the Castlereagh, the Macquarie, and the Bogan were represented in Cretaceous times by rivers flowing in approximately the same latitudes as these modern rivers, but it can confidently be affirmed that in all probability several rivers, of which the above mentioned are the modern equivalents, must have existed in Cretaceous Time and have drained westwards into the Cretaceous Ocean. Extensive gravels, must therefore, have been continuously in course of deposition from early Cretaceous Time until the Present, and unless the latitude of the main valleys has altered since Cretaceous Time, the gravels belonging to successive geological periods must in places be superposed on one another, and so they would afford means of ingress for large bodies of water, which sink through the older gravels forming the channels of the modern rivers above mentioned. It is probable then, that a considerable amount of water finds its way into the artesian beds of the Rolling Downs Formation through percolating through ancient river gravels. There certainly is a considerable difference in the amount of water discharged by these rivers near the foothills of the Main

Dividing Range, and at a distance of fifty to one hundred miles westwards of the foothills. This fact is partly due to percolation and partly perhaps, to evaporation and transpiration through the leaves of trees.

The statements of Mr. H. G. McKinney, M. Inst. C.E., Chief Engineer for Water Conservation and Irrigation, New South Wales,* are worthy of being quoted here:—"When the discharge of the river (Macquarie) at Dubbo was 114½ cubic feet per second, at Warren it was only 52 cubic feet, and when the discharge at Dubbo fell to 20 cubic feet per second the current ceased at about eighteen miles above Warren. I also showed that of the total loss of water between these places, sixteen and a half per cent. in the former case, and thirty-eight per cent. in the latter, might be due to evaporation, while by absorption the trees on the river bank could account for 12½ cubic feet per second. The opinion which I formed regarding percolation in that part of the Macquarie was that at least, when that river is low, very little loss is due to that cause. It is in fact unlikely that any considerable proportion of the waters of our western rivers is lost by percolation, excepting in the higher parts of their courses for the natural tendency of a river flowing through alluvium is to tamp up all interstices in its channel."

On the other hand the tunnel carried below the channel of the Macquarie River at Bathurst, which tapped the water in the extensive gravel beds below the level of the river yielded large volumes of water without any evidence of the supply becoming diminished. In the opinion of the author there is a considerable quantity of water in these gravels which underlie the channels of the modern rivers, and perhaps as much (if not more), water drains through them into the delta gravels formed by the Cretaceous rivers, and so into the vast sand beds of the Cretaceous Formation further west, as drains into all the outcropping edges of the

* Australasian Association for the Advancement of Science, Vol. I., p. 399—Rivers of New South Wales by H. G. McKinney, M. Inst. C.E.

Cretaceous porous beds occupying the areas intermediate between the positions of the former estuaries of the Cretaceous Rivers.

If the same formula, which Mr. Henderson has suggested as being possibly applicable to the artesian beds of Queensland be adopted for estimating the area of the intake beds of the New South Wales Cretaceous Formation, the figures would be about 350 miles $\times \frac{1}{8} = 44$ square miles in round numbers, with an average rainfall of about one-quarter less than that for the Queensland outcrops, viz., about twenty-two inches. This would equal an outflow of about 38,000,000 gallons per day for one year. Now the present estimated capacity of outflow of all the artesian wells of New South Wales, as I am informed by Mr. Boultbee, the Officer-in-Charge of the Water Conservation Branch of the Department of Mines and Agriculture, is about 41,000,000 gallons daily, so that according to this estimate the outflow should already have more than counterbalanced the supply, and the sinking of any further flowing wells would be at the expense of existing wells and would tend to lower the hydraulic grade. If however, allowance be made for the water which probably drains into the Cretaceous outcrop through the ancient valley gravels the estimates are capable of being considerably altered. For example, from Bathurst to Narromine there is a length of about 130 miles of ancient valley gravels of Post-Tertiary Age, and covering Tertiary, and perhaps even Cretaceous gravels for the last thirty miles. These gravels would average probably at least half a mile in width, having a total area therefore of about sixty-five square miles, and the water draining into them would be derived not only from the annual rainfall of about twenty-two inches on their surface, but also from the rain falling upon an area at least twenty times as great, even after allowing for the rain which is lost by evaporation and discharged by the river and its tributaries.

Instead therefore of adding an area of sixty-five square miles with an average rainfall of twenty-two inches to the area of intake of the porous beds of the Rolling Downs Formation in New South

Wales, we might perhaps add an area of as much as 1,300 square miles with an annual rainfall of twenty-two inches. To allow however, for evaporation, one-half of this area might be taken for the Macquarie River = 650 square miles, and to this must be added the ancient gravels of the Bogan, Castlereagh, Namoi, Gwydir, and Dumaresq Rivers. The total area might be very approximately summed up as follows :—

		sq. m.
Macquarie River—	65 square miles of gravel × 10 on account of area draining into the gravels	=650
Bogan River—	20 × 10	=200
Castlereagh River—	30 × 10	=300
Namoi River—	30 × 10	=300
Gwydir River—	20 × 10	=200
Dumaresq River—	50 × 10	=500
		2,150

These numbers must be taken as only very approximate, but they serve to show the possibility and even probability of the intake area being very much larger than forty-four square miles, and instead therefore, of the outflow equalling the annual supply, when the daily yield of the wells in New South Wales has reached 38,000,000 gallons a day, it may be possible to increase the yield to fifty times that amount, that is to 1,900,000,000 gallons per day without exceeding the annual supply. Even if the amount be halved in order to allow for the Cretaceous Beds being partly covered by impervious beds, or having become locally tamped through fine sediment carried into it by the percolation through several periods of geological time, it would still be possible to increase the quantity of water supplied by the artesian wells of New South Wales by at least twenty times the present amount. It is hardly fair however, to apply a formula applicable to the Queensland artesian beds to those of New South Wales, where the conditions are somewhat different.

The question however, is capable of being attacked from another direction, as Mr. H. C. Russell has done in his excellent paper on the "Source of the Underground Water in the Western districts," read before this Society August 7, 1889. On p. 4 of this paper Mr. Russell states :—"The mean rainfall on the Darling River catchment for the past ten years has been 22·14 inches, and of this, as we have seen, only $1\frac{1}{2}$ per cent. or = 0·33 inches of rain passes Bourke in the river. If twenty-five per cent. of it, which is equal to 5·53 inches of rain passed away in this river as it does in the Murray there would be seventeen times as much water passing Bourke as now actually does pass; . . . and we ought therefore to have an underground water supply at least equal to sixteen times as much water as passes Bourke now, and this or at least a great part of it should be useful for irrigation. That we do not find it in the Darling, is to my mind proof that it passes away to underground drainage."

The mean daily discharge of the Darling at Bourke is equal to about 1,400,000,000 gallons, so that a volume of water flowing underground sixteen times as great, as required by Mr. Russell's hypothesis, would amount to 22,400,000,000 gallons, equal to about five hundred and forty-six times the present capacity of all the artesian wells of New South Wales, a quantity as far in excess of that stated provisionally by the author as his own estimate exceeds that which results from an application of Mr. Henderson's formula for Queensland, to the artesian beds of New South Wales, and yet Mr. Russell's estimate may be the most correct.

The whole of the above statements show that our present knowledge of the actual amount of water draining into the artesian beds is only very approximate, but that it is certainly far in excess of what would be received by the mere rainfall on a strip of outcrop sands and gravels one-eighth of a mile wide and about three hundred and fifty miles long. It must not of course, be thought that because any particular artesian well begins to fail that therefore the whole outflow from the artesian basin is in excess of the annual intake. The amount of outflow from a well is governed not only by the amount of water present in the surrounding sand beds and the pressure to which it is subjected, but also by the amount of frictional resistance which the sand offers to the passage of the water. The effect of multiplying the number of large bores in a restricted area would be undoubtedly to drain the water out of the sands faster than it can drain into that particular district, and so all these wells might become sub-artesian instead of artesian, just as the Native Dog Bore in New South Wales has had the effect of drying up the adjoining mud springs; and at the same time it might be the case that the total outflow from all the artesian bores in the artesian water basin did not amount to more than one per cent. of the total annual supply.

In the future, therefore, if the hydraulic grade is found to fall in a special district, there should be no widespread panic amongst all the proprietors of artesian wells lest the whole supply of artesian water should fail, as such a failure will affect that district only where the wells have been overcrowded, and will not necessarily make its effects felt over the whole basin.

(2) As regards the angle of dip of the Rolling Downs strata, this must be but slight. If the case of the Muckadilla Bore be taken as an example, the bore is 3,262 feet deep, and it is distant about fifty miles from the base of the Rolling Downs Formation at the nearest point, there being little difference in the surface levels between these points and the Muckadilla Bore being in Cretaceous strata throughout. The maximum dip might therefore in this case be 3,262 feet in fifty miles, that is a dip of about one in eighty-one, provided the amount and direction of dip between these two points is uniform. A bed of porous rock, therefore, one hundred feet thick would have an outcrop, if the surface were level, 8,100 feet wide, that is a trifle over a mile and a half in width. At the Darr River the Rolling Downs Formation, as judged from the temperature of the water, may be as much as 6,000 feet thick, but as this is over one hundred and thirty miles from the edge of the Cretaceous basin at the nearest point, the general dip, (allowing that the surface level at the bores at the Darr River is about five

hundred feet lower than that of the edge of the basin) would be about one in one hundred and six. As regards (3), the surface level would be practically flat, and as regards (4), there is at present, insufficient evidence to warrant any kind of inference.

As regards the question as to whether the water in the artesian beds of New South Wales is hydraulic or hydrostatic it must be confessed that even now the question is far from settled. In any case the question does not probably materially affect the economic aspect of the artesian water question. If the pressure is hydraulic there must be a natural outlet somewhere for the artesian water, and the water must have been undergoing for ages a slow process of circulation. The freshness of the artesian water has been quoted as an argument by many writers on this subject, the author included, in favour of the artesian water being able to circulate, but it must be remembered, that to a limited degree, the mud springs have afforded a means of circulation for this water for ages in the past, and the author is informed by Mr. E. F. Pittman, that numbers of extinct mud springs are to be seen on the Western Plains of New South Wales in the vicinity of existing mud springs, showing that the outflow of artesian water from them has proceeded uninterruptedly for a vast period of time. The proportion however, of water discharged by the mound springs must be very small as compared with the enormous quantities of water which must percolate annually into the Cretaceous beds. It is probable in the author's opinion, as stated in his previous paper, that the artesian water has outlets, and its pressure therefore, especially near these outlets is hydraulic, rather than hydrostatic, but of the three possible outlets previously suggested by him, (1) to the Gulf of Carpentaria under the Dividing Range at the head of the Flinders River in Queensland; (2) to the Great Australian Bight viâ Lake Eyre; (3) Under the present channel of the Darling-Murray to the Coorong coast, he now considers that the last mentioned may be abandoned. It follows then that the outlets, if any, must be situated at the Gulf of Carpentaria or at the Great Australian Bight under the Tertiary Limestones of the Nullarbor Plains; or very probably in both these directions.

Some of the deepest portions of the Cretaceous basin in Queensland have been proved to exist at Malvern Hills, and, if high temperatures are a test, at the Darr River, Westland, Tara, and Toorak. It is interesting to note that water having a temperature of 140° Fah., though the bore is only 1,550 feet deep, has been obtained at Toorak on the north side of the Main Divide at the head of the Flinders River. This water is therefore probably derived from a depth of over 4,000 feet below the surface of the Cretaceous rocks. The surface level of Toorak is not known to the author, but judging from the levels in its vicinity, given by Mr. Henderson, it would be about 600 feet, the bottom of the bore then is nearly a thousand feet below sea-level, and the base of the Cretaceous strata in its vicinity would probably be 3,000 feet below sea-level. At Strathfield also, in the same neighbourhood, the high temperature of the water implies a considerable depth for the Cretaceous strata. The bore is only 841 feet deep, but the temperature of the water flowing from it is quoted as 130° Fah. which would give a depth for the Cretaceous strata in its vicinity of 3,780 feet. There is probably therefore a deep outlet between Cloncurry and Croydon for the underflow of artesian water to the bed of the Ocean in the Gulf of Carpentaria, the artesian water probably working its way into the sea through the porous beds of the Cretaceous as through an inverted siphon.

There can, however, be little doubt in the author's opinion that the main outlet for the water, if there be any outlet at all, is in the direction of the Great Australian Bight.

At Malvern Hills the Cretaceous strata, (if the surface level be about 700 feet), have already been proved to extend to at least 3,200 feet below sea-level, and at the Darr River, if the temperature of the water can be relied on as a test, the thickness of the Cretaceous strata must exceed 6,000 feet and the base of the series must be at least 5,000 feet below sea-level. At Westland also, which is not far distant from Malvern Hills, whereas the surface level of the bore is 600 feet and the depth 2,848 feet, the temperature is 162° Fah., and this implies a depth for the source of the water of 5,200 feet. This locality would appear to be the deepest as yet proved in the Cretaceous basin.

None of the artesian bores in New South Wales have so far attained a depth of 3,000 feet, the deepest bore at present being 2,573 feet, viz., that situated at Moongulla on the Collarendabri to Angledool road, and there is no direct, nor indirect evidence so far to show that the base of the Cretaceous anywhere in New South Wales is much over 2,000 feet below sea-level. The general dip therefore of the bed-rock in New South Wales is in a northerly direction towards Malvern Hills, as far as proved at present.

The surface of the Rolling Downs Formation has however a general inclination to the south-west from the Dividing Range at the head of the Flinders River towards the Lake Eyre Basin. The altitude of the Dividing Range is a little over 1,000 feet, whereas few portions of the Lake Eyre Basin exceed 200 feet above the sea, the surface of Lake Eyre itself being thirty-nine feet below sea-level. But although the present fall is slight in a south-westerly direction, in early Tertiary Time it was probably greater for since the close of the Cretaceous Period, and chiefly subsequent to the deposition of the Eocene (?) limestones of the Nullarbor Plains, the southern portion of South Australia, Victoria and part of West Australia have been elevated from 600 to 800 feet, while possibly the northern portion of the Cretaceous basin near the Gulf of Carpentaria has partaken in the downward movement of the northern portion of Queensland in the neighbourhood of the Barrier Reef, but of this latter movement, as far as known to the author, there is no good evidence. The effect of this tilting up of the earth's crust from the south-west extremity near the Australian Bight towards the north-east would have the effect of reducing the amount of surface slope from the head of the Flinder's to the Great Australian Bight. It is more than probable then, that a submarine outlet exists for part of the artesian basin viâ Lake Eyre.

The fact should here be mentioned that there is undoubted evidence of a movement in an opposite direction to that referred to above in the northern half of the Cretaceous basin ; but beyond the fact that the elevation was subsequent to the deposition of the Upper Cretaceous rocks, the Desert Sandstone, little is known as to the date of the upheaval. The radiolarian earths elevated to a moderate height above the sea, described by Mr. J. G. Hinde* are thought to be of probable Tertiary Age, but it is stated that these earths are the equivalents of the so called "magnesites," described by the late J. E. Tenison-Woods. These magnesites are now several hundred feet in places above sea-level to the south of Port Darwin, and if the above suggested identity can be proved, portions of the northern coast of Australia must have been elevated by a similar amount since some portion of the Tertiary Era.

It is at any rate certain that whereas the top of the Marine Cretaceous strata are not more than about 700 feet above sea-level at the south-east extremity of the Cretaceous basin near Narromine in New South Wales, the same horizon is over 1,300 feet above sea-level in the latitude of Roma, 1,200 feet in the latitude of Hughenden, and 1,020 feet above sea-level at the top of the Divide, between the Flinders and Thomson Rivers. The Marine Cretaceous rocks therefore are about five or six hundred feet higher to the north of Roma, at Darby Point, and to the east of Hughenden than in New South Wales. It would seem then, that since the close of the Cretaceous Period, the northern end of the basin was first uplifted 1,300 to 1,400 feet, then the south-west extremity since Miocene or early Pliocene Time underwent a total elevation of six to eight hundred feet, and possibly the north-east extremity of the basin has shared with Cape York and the Great Barrier Reef in a downward movement during perhaps late Tertiary and Post-Tertiary Time.

Some have found a difficulty in the way of accepting the opinion that the water in the artesian basin is in circulation through submarine outlets because of the smallness of the fall in the surface between the level of the intake and the level of the overflowing wells. For example, the surface level at the Muckadilla Bore is

* Quart. Journ. Geol. Soc., London 1893, Vol. XLIX., pp. 221 - 26.

1,139 feet, a level probably nearly as high as that of any portion of the Cretaceous intake in its neighbourhood, for the level of the intake in few places in Queensland attains a greater altitude than 1,200 feet, excepting where it is capped with the Desert Sandstone (Upper Cretaceous), and the Muckadilla Bore is distant about fifty miles from the intake outcrop. The flow however, at the Muckadilla Bore is but feeble, and the pressure slight on account of this small difference in level.

Charleville is distant about one hundred and forty miles from the probable edge of the artesian basin, and its surface level is 966 feet, whereas that of the intake is probably not more than 1,200 feet, which allows a fall of only one foot eight inches per mile, and the pressure of the water at the surface of the bore is exqual to 100 lbs. to the square inch, which would raise the level of the water at Charleville to about 231 feet, so that it should stand at a level of 966 + 231 = 1197 feet, which is about equal to the level of the intake. Possibly however, part of the water may be derived from rain falling on the high ridge of Cretaceous rocks between Charleville and Mitchell, where the Rolling Downs Formation attains an altitude of about 1,380 feet, but this supposition is extremely doubtful.

At Cunnamulla, with a surface level of 627 feet, the pressure is 165 lbs. to the square inch, so that the water would rise here to a level of 1,008 feet. Cunnamulla is about two hundred and twenty miles distant from the principal intake.

At Noorama, the surface level being approximately 550 feet, the pressure of the water per square inch is 200 lbs., so that it would rise to approximately a level of 1,012 feet above the sea, which is nearly about the same level as that to which the water would rise in the Cunnamulla bore. At Weelawurra, about thirty-three miles E.S.E. from Cunnamulla, with a surface level of 625 feet, the pressure is 150 lbs. per square inch, which would produce a column of water, the top of which would be about 972 feet above the sea.

An artesian bore is shown on Mr. Henderson's map at Darby Point, on the Nive River, at an altitude of 1,360 feet, but it is not stated whether this is an overflowing well or not. If it be an overflowing well it is difficult to find any intake beds sufficiently high to give the necessary amount of fall, unless the source be in the high ridge of Cretaceous rocks referred to above, between Charleville and Mitchell, and trending towards Springsure.

The decrease in the hydraulic grade between Muckadilla and Noorama is due, not necessarily to any actual flow of the artesian water in the beds towards a submarine outlet to the south-west, or to north-north-west, but may be owing to the gradual decrease in the level of the outcrop of the intake beds from north to south, between the latitudes of these respective bores. At Dulacca for example, on the railway line, between Dalby and Roma, the level of the outcrop is 1,050 feet. Whereas on the southern border of Queensland where the outcrop crosses the Dumaresq River, the level is only about 900 feet, and in New South Wales it is probably not more than about 700 feet above sea-level near Narrabri, and about the same near Narromine. In view therefore, of the very slight amount of fall (only about one foot per mile in the case of Cunnamulla) between the intake and point of discharge, and the vast frictional resistance which would be offered by the beds of fine sand, which would have to be traversed by the artesian water from the east central portion of the basin for a length of eight hundred miles in either direction, before the water could reach either the Gulf of Carpentaria or the Great Australian Bight, it must be the case that, in its central portions at all events, the basin behaves like a sealed basin, and the pressure of the water in the central portions of it is therefore probably more hydrostatic than hydraulic. Approaching however, the Gulf of Carpentaria or the Great Australian Bight, the artesian water may be in a state of somewhat stronger circulation oozing slowly through the porous strata until it finds an outlet in the bed of the ocean.

As a possible explanation of the smallness of the fall between the intake and some of the artesian bores, if the hydraulic hypothesis be adopted, the model exhibited might serve as an explanation. It has the form of a bent pipe with the convexity downwards, like an inverted siphon in shape, with the short leg however placed uppermost, so that following the gradient of the pipe from the highest point downwards, the curve is at first steep then more gradual to imitate the curve of the Cretaceous strata as they dip off the impervious Palæozoic and Mesozoic Rocks, forming the axis and foothills of the Main Dividing Range, into the Western Plains. The lower end of the pipe is filled with sand, then succeed coarse lead shot, and lastly marbles, this arrangement being intended to imitate the decreasing porosity of the water-bearing beds of the Rolling Downs Formation as they recede from the foothills of the Main Dividing Range towards the Western Plains. Three glass tubes ascend vertically from the pipe, tapping respectively the parts of the pipe filled with sand, shot, and marbles. Water coloured by permanganate of potash is now poured in at the upper end of the pipe until the pipe is filled, and the water at once begins to ooze out through the sand at the lower end of the pipe, to replenish which loss more water is being continually added at the upper end of the pipe. It will be observed that the water gradually ascends each of the three vertical glass tubes, which communicate at their lower ends with the lead pipe, until the water eventually becomes stationary at a certain level in each of the tubes. A line drawn from the point of intake through these points in the glass tubes to the point of outlet represents the hydraulic grade, and it will be noticed that under the conditions arranged, the hydraulic grade has the form of a convex curve (the convexity uppermost). If the artesian basin of Australia be hydraulic rather than hydrostatic, the hydraulic grade would probably have the above form, and consequently very little fall might be expected in the hydraulic grade near the central portions of the basin.

In writing these notes the author would express his special indebtedness to the valuable report accompanied by map and sections prepared by Mr. J. B. Henderson, and to the similar

report prepared by Mr. J. W. Boultbee, on the "Artesian Water Supply of New South Wales. He has also to acknowledge having received much valuable information personally communicated to him by Mr. Boultbee.

Since writing the above paper, the author has been informed of a curious phenomenon relating to oscillations of the hydraulic grade in New South Wales. Mr. E. F. Pittman, on the authority of Mr. T. T. W. Mackay, Acting Inspector of Stock, Wanaaring, informs him that at Urisino Station, a bore which has proved to be sub-artesian was sunk to a depth of 1,680 feet. The water in this bore now stands at a mean height of about seventeen feet below the surface, but rises and falls with a rhythmical pulsation for two feet on either side of this mean level every two hours, that is it is subject to a tide of four feet every four hours.

Mr. J. W. Boultbee has also informed the author that a similar phenomenon has been observed on Urisino Station, at ninety-one miles on the Milparinka-Wanaaring Road in the water from a bore 2,000 feet deep. The water in this bore, which is also sub-artesian, is subject to six tides of about four feet each, every twenty-four hours. No explanation of these phenomena has as yet been afforded.

The following are some recent observations of these tidal movements made by Mr. T. T. W. Mackay :—

Time.	Depth to surface of water below surface of ground.
5·30 p.m.	19 feet 2½ inches
7·35 „	15 „ 9 „
9·0 „	19 „ 2 „
11·35 „	15 „ 7½ „
1·0 a.m.	19 „ 1½ „
3·10 „	15 „ 6 „
5·0 „	19 „ 2 „
7·0 „	15 „ 6 „
9·0 „	19 „ 10 „
11·0 „	15 „ 8 „
12·45 p.m.	19 „ 3½ „
2·45 „	15 „ 8 „
4·45 „	19 „ 3 „

Mr. Boultbee says that he has excellent authority for stating that live fish were thrown out of the Youngerrina Bore in New South Wales when the water was first struck. The statement however, has not yet received confirmation. It is to be hoped that steps will be taken to test this question by allowing the water from the bore to flow through fine netting. He also states that by direction of Mr. Harrie Wood, steps are being taken to gauge the flow and pressure at all the Government artesian bores.

With regard to the suggestion by Mr. R. L. Jack, that increase in temperature of the water, aided presumably by capillarity, may assist in forcing artesian water to the surface, and as possibly having some bearing upon the tide phenomena described above the following calculations might be given :—The superficial area of the Cretaceous rocks in New South Wales is estimated as 62,000 square miles, but the area of the porous beds is less by perhaps as much as about one-third. The area of the porous beds of the Lower Cretaceous in New South Wales being taken as 40,000 square miles, and the average thickness of the porous beds as ten feet, (a minimum estimate) and the imbibition of the porous beds being taken as about two and a-half gallons per cubic foot, then the quantity of water stored in these beds would amount to 27,878,400,000,000 gallons, a quantity which, (if the supply were being continually replenished so as to maintain a constant pressure) would supply the whole of the present yield of the artesian wells of New South Wales for 1,863 years, and an expansion of the water to the extent of about $\frac{1}{15}$ of an inch vertically in this thickness of ten feet, that is $\frac{1}{1800}$ of the total thickness of the undersheet, would keep the whole of the artesian wells of New South Wales overflowing for one year. Such an expansion would be caused by raising the temperature of the water in the undersheet from 70° Fah. to $74\frac{1}{2}$° Fah., and the water at several of the wells as has been shown, has had its temperature raised by over 70° Fah. The resulting expansion would be twenty-six times as much as in the case first mentioned, and would be sufficient to keep the present artesian wells supplied with water for twenty-six years, on the assumption of course, that it did not expend itself in forcing the water out at the intake.

Discussion.

Mr. F. B. Gipps—Professor David in the course of his interesting paper remarked on my difference of opinion as to the generally accepted theory that the origin of artesian supply is due to hydrostatic or hydraulic pressure. My objection to such a conclusion, which becomes the more strengthened the more I examine artesian basins, is the impossibility of tracing, except in few instances, a direct connection or continuity of strata between the artesian basin and the presumed source of supply. For instance, take the artesian well at Grenelle near Paris, which is 2,000 feet deep. Water was struck at 1,798 feet, and burst up with a pressure of 1,160 ℔s. per square inch equal to a column of water 2,673 feet high. If this artesian supply is due to hydrostatic pressure, where is its source? The Vosges Mountains about two hundred miles distant, have a limited area above that height, but after accounting for frictional and capillary forces, the extra head would not be sufficient to account for such pressure. The Jura Mountains, about two hundred and thirty miles south-east, afford the only area of sufficient height and extent to provide it, but there is no evidence of a continuity of strata from the Jura to the Paris basins. In the case of the well at Kissingen in Bavaria, 1,878 feet deep, where the jet rises four feet higher than at Grenelle, the projecting force has been distinctly proved to be due to carbonic acid gas generated along the junction line of gypsum with limestone. The rise of the oil in the petroleum wells of America most certainly cannot be attributed to hydrostatic pressure. The oil collects in free sand enclosed between an impervious shale or slate at bottom, and a shell of siliceous schist with quartz pebbles at the top thus occupying the same position as most artesian waters. The average depth of these wells is from 1,600 to 1,800 feet. Some shallow wells are only 500 feet, whilst the deepest well is 3,000 feet deep. The force which compels these wells to overflow has given rise to many conjectures but no certain proof. In opposition to the hydrostatic pressure theory I would suggest the great dynamical effects of the contraction of the earth's crust acting on the superincumbent as well as subterincumbent strata, as offering a more probable solution of the cause and origin of artesian supply. Geologists tell us that this contraction accounts for the flexures of the earth's crust and strata, and for fractures and earthquakes, even for climatic changes. The evolution of the earth's features is therefore almost controlled by it. This contraction induces lateral pressure, which acting in a horizontal direction produces those flexures which originate mountain chains and valley depressions. Its effect has been distinctly proved by geological science to have occurred at different periods up to and even after the lignitic period of the Tertiary. The action of the wind on the sea gives in a modified degree some impression of the effect of this contractive force on the earth's surface. Now artesian basins, whether of large area, as in the Cretaceous System, or of smaller dimensions as in the Tertiary, represent in their overlying strata a series of broad tabular masses which are subject to very gradual flexure by this lateral pressure inducing a depression in the centre, and it is this force combined with expansion from heat which causes artesian supply in most instances rather than hydrostatic pressure. Lyell calculates that sandstone one mile thick raised in temperature 200° Fahrenheit, would have its upper surface elevated ten feet, showing the great force of this expansion. Professor Tate's paper, recently read in Adelaide, seems to me somewhat to strengthen my conclusions. He premises that the isolation of West from East Australia which existed while Central Australia was a marine area was partially continued into late Tertiary times, not by geological but by climatic conditions, first by the conversion of the depressed area into a vast fresh water sea to be followed in our own time by utter desiccation. In my opinion it is this fresh water sea, or contemporaneous inland lakes, filled in by the wasting and erosion of surrounding strata, and then completely sealed by a siliceous crust probably formed by the overflowing of numerous thermal springs, which is the principal source of the water supply of our Cretaceous artesian basins. During the long period between the sealing of these basins and the formation of the superincumbent strata, the action of the earth's contraction must have induced a certain degree of lateral pressure. In consideration that the weight of ordinary sandstone is 150 ℔s. per cube foot, it would require but little thickness of overlying strata to induce, in conjunction with the vast indefinable dynamical action of lateral pressure, all the propelling force evidenced by artesian flow independent of any other agency.

Mr. G. H. Knibbs—In accounting for the velocity of flow from artesian wells, said the theory of expansion of the water by heat can only apply where the water is actually imprisoned, as assumed by Captain Gipps. Its effect moreover must soon pass off, and continued flow would have to be accounted for in some other way, as by superincumbent pressure. If, however, there be a point of intake where the water-bearing stratum is covered only by permeable strata, the heat-expansion cannot raise the effective head above that point. In considering the efficiency of the head it is necessary to distinguish between 'hydraulic' and 'hydrostatic' head and pressure. Were there no outlet, the hydrostatic head, *i.e.*, the elevation of 1,000 or 1,100 feet of the point of intake, would more than account for any known flow in the artesian wells of the Colony. But if there be an outflow, the head will be hydraulic and not hydrostatic. Then assuming that the sectional area of the region of subterranean flow is constant, the hydraulic gradient will be a curve with its convexity upwards, provided that the condition of increasing resistance to flow by diminution in the porosity of the stratum as the point of outflow is approached, is as postulated by Professor David, a geological fact. For the hydraulic head is expended not only in producing the velocity of outflow, but also in overcoming resistances to flow. This result of hydro-dynamic theory, it seems to me, is correctly and interestingly illustrated by Prof. David's apparatus. In regard to the effect of superincumbent pressure, it cannot promote flow except the water-bearing stratum be regarded as more or less collapsible or sponge-like. Were the water-pressure hydrostatic, it is interesting to notice that, assuming a density of 2·5 for the overlying strata a depth equal to two-thirds of the elevation of the point of intake above the general surface in the vicinity of the wells would be supported. For example, an elevation of 1,000 feet above the general level would give at a depth of six hundred and sixty-seven feet a pressure (forty-six and a-half tons to the square foot), equal to the weight of the overlying stratum. At less depths, the head ought to raise the surface till an equilibrium was established through the inflow into the stratum and the consequent reduction of the head. In all cases however, with a collapsible stratum, the weight of the overlying strata will serve to maintain the artesian flow, until the point of maximum consolidation is reached, and that too, whether the head be hydrostatic or hydraulic.

Mr. H. C. Russell remarked that he had understood Mr. Gipps to say, that the origin of our artesian water was an old fresh-water sea, which by the action of hot springs on its shores had been slowly covered over with a layer of silica, and that this supported the denuded gravel and soil carried down to the sea by rain-water until the present strata overlying the water was formed, and pressing on the water caused it to rise in bores artificially made. He could not understand how this was possible, for it had been proved that the water beds extended hundreds of miles, and Mr. Gipps' theory obliged us to assume that the hot springs had covered this enormous area with a deposit of silica, thick enough to carry the gravel and other matter carried down by the rains on to it, which deposits would be very thick at the rivers and very little in other places. The theory seemed to him contrary to all experience, and also to what one would expect from the laws governing such deposits, and he therefore could not accept Mr. Gipps' view of the origin of our artesian water.

Mr. J. W. Grimshaw did not consider that Capt. Gipps had given them any information which would justify them in discarding the theory of the hydrostatic pressure of artesian water. The statement that there were wells at a higher level than the intake or source of the supply had not been proved. If the pressure of the water was caused by the shrinkage of the surrounding earth or by the generating of carbonic acid gas, the supply of water would be driven back towards the intake, and the pressure would not exceed the hydrostatic pressure, except in cases where the intake got blocked, in which cases the supply could not be replenished and would be intermittent and not continuous as in most artesian wells. Oil was not artesian water and the hydrostatic pressure theory was not applied to it. The pressure was probably due to chemical action, that was the generating of gas. In most cases the pressure of oil wells was found to decrease after a time. The experiment shown by Professor David was very instructive, especially as the results were too often overlooked, although it was well known that where the velocity of water flowing through a conduit was checked (in this case by sand), the pressure would rise, and where the velocity increased the pressure would fall; the explanation of this could be obtained from text books on hydraulics.

Mr. H. G. McKinney remarked that the apparatus exhibited by Professor David to illustrate the flow of artesian water, made clear not only the ordinary features of the underground flow, but also the cause of the rise of artesian water under certain conditions to a greater height than might have been anticipated. He pointed out that popular opinions regarding the extent of land likely to be irrigated from artesian bores were generally wide of the mark. If the flow from a successful artesian bore were expressed in cubic feet per second instead of gallons per day, exaggerated anticipations would often be avoided. Among the highly successful bores there are very few which yield more than five cubic feet per second—that is 2,700,000 gallons per day. The area which a flow of a cubic foot per second will irrigate depends on a variety of conditions; but taking average circumstances and high class management, it is unlikely that that area would exceed one hundred and fifty acres. Hence an artesian well with the flow mentioned, would irrigate only seven hundred and fifty acres. Still the question of irrigation from artesian wells is an important one, as it affords the means of producing fodder and other crops on a moderate scale at intervals through a large district which is badly provided with surface water. The cost of artesian water is another point on which there is much misapprehension. If a flow of three cubic feet per second, or 1,620,000 gallons per day, were obtained from an artesian well at a cost of £3,000, the result would be considered very satisfactory. If interest on the outlay be taken at six per cent. this would make the cost £60 per annum for every cubic foot per second. This is just double the rate at which it is estimated that water could profitably be supplied by the proposed Murrumbidgee Southern Canal. With reference to a remark of Mr. J. Wilson of Dunlop Station, on the river Darling, Mr. McKinney pointed out that a study of the conditions existing on the higher parts of the catchment areas of the tributaries of the river Darling, shows that there is nothing in regard to either the volume or the pressure of the artesian flow which is not easily accounted for. The elevation of the higher parts of these catchment areas and the rainfall are sufficient to account for a much larger quantity of water than has yet been struck. Regarding the danger of the spread of a salty efflorescence by the water used for irrigation, while such a danger undoubtedly exists, whether the source of the salts be the water or the soil, many statements publicly made with more or less authority, have certainly given an exaggerated idea of this danger. During a considerable part of Mr. McKinney's service in the Irrigation Department in India, he was in districts which suffered much from the saline efflorescence locally known as "reh." Large areas of land impregnated with this salt, or rather mixture of salts were well known long before the canals were constructed. It was also well known that if careless irrigation were allowed, the "reh" would spread, and every precaution was therefore taken with, it is believed, satisfactory results.

Mr. W. M. Hamlet, said, that the theory set forth by Mr. Gipps, that one of the causes of the flow of water from artesian bores was caused by large quantities of carbon di-oxide in the earth is not borne out by facts here in Australia, since most of the artesian waters examined contain little or no carbon di-oxide to speak of, hence the pressure at the outflow has to be accounted for in some other way.

Mr. W. A. Dixon said, that before beginning to build castles in the air as to the great results likely to be obtained from irrigation with artesian water, it is necessary to be sure of its source. In some cases water may arise from a porous stratum which forms merely an underground reservoir. One case of such a condition came under his notice in connection with the sinking of coalpits near Hamilton in Scotland, when at a depth of about sixty fathoms a water-bearing rock was cut in four shafts almost at the same time. The water rose high in the shafts and was simply pumped out at the rate of about twenty thousand gallons per minute from the four together, working night and day for nine months, and now the pits are quite dry. Another point in connection with the use of water for irrigation is that it is necessary to be sure of efficient drainage which is not to be relied on with certainty every where. All the salts held in solution in water, (and these may amount to over one hundred grains per gallon in fresh water) would gradually accumulate in the soil and render it absolutely sterile as has been the case in some places in India. This effect might not be noticed or act injuriously for ten, twenty, or fifty years, but under the conditions stated it is sure to come sooner or later according to the quantity of matter held in solution. As to the rise of the water being caused by pressure of carbonic acid, it is impossible that gas could be generated by the action of gypsum on dolomite or limestone as suggested by Mr. Gipps, as these substances have no action on one another.

Prof. Liversidge stated, that, from what he had seen of the action of siliceous springs and geysers, he must oppose Mr. Gipps' explanation that the artesian waters of Australia had been covered over and preserved by a layer of siliceous material or of sand and gravels cemented together by silica. Siliceous springs on the contrary tend to choke up their basins by continually depositing silica in successive films on their walls and around their margins, and not to form a crust over the surface and thus enclose supplies of water. He also stated that the artesian wells of Christchurch, New Zealand, were not in a true artesian basin, such as those of London and Paris, but that at the former place there is a bed of gravel and sand charged with water, overlaid by a less porous stratum and that it is thought that the water is in part squeezed up through the comparatively shallow bores by the superincumbent pressure [just as water would be forced up through a perforated board pressed down upon a sponge charged with water], and this idea is borne out by the shallow wells gradually giving out. The main bulk of the water is however probably forced up by hydrostatic pressure from the higher outcrops of the porous beds along the hills.

Mr. L. Whitfeld said, if the theory put forward by Professor David is correct, it should be easy to test it. The highest point to which the water will rise at the bore can be easily ascertained. The lower end of the subterranean channel being open to the sea, the height to which the water can rise at the bore must in the absence of further supply be continually diminishing. The extent and locality of the intake area are given by Professor David and the rainfall upon it can be ascertained, and thus it can easily be determined whether a period of dry weather over the intake area is accompanied by a constant diminution in the height to which the water will rise at the bore, and whether a fall of rain causes a rise in the height to which the water will flow. Also by observing which bores are affected by the rainfall on particular spots of the intake area, the direction of the subterranean flow can be determined.

Professor David stated with regard to the first theory put forward by Captain F. B. Gipps that one cause of the rise of artesian water was gas pressure, that the instance cited, that of the artesian well at Kissingen in Bavaria, was of a very exceptional character.

It was true that at Kissingen carbon dioxide probably played an important part in the forcing of the water to the surface. It was generated, not of course, as Mr. Dixon had already shown, by any possible action of the gypsum beds on limestone, but probably by the same cause which originally converted the limestone into gypsum, which might be still in operation at a depth, the cause possibly being the action of weak sulphuric acid on limestone. In New South Wales carbon dioxide was rarely met with in artesian water. The group of mud or mound springs on the Lower Flinders River in Queensland, referred to in his previous paper were an exception, as bubbles of carbon-dioxide were constantly rising through the water at these springs, but it was nevertheless not present in sufficient quantities to justify the supposition that this gas exercised any material expulsive force on the water. It was probably generated by the action of sulphuric acid resulting from decomposing pyrites in the lignitic beds or brown coals of the Lower Cretaceous rocks on the associated marly clays. He did not consider the oil wells of America a fair parallel to cite for comparison with the artesian wells of New South Wales. It was the fact that gas pressure contributed largely to force the oil to the surface at the American oil wells, but the gas pressure was assisted by hydrostatic pressure, as it was commonly the experience that when the gas and oil in the well became exhausted, brackish water took their place, and this rose to some height in the bores. The actual amount of pressure measured at any of the bores in New South Wales or Queensland, did not much exceed 200 ℔s. per square inch, a pressure which could easily be explained by the difference in level between the hydraulic grade and the level at the point where the pressure was experienced.

The theory as to the artesian water having its origin in great subterranean lakes, which had become crusted over with siliceous sinter had already been shown to be untenable by Professor Liversidge and Mr. Russell. He would like however to add that it was a geological anachronism to assume that artesian water could be derived, as suggested by Captain Gipps, from the lakes described by Professor Tate of Adelaide as formerly occupying large areas of Central Australia, inasmuch as these lakes were of Tertiary Age, whereas the age of the strata yielding the artesian water was Lower Cretaceous. As Mr. Knibbs had pointed out, neither expansion of the artesian water nor of the associated strata consequent on increase of temperature at a depth, could raise the hydraulic grade of the artesian water. The expansion of the strata would be irresistibly powerful, and would force the artesian water once it had filled the water-bearing strata back towards the intake, but once the expansion had taken place it would be subject to fluctuations so slight as to be practically a negligible force in the dynamics of artesian water. If the pressure of the artesian water of New South Wales was hydraulic and not hydrostatic, then the expansion of the water as it descended to lower levels by gravitation would perhaps help towards increasing the pressure, but only to a slight degree. The theory that the artesian pressure was due to secular contraction of the earth's crust compressing sealed beds of deep-seated water-bearing sands was open to the following objections:—(1.) The Lower Cretaceous water-bearing beds had been folded, only to a very limited extent, over the vast areas where they had hitherto been geologically examined in Australia, so that the segments of the earth's crust, where they had been deposited, could not be held to have been materially shortened since the Cretaceous Period. (2.) Had the shortening and compression been material, the pressure it would have exercised on the water-bearing beds would again have been irresistibly strong, and would have come on too gradually to account for the continuous flow of water from the mud springs throughout a large portion of the Tertiary and probably the whole of Post-Tertiary Time. In his opinion the chief question at issue was, is the supply of artesian water hydrostatic or hydraulic? In his opinion it was probably hydraulic, the deep-seated water flowing sea-wards as already explained, as through an inverted siphon. The central portions however of the basin must be practically hydrostatic. No other hypothesis seemed to account satisfactorily for the freshness of the water in the artesian basins, unless possibly it were the case that the outflow of artesian water through the mound springs had in itself been sufficient to maintain its freshness. In his opinion the supply of artesian water was entirely dependent upon the rainfall of the country near the intake of the artesian strata, and the chief force which made the water artesian was gravitation, assisted perhaps, but to a very limited degree, by the expansion of the water as it gravitated to lower levels.

Mr. McKinney had alluded to the "reh" of India, which had been quoted by some as a possible example of the danger, which might be incurred by using our artesian water for irrigation. He agreed with Mr. McKinney in considering that this danger had been much exaggerated. Mr. Harrie Wood, the Under Secretary for Mines and Agriculture, had proved by actual experiment, that various fodders, fruits, and vegetables could be successfully grown by means of artesian water, as had been detailed in the reports published by Mr. J. W. Boultbee the Officer-in-Charge of the Water Conservation Branch. The artesian water did not contain, as a rule, much mineral matter in solution hurtful to plants, with the exception of, in a few cases, carbonate of soda. There would however, no doubt be a danger of the ground suffering from an excess of alkali in areas which had been subjected to irrigation with artesian water for a number of consecutive years. The source of this alkali was twofold. It was partly derived from the artesian water itself, and partly was contained in the ground at a depth of a few feet below the surface. Rain had washed it down for perhaps two or three feet or more below the surface of the ground, but it had been the experience in America that ground of this kind, after it had been irrigated for a few years, became subjected to "black alkali," that is carbonaceous material dissolved by an excess of carbonate of soda. The ground being kept constantly saturated with water, and there being no means of escape for the water downwards by soakage, the saline material dissolved by it at a depth of about three feet below the surface was circulated upwards by capillarity etc., until the surface soil, out of which the alkali had previously been leached by the rainfall of ages became re-impregnated with alkali. The remedy in Australia as in America was no doubt sub-drainage.

Mr. J. C. H. Mingaye, F.C.S., M.A.I.M.E., Analyst and Assayer to the Department of Mines, in his valuable paper read before the Royal Society of N. S. Wales, June 1st, 1892, p. 100, has suggested the addition of a small quantity of gypsum to the soil previous to irrigation as a remedy against an excess of alkaline carbonates, the resulting sulphates being less hurtful to plant life.

In Queensland Mr. R. L. Jack, F.G.S., the Government Geologist, and Mr. J. B. Henderson the Government Hydraulic Engineer, had with remarkable foresight and courage spoken in no uncertain tones as to the comparatively limited extent of the artesian water supply, and he would like once more to emphasise the fact that in New South Wales also the supply was limited, so that possibly by the time that the quantity of water drawn from the artesian wells had been increased ten or twenty-fold, it would be found that the demand had overtaken the supply, that the annual outflow had equalled the annual intake of rain water into the artesian water beds. It was daily becoming more urgent that the pulse of the artesian water supply should be felt with a view of ascertaining whether the hydraulic grade was already being lowered or not by the existing wells. This end would probably be best attained by the application of pressure gauges to all the available artesian bores. The results of accurate measurements taken by means of these gauges would probably not only be of considerable economic importance, but would also, as stated by Mr. Whitfeld, throw more light on the questions (1.) as to whether the supply was hydrostatic or hydraulic; (2.) as to whether it was directly dependent on the amount of rainfall, and if so as to how long a period was necessary for the percolation of the rain from the intake to the artesian wells, and (3.) as to the principal channels, if any, through which the artesian water flowed. The application of pressure gauges and the desirability of locating new bores along axes of anticlinal curves were the two points to which he hoped attention might in future be specially directed.

Professor ANDERSON STUART said, that upon the whole, the theory as described by Professor David appeared to him to best explain the conditions as he understood them. He thought that Mr. McKinney's remarks as to the hopes entertained by some that artesian water would yet convert the dry arid back country into verdant fields should be emphasized, for he too considered that the hope was vain. One had only to see what vast constructions, what great pipes were needed to irrigate what was after all a mere patch of the surface, to be convinced that artesian water would never be able to do more than make fertile oases in the vicinity of the bores. Further, that even depended, as had been said on efficient drainage being possible—and it was not always so. He concluded by appealing to the Under Secretary for Mines and Agriculture (Mr. Harrie Wood), who was present, to use his influence in fitting all the bores systematically with pressure gauges, so as to give the important information spoken of by Professor David.

NOTES ON THE CREMORNE BORE.

By T. W. E. DAVID, B.A., F.G.S., Professor of Geology, Sydney University, and E. F. PITTMAN, A.R.S.M., Government Geologist.

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

I. *Introduction.*—The problem as to the exact relation between the Newcastle and Illawarra Coal-fields having been at last practically solved by the results of the Cremorne Bores, the present opportunity seems to us a favourable one for bringing before the Society a subject of so much scientific, as well as economic interest. The detailed section of the strata penetrated at the second bore is given by one of the authors in the Annual Report of the Department of Mines for 1893,* now in course of

* Annual Report, Department of Mines, 1893—Progress Report by E. F. Pittman, A.R.S.M., the Government Geologist.

publication. The present paper, however, is intended to be a short summary of the chief results attained by these bores.

The proving of a magnificent seam of steam coal over ten feet in thickness, at the second bore on the shores of Port Jackson, should mark an epoch in the history of the development of the coal resources of Australia, and shows that the estimates previously formed as to the available coal supply of this country have been probably under estimated.

II. *Previous References to the probable occurrence of Coal under Sydney.*—The late Rev. W. B. Clarke was probably the first who argued on scientific evidence, the probable occurrence of coal under Sydney. In his evidence before the Select Committee of the Legislative Council on coal enquiry held in Sydney in 1847, Mr. Clarke said, "If we take a dip of only 1° from Newcastle to the South and from Illawarra to the North, the synclinal curve will meet at the entrance to Broken Bay, which is exactly half-way (the extremity probably of the minor axis) at a depth of 4,680 feet, the depth of the coal seams if continuous."*

The late Examiner of Coal-fields, Mr. William Keene, prepared a geological section illustrative of the manner in which the coal seams in the Newcastle and Illawarra Coal-fields respectively, dipped under Sydney. We are not aware whether this section was ever published, but it was exhibited to one of the authors by Mr. T. Adams, the late Mayor of Raymond Terrace.

Mr. J. Mackenzie, F.G.S., the present Examiner of Coal-fields, as early as 1866, referred to the probable occurrence of coal under Sydney, in a lecture delivered in Sydney, and in "Mines and Mineral Statistics 1875," published some sections of the coal measures of New South Wales, dividing them in descending order into (1) Upper Upper Coal Measures, (2) Lower Upper Coal Measures, (3) Upper Marine Series, (4) Lower Coal Measures,

* Appendix, Report from the Select Committee Legislative Council on Coal Enquiry, 1847. *Vide also,* "A Sketch of the Physical Structure of Australia," by J. Beete Jukes, M.A., F.G.S., London 1850, pp. 19-22.

(5) Lower Marine Series. Each of the three groups of productive coal measures above mentioned, is specially characterised by the enormous predominance of *Glossopteris* or of *Gangamopteris* in its flora.

Summarising the result of his later researches Mr. Clarke classifies the productive *Glossopteris* coal-beds of Australia and their associated strata as follows:—1. Upper Coal Measures. 2. Upper Marine Beds. 3. Lower Coal Measures. 4. Lower Marine Beds.*

These productive coal measures are most extensively developed in the Hunter River or Northern Coal-field, the Lithgow or Western Coal-field, and the Illawarra or Southern Coal-field. Mr. Clarke did not definitely state his views as to the correlation of these various coal-fields, but it is clear that he regarded the Illawarra Coal Measures as being newer than the Upper Marine Series and than the Lower (the Greta) Coal Measures, inasmuch as in the work above referred to (*loc. cit.*, p. 169, Section to illustrate the structure of Burragorang), he speaks of the marine beds underlying the coal measures of the Mittagong Coal-field as the "Muree Beds," a name which he had previously given to the Upper Marine Series, or at any rate to a portion of them, which in the type district at Greta in the Hunter River Coal-field overlie the Lower Coal Measures, as illustrated by Mr. Clarke in another Section (*loc. cit.*, p. 171). Mr. Clarke also in his Section of Mt. Victoria (*loc. cit.*, p. 167), refers to certain hard shales occurring there as being like the "Silicated clay of Nobby Island." The island of Nobbys at Newcastle is formed of Upper Coal Measures. It is evident that Mr. Clarke considered the productive coal measures of the Newcastle, the Lithgow, Mittagong, and Illawarra Coal-fields as belonging to the Upper Coal Measures, and Mr. Mackenzie concurred with him in this opinion.

Mr. C. S. Wilkinson, the late Government Geologist subsequently adopted the following divisions for the *Glossopteris* Coal

* Remarks on the Sedimentary Formations of New South Wales, Fourth Edition.—Government Printer, Sydney 1878, p. 66.

Measures of New South Wales together with their associated marine strata :—

Permian { Upper Coal Measures or Newcastle Coal Measures.
Middle Coal Measures or East Maitland Coal Measures.

Carboniferous { Upper Marine Series.
Lower Coal Measures or Greta Coal Measures.
Lower Marine Series.

With regard to the relation of the Illawarra Coal Seams to those of Newcastle, Mr. C. S. Wilkinson, the late Government Geologist, wrote in 1887,* that in his opinion the former belonged to the series below the Newcastle beds, probably to the Lower Coal Measures, that is to the Greta Coal Measures. Mr. Wilkinson was led to this provisional conclusion from a consideration of the fact that kerosene shale had been proved to occur in the Greta Coal Measures alone out of the three sets of coal measures developed in the type district, that of the Hunter River, and he thought therefore that as kerosene shale had been proved to exist there and also at America Creek, Mt. Kembla, in the Illawarra Coal-field, that the two deposits occupied an identical horizon. This inference appeared to be corroborated by the fact that at the head of the Clyde River some coal measures, at first considered to be the equivalents of the Illawarra Coal Measures, were found to be capped by marine strata similar to those covering the Greta Coal Measures, and also to contain a seam of kerosene shale.

A subsequent examination however by Mr. Wilkinson of the Clyde Coal Measures in the southern extremity of the Illawarra Coal-field, while it convinced him of the probable identity of these measures with those of Greta, proved at the same time that the Clyde Measures were quite distinct from the Illawarra Coal Measures at Mt. Kembla, and the fact was thus established that in the Permo-Carboniferous strata of New South Wales there existed at least two distinct kerosene shale horizons.

The question still remained to be settled as to whether the Illawarra Coal Measures were a continuation of the Newcastle

* Mineral Products of New South Wales, etc., Department of Mines—Government Printer, Sydney 1887, p. 68.

Coal Measures or of the Tomago Coal Measures of the Hunter District. The abundance of bands of clay ironstone in the Tomago as well as in the Illawarra Coal Measures inclined Mr. Wilkinson towards the latter opinion.

A later examination of the Illawarra Coal-field, however, by one of the authors,* revealed the fact that there was an unconformability between the top of the Upper Marine Series and the base of the Illawarra Coal Measures, as seen in the coast section between Wollongong and Bellambi. This suggested the probability that the Middle or Tomago Coal Measures had been overlapped by the overlying coal measures (the Upper or Newcastle Measures) in the manner illustrated in the sections accompanying the report above quoted.

An examination of the section at the top of the Newcastle Coal Measures confirmed the opinion that the Illawarra Coal Measures were probably chiefly the equivalents of the Newcastle Measures, and the inference was drawn that the Bulli Coal Seam, the uppermost in the Illawarra Coal Measures, was identical with the Wallarah Coal Seam, the uppermost seam in the Newcastle Coal Measures at Wallarah near Catherine Hill Bay, Lake Macquarie. On palæontological evidence alone, Mr. R. Etheridge, Junr., the Palæontologist to the Geological Survey of New South Wales and to the Australian Museum, had previously arrived at somewhat similar general conclusions.

The classification at present adopted by us is as follows :—

Permo-Carboniferous.

(6) Newcastle Coal Measures typically developed at Newcastle, Lithgow, Mittagong, and in the Illawarra District.
(5) Dempsey Beds.
(4) Tomago Coal Measures typically developed at Tomago and East Maitland.
(3) Upper Marine Series.
(2) Greta Coal Measures typically developed at Greta, West Maitland, and at the Clyde River.
(1) Lower Marine Series.

The following is a table showing the relation of the new classification to those formerly adopted :—

* Annual Report, Department of Mines, 1890, p. 234.

Rev. W. B. Clarke—
(4) Upper Coal Measures.
J. Mackenzie, F.G.S.—
(4*a*) Upper Upper Coal Measures.
(4*b*) Lower Upper Coal Measures.
C. S. Wilkinson—
(4*a*) Upper Coal Measures, Newcastle Coal Measures.
(4*b*) Middle Coal Measures, E. Maitland Coal Measures

} Permian.

Rev. W. B. Clarke—
(3) Upper Marine Beds.
(2) Lower Coal Measures.
(1) Lower Marine Beds.
J. Mackenzie, F.G.S.—
(3) Upper Marine Beds.
(2) Lower Coal Measures.
(1) Lower Marine Beds.
C. S. Wilkinson—
(3) Upper Marine Series.
(2) Lower or Greta Coal Measures.
(1) Lower Marine Series.

} Carboniferous.

T. W. E. David and R. Etheridge, Junr.

Permo-Carboniferous {
(4*a*) Newcastle Coal Measures.
(4*b*) Dempsey Series.
(4*c*) Tomago Coal Measures.
(3) Upper Marine Series.
(2) Greta Coal Measures.
(1) Lower Marine Series.

The following are sections of the seams at Amos Brothers Bore near Wallarah and at the No. 2 Bore, Cremorne, placed side by side for comparison :—

*Amos Brothers Bore near Wallarah.**			*Cremorne.*		
Feet.	Inches.		Feet.	Inches.	
0	3	shale	0	1	coal, clay, shale
3	9	coal	0	8	coal, splint, somewhat inferior with minute veins of calcite
0	$0\frac{3}{4}$	sandstone	2	9 (about)	coal splint and bituminous of good quality
			0	$0\frac{1}{4}$	band dark brown clay shale adhering firmly to coal.
6	$8\frac{1}{4}$	coal	6	$5\frac{1}{4}$	coal splint and bituminous of good quality, the last 3 inches rather soft and bituminous.
			0	$3\frac{1}{2}$	coal, soft bituminous, a trifle clayey.
10	9		10	3	

Not only do the sections of these two seams agree tolerably closely, but the section of the two seams next below this top seam in the Newcastle and Illawarra Coal-fields respectively, also agrees, a seam four feet in thickness usually underlying the seam at Wallarah in the Newcastle Coal-field and at Bulli in the Illawarra Coal-field, and a seam fourteen feet in thickness underlying the four feet seam in places at both these coal-fields. The last mentioned seam however, in the Illawarra Coal-field is split up into a number of smaller seams at several localities. It is typically developed at Wongawilli near Dapto.

One important scientific result of the Cremorne Bore is therefore the practical settlement of the question as to the identity of the Newcastle Coal Measures with those of the Illawarra Coal-

* Annual Report, Department of Mines, 1882, p. 128.

field, and it may now be considered almost an established fact that the Tomago Coal Measures have been overlapped by the Newcastle Coal Measures and have thinned out against a rising surface of the Upper Marine Series throughout the greater portion of the Illawarra District.

III. *Previous Bores for Coal in the neighbourhood of Sydney.*

(1.) A bore was put down to a depth of 1,312 feet at Newington near Parramatta, by Mr. Coghlan, with a view of reaching the coal measures.* According to this report, which was made by the late Government Geologist, Mr. C. S. Wilkinson, the coal measures were reached near the bottom of the bore, and a specimen of *Glossopteris* was found in part of the core. We are of opinion however, that Mr. Wilkinson in making this statement was merely quoting the information supplied to him, and did not intend to record them as the result of his own observation, as he never, as far as we are aware, alluded to this statement, although he on more than one occasion discussed the subject of this bore with one of the authors. It seems incredible that the coal measures should lie at a depth of only 1,300 feet at Newington, near Parramatta, when they are 2,500 feet deep at Liverpool, about twelve miles southerly from Parramatta, and over 2,900 feet deep at Cremorne, about sixteen miles easterly from the same locality, there being little difference in the respective surface levels, and there being probably but very little dip between Liverpool and Parramatta. In all probability therefore this bore did not reach the coal measures.

(2.) At Moore Park a bore was carried down to a depth of 2,170 feet without striking the coal measures.†

(3.) At Botany a bore was put down to a depth of about 2,200 feet without penetrating the horizon of the coal measures. The chocolate shales were struck at a depth of 1,000 feet.‡

* Annual Report, Department of Mines, Sydney, 1878, p. 155.

† Annual Report, Department of Mines, 1880.—Report by Mr. C. S. Wilkinson, p. 241.

‡ Annual Report, Department of Mines, 1879, p. 208, and Mineral Products etc. of New South Wales, 1887, plate vi.

(4.) At Narrabeen a bore executed by Mr. Coghlan attained a depth of about 1,985 feet and failed to reach the coal measures.* The chocolate shales were struck at a depth of 379 feet 6 inches, and the purple and green tuffaceous shales representing the horizon of the cupriferous tuffs at a depth of 1,715 feet. Natural gas is stated to have been struck in this bore at a depth of 1,560 feet, and also at a depth of 1,200 feet in a bore within a few yards of the first. This natural gas was probably coal gas mixed with atmospheric air. The height of the bore above sea-level was about four feet.

(5.) At Rose Bay near Sydney, Mr. Coghlan bored on the Cowper Estate, to a depth of approximately 1,700 feet. Neither coal measures nor gas were obtained at this bore.

(6.) At Camp Creek, near the present site of the Metropolitan Colliery, about twenty-seven miles from Sydney, a bore executed by Mr. Coghlan was successful in reaching the Bulli coal seam, there about twelve feet thick, at a depth of 846 feet. Height above sea-level 336 feet.

(7.) The bore put down by the Department of Mines between Waterfall and Heathcote, about twenty-three miles southerly from Sydney, struck the upper portion of the Bulli seam at a depth of 1,513 feet, thickness four feet eight and a-half inches, and the lower portion six feet one inch thick at a depth of 1,583 feet ten inches. The chocolate shales were struck at a depth of 307 feet, and the cupriferous tuffs at a depth of 1,047 feet. Height above sea-level 467½ feet.†

(8.) At Dent's Creek near Holt Sutherland, the Diamond Drill belonging to the Department of Mines, struck the upper coal seam proved at the Heathcote bore at a depth of 2,228 feet, the seam being four feet two inches thick, and the lower seam at 2,296½ feet, the thickness of the latter being five feet three inches. The

* Annual Report, Department of Mines, 1890, pp. 233 – 237.—Report by T. W. E. David.

† Annual Report, Department of Mines, 1885, [1866] p. 176.

chocolate shales were struck at 787 feet, and the cupriferous tuffs at 1,728 feet. The total depth of this bore was 2,307 feet.

The results of these bores 6, 7 and 8 proved the Bulli Seam to have a dip from Coal Cliff, where it outcrops near sea level, to Holt Sutherland at a rate of about 139 feet per mile. The height above sea level is 132 feet.*

(9.) At the Liverpool Bore, situated on the Moorbank Estate, three miles southerly from Liverpool near Sydney, three small seams of coal, probably representing in the aggregate the upper division of the Bulli seam, were struck at depths of 2,493½ feet, 2,507 feet 7 inches, and 2,532 feet 8 inches; their respective thicknesses being one foot five inches, one foot four inches, and two inches, and the lower division of the Bulli Seam six feet six inches thick was struck at 2,584 feet 10 inches.

(10.) The first Cremorne Bore put down by the Department of Mines on the shores of Port Jackson, near Mossman's Bay, struck the main Bulli Seam, here probably representing a combination of the two seams struck at Heathcote and Holt Sutherland, and of the four seams struck at Liverpool at a depth of 2,801 feet 9 inches. As however, the seam was much intermixed with dyke material and wholly calcined, this thickness must be considered as only approximate. At a depth of 2,838 feet 9 inches a dolerite dyke was struck, which was not completely penetrated until a further distance of thirty-four feet four and a-half inches had been bored. The bore was continued to a depth of 3,095 feet without proving any other coal seams of importance. The following small seams however were penetrated :—one foot one inch of clayey calcined coal at 2,829 feet 6 inches; one foot two inches of dirty splint coal at 2,898 feet 3 inches; one foot of coal at 2,941 feet 2 inches; five feet of carbonaceous clay shale passing downwards into about one foot of clayey coal at 2,947 feet 2 inches; two feet four inches of coal at 3,020 feet 2 inches; one foot four inches of coal and bands at 3,030 feet; five inches of coal at 3,054 feet 11 inches.

* Annual Report, Department of Mines for 1883, p. 197.

The chocolate shales were struck at a depth of 943 feet 4 inches. The surface level at this bore was fifty-four feet above the sea.

(11.) *Second Cremorne Bore.*—In consequence of the coal in the seam struck at the first bore having been damaged by the dolerite dyke, the syndicate resolved to put down a second bore, and with a view of avoiding the dykes in the second bore, applied for a geological survey of the neighbourhood with the object of determining the exact trend of the dykes. An examination was accordingly made by the Geological Survey, and it was found by the authors that a dyke of dolerite about five feet wide outcropped near the first bore, dipping towards the borehole at a rate which would make it approximately intersect the bore at the depth at which the dolerite dyke was actually encountered in the bore. A subsequent examination by one of the authors led to the discovery of a second dyke, trending so as to almost exactly intersect the spot where the bore was commenced.*

The site for the second bore was accordingly placed as far as possible from the outcrops of these two dykes, though the boundaries of the Syndicate's property did not admit of its being distant more than a quarter of a mile from either outcrop. At a depth of 2,917 feet a seam of coal was struck, which proved to be ten feet three inches in thickness. The upper eight inches of this seam was slightly damaged through the action of superheated water carrying mineral matter in solution from the dyke, but the remainder of the seam proved to have been quite unaffected by the dyke, and the analysis of the coal shows it to be a steam coal of very good quality. The following is a section of the seam:—

Roof, clay shale.

Feet.	Inches.	
0	1	coaly clay shale.
0	8	splint coal somewhat inferior, with minute veins of calcite (?).
2	10	coal splint and bituminous of good quality.

* Annual Report, Department of Mines and Agriculture, 1892, p. 109-110—Report by E. F. Pittman, A.R.S.M., Government Geologist.

Feet.	Inches.	
0	0¼	band dark brown clay shale, adhering firmly to coal.
6	4¼	coal, splint and bituminous of good quality, the last three inches rather soft and bituminous.
0	3½	coal, soft bituminous, a trifle clayey.
Total 10	3	

Floor black carbonaceous clay shale passing downwards into a hard mudstone. This bore was carried to a depth of 2,929 feet.

The quality of the coal in this seam is shown by the following analyses by Mr. J. C. H. Mingaye, F.C.S., Analyst and Assayer to the Department of Mines :—2572 No. 1. Average sample from the first eighteen inches of coal next below the eight inches of coal with calcite veins at the top of the seam :—

Hygroscopic moisture	·65	
Volatile hydrocarbons	17·30	
Fixed carbon	71·75	Coke 82·05%
Ash	10·30	
	100·00	

Sulphur in coal ·795%. Specific gravity 1·207. Ash, reddish tinge, flocculent.

One pound of this coal by experiment in a Thompson's calorimeter will convert 12·7 lbs. of water into steam.

2573 No. 2. Average sample from the next eighteen inches of coal :—

Hygroscopic moisture	·70	
Volatile hydrocarbons	17·80	
Fixed carbon	71·60	Coke 81·50%
Ash	9·90	
	100·00	

2574 No. 3. Average sample from the next fourteen inches of coal :—

Hygroscopic moisture	·80
Volatile hydrocarbons	16·90

Fixed carbon	71·05	Coke 82·30%
Ash	11·25	
	100·00	

Sulphur in coal ·617%. Specific gravity 1·398. Ash, reddish tinge, flocculent.

One pound of this coal will convert 12·9 lbs. of water into steam.

2575 No. 4. Average sample from the next fourteen inches of coal:—

Hygroscopic moisture	·70	
Volatile hydrocarbons	17·05	
Fixed carbon	71·25	Coke 82·25%
Ash	11·00	
	100·00	

Sulphur in coal ·809%. Specific gravity 1·374. Ash, reddish tinge, flocculent.

One pound of this coal will convert 12·9 lbs. of water into steam.

2576 No. 5. Average sample from the next fourteen inches of coal:—

Hygroscopic moisture	·65	
Volatile hydrocarbons	17·95	
Fixed carbon	70·15	Coke 81·40%
Ash	11·25	
	100·00	

Sulphur in coal ·878%. Specific gravity 1·373. Ash, reddish tinge, flocculent.

One pound of this coal will convert 13·1 lbs. of water into steam.

2577 No. 6. Average sample of the last fourteen inches of coal:—

Hygroscopic moisture	·45	
Volatile hydrocarbon	18·45	
Fixed carbon	71·75	Coke 81·10%
Ash	9·35	
	100·00	

Sulphur in coal ·686%. Specific gravity 1·362. Ash, reddish tinge, flocculent.

One pound of this coal will convert 13·2 lbs. of water into steam.

Mean analysis of the six samples :—

Hygroscopic moisture	·66	
Volatile hydrocarbons	17·57	
Fixed carbon	71·09	Coke 81·77
Ash	10·68	
	100·00	

Mean sulphur ·724%. Mean specific gravity 1·346.. Mean calorimetric value 13·0.

The above analyses prove the coal to be a steam coal of good quality, slightly superior to the Bulli coal, but resembling it in general physical characters, as might have been expected, seeing that it belongs to the same seam. The Bulli coal however, contains at least two per cent. more ash than that from Cremorne.

Mr. Mingaye adds that the Cremorne coal forms an excellent coke. The mean percentage of ash in the coke would be 13·06.

General character of the Coke of the Bulli Seam.—The coke hitherto made from coal taken from the Bulli Seam contains a rather higher percentage of ash than that made from the Northern or Newcastle coal, and although at the Bulli Colliery Coke Works the coal was passed through a Sheppard Coal Washing Machine prior to its introduction to the coke ovens, the percentage of ash in the resulting coke amounted to 13·4.* This is said to be due to the fact that the dirt or ash-forming material is intimately mixed with or distributed through the Bulli coal in a very fine state of division. Nevertheless it appears probable that if the washing were preceded by sufficiently fine crushing, a very material reduction in the percentage of ash would result. One distinct advantage possessed by coke made from the Bulli Seam is its capacity for resisting crushing strain, or in other words, its

* *Vide* Report on Colonial Coke by E. F. Pittman, A.R.S.M., Government Geologist—Annual Report of the Department of Mines and Agriculture for 1892, pp. 35-37.

excellence for smelting purposes in those cases where it has to resist a heavy furnace burden. It will be seen by reference to the report last quoted, that in some tests made by Professor Warren, samples of the Bulli coke resisted a pressure of from 2,400 to 3,100 lbs. per square inch—a pressure which was largely in excess of that withstood by any of the other specimens of foreign or colonial coke experimented with.

Gas.—Coal gas was given off abundantly from the coal core for over two hours after it had been drawn to the surface. The coal dust floated up in the water which was being circulated in the borehole by the force pump in the process of drilling, discharged coal gas so copiously that it bubbled up strongly through the water, and was readily ignited, burning with a bluish flame six to eight inches in length. It will be recollected that gas, probably coal gas mixed with atmospheric air, was given off from both the bores for coal at Narrabeen. It was probably derived from the same seam as that struck at Cremorne, and was conducted into the Narrabeen bores possibly by an oblique joint in the strata, which intersected one bore at a depth of 1,200 feet, and the other at 1,560 feet.

IV. (a) *Details of No. 2 Cremorne Bore.*—The following is a generalised section of the strata penetrated in this bore from the surface down to the total depth 2,929 feet:—

			Thickness. Ft.	In.	Total depth. Ft.	In.
Triassic—Hawkesbury Series.		Hawkesbury Sandstone ...	1,020	6	1,020	6
	Narrabeen Beds.	(*a*) Chocolate shales...	163	6	1,184	0
		(*b*) Sandstones, shales and conglomerates, with *Thinnfeldia, Sphenopteris, Sagenopteris, Macrotæniopteris, Odontopteris, Schizoneura,* and *Estheria.*	1,112	6	2,296	6
		(*c*) Tuffaceous dark green gritty shales—horizon of the Cupriferous tuff of the Holt Sutherland and Heathcote bores.	60	6	2,357	0
		(*d*) Sandstones, shales and conglomerates	560	0	2,917	0

		Thickness. Ft. In.	Total depth. Ft. In.
Permo-Carboniferous—Newcastle Series.	Coal seam ...	10 3	2,927 3
	Clay shale and mudstone with *Vertebraria.*	1 9	2,929 0

The line of division between the Mesozoic and Palæozoic rocks has been drawn at the top of the coal seam for the reason that the horizon of the ironstone nodules, which is well marked as forming the basal bed of the Hawkesbury Series, was found to descend at this bore to within a few feet of the coal seam.

(b) *Dip of the Seam.*—At the No. 1 Cremorne Bore the surface level was fifty-four feet above the sea, and at the No. 2 Bore one hundred and forty-three feet above sea-level. At the No. 1 Bore, the coal was struck at 2,801 feet 9 inches, and at the No. 2 Bore at 2,917 feet. Consequently the seam at the No. 2 Bore was one hundred and fifteen feet deeper (in round numbers) than at the No. 1 Bore, whereas there was a difference in the surface levels of only about eighty-nine feet. The seam has therefore dipped from the No. 1 Bore towards the No. 2 Bore twenty-six feet in a distance of forty chains in a direction of North 34° West.

At the Narrabeen Bores the chocolate shales were struck at a depth of three hundred and seventy-nine feet six inches, the distance from the No. 2 Cremorne Bore being nine and a-half miles and the bearing North 5° 45′ East. The surface level being about four feet above the sea.

At Holt Sutherland, the surface level being one hundred and thirty-two feet above the sea, the depth to the first seam of coal was 2,228 feet, and to the second seam 2,296½ feet. If the authors' opinion be right that these two seams come together and become united to form the single ten feet three inches seam at Cremorne, the depth to the top of the lower seam with the thickness of the upper seam subtracted from it should be taken as the level from which to measure the dip of the seam from Holt Sutherland towards Cremorne, that is 2296½ feet — 4 feet 2 inches = 2,292 feet in round numbers. The total dip therefore from the Holt Sutherland Bore to the No. 2 Bore at Cremorne has been six hundred and fourteen feet, the bearing being N. 21° 30′ E. and the distance sixteen and a-half miles. The chocolate shales at the Holt Sutherland Bore were struck at a depth of seven hundred and eighty-seven feet,* whereas at the No. 2 Bore at Cremorne they were struck at 1,020 feet, a total dip of two hundred and twenty-two feet, so that, whereas the coal measures dip six hundred and fourteen feet, the top of the Narrabeen beds and base of the Hawkesbury Sandstone has dipped only two hundred and twenty-two feet, which proves that the Narrabeen Beds thicken between Holt Sutherland and Cremorne three hundred and ninety-two feet in a distance of sixteen and a-half miles.

The surface level at the Liverpool Bore is about forty feet, and the depth to the top of the main seam 2,584 feet 10 inches, so that the main seam dips from Liverpool towards the No. 2 Bore, Cremorne, two hundred and twenty-nine feet, the bearing being N. 53° E., and the distance twenty miles.

These data are not sufficient to admit of the exact amount and direction of dip of the coal measures at Cremorne being calculated. From Coal Cliff to Holt Sutherland the dip is northerly at about one hundred and thirty feet per mile; from Lithgow to Liverpool it is easterly at about sixty feet per mile without allowing for the downthrow fault and sharp monoclinal fold at Lapstone Hill, which amounts to perhaps about six hundred feet. If this six hundred feet be added, the dip from Lithgow to Liverpool would be about sixty-seven feet per mile.

The general dip from the coast towards the No. 2 Cremorne Bore is westerly at one hundred and ten feet per mile. At Wyong, about forty miles northerly from Cremorne, the same chocolate shales which are about eight hundred and seventy-seven feet below sea-level at Cremorne, are at sea-level, dipping in a southerly direction. It is obvious from these facts that Sydney cannot be far from the centre of the great coal-field, which extends from near Ulladulla to Port Stephens, and from the sea coast to

* Annual Report, Department of Mines, 1883, p. 197.

beyond Lithgow. The westerly dip at Cremorne proves that the bore is situated on the eastern half of this coal basin, and as the seam is rising in an easterly direction at Cremorne at the rate of about one hundred and ten feet per mile, it should outcrop at sea level at a point about twenty-four and three-quarter miles from the coast eastwards from the bore. The ocean however here is about one hundred fathoms deep, so that the submarine outcrop of this seam should lie approximately nineteen and a-quarter miles easterly from the entrance to Port Jackson.

It may be safely predicted that in the near future the coal seam at Cremorne will be worked far under the ocean, and already a company "The Sydney and Port Hacking Coal Company Limd.," name since changed to "The Sydney Harbour Collieries, Limited," has acquired the right to mine for coal under an area of about 8,000 acres of Port Jackson, Middle Harbour, and Manly Cove.

V. *Temperature.*—With a view of ascertaining the temperature as accurately as was practicable in the short space of time available for the experiment, by the advice of Professor Threlfall and Mr. H. C. Russell, the Government Astronomer, some maximum-register thermometers were hermetically sealed in a strong piece of wrought iron water pipe about two feet three inches in length. A cap piece was "sweated on" to the lower end of this tube, the threads of the screw in the cap piece and pipe being filled with molten solder and the cap piece being screwed on, while the solder was still molten. By this means a joint was formed capable of withstanding the great pressure to which it would be subjected, when lowered to the bottom of the bore, the bore being full of water from a level of 2,900 feet to within about three hundred feet of the surface, and it being necessary therefore to protect the bulbs of the thermometers against this water pressure, in order to preclude the possibility of their registration being unduly high from that cause. The lower end of the pipe was then filled to a depth of about two inches with brass turnings. The thermometers were next carefully lowered into the tube. Three of these were maximum registering overflow thermometers, made by Negretti and Zambra, two of them kindly lent for the purpose by Mr. H. C. Russell, and being Kew-certificated. A fourth was a combined spirit and mercury thermometer registering both maximum and minimum temperatures by means of small steel pistons washered with vulcanite.

The three overflow thermometers were placed with their bulbs uppermost to facilitate the breaking of the mercury column when the maximum temperature had been reached. Brass turnings were then packed around them in order that the heat might be conducted rapidly to their bulbs from the water in the bore. Strings were fastened to the bulbs to facilitate the withdrawal of the thermometers from the tube after the experiment of taking the temperature had been completed. The ends of these strings were carried close up to the top of the pipe, the brass turnings being packed around them like tamping around a fuse in a shot-hole. A few card-board wads and a layer of loose paper two inches in thickness were inserted in the upper portion of the tube to prevent the conduction downwards of the artificial heat, which would otherwise travel down to the thermometers from the upper end of the tube when it was dipped in the molten solder, previous to the upper cap-piece being "sweated on." A ring-bolt for attaching the lowering cord was screwed into the upper cap-piece with molten solder sweated into it; and the whole cap-piece was then screwed and sweated on to the upper end of the tube in the same manner as the lower cap-piece.

The tube carrying the thermometers was then lowered down the borehole by means of about five hundred feet of piano wire attached to two thousand five hundred feet of tarred rope. Owing however, to the fact that the bulbs of the two Kew thermometers (these two alone were used on the occasion of the first experiment) having a few thicknesses of soft paper around their bulbs it was found on raising the tube after it had remained near the bottom of the bore for about an hour, that no sensible alteration had taken place in the level of the mercury. Considerable delay however had occurred between the time that the thermometers reached the surface and the time that the reading was taken, as it was necessary to convey the tube from the site of the bore back to the plumber's in order to have the upper cap-piece removed. It is just possible therefore that as both thermometers were in a vertical position in the tube, the mercury may have become gradually sucked back into the bulbs after having been forced up the graduated tube to the temperature of the water near the the bottom of the bore.

On the occasion of the second experiment all the four thermometers previously described, were employed, no paper being wrapped around the bulbs, but the brass dust being continuous from the bulbs to the side of the iron pipe. On that occasion, however, owing to an obstruction in the bore at a depth of 2,733 feet, the piano wire became slackened, as the lowering was continued until it was estimated that the tube with the thermometers had reached a depth of about 2,880 feet. Consequently about one hundred and sixty-seven feet of rope was paid out after the tube had reached the depth of 2,733 feet, the reduction in weight on the rope consequent on the tube becoming lodged at that level not being sufficiently perceptible to apprise those in charge of the lowering that the bore had become blocked. When, therefore, after the tube had remained down the bore for over an hour, the work of winding up was commenced, the slackened coils of piano wire kinked, and the wire snapped, and the tube was left remaining in the bore at the depth above mentioned. After an immersion of about twenty-seven hours, the tube together with over a hundred feet of tangled wire was brought to the surface by the Superintendent of Drills, Mr. W. H. J. Slee, with the assistance of his foreman, Mr. Ayles, who succeeded in grappling the wire with an improvised recovering tool in the shape of a heavy iron coupling, terminating downwards in an iron prong about a foot long, armed at the sides with stiff springs riveted on to the prong at one end, and with the free ends pointing outwards and upwards, like the barbs of a harpoon.

The upper cap-piece was then rapidly heated in a chafing dish of charcoal made of an old nail can with a hole cut out of the bottom just sufficiently large to admit of the upper end of the tube being passed up it, and oxygen gas from a compressed cylinder was blown through a Fletcher's Blowpipe on to the charcoal, so that in less than half a minute the solder in the threads of the cap-piece was melted—the lower portion of the tube containing the thermometers being meanwhile wrapped in wet cloths to prevent the heat travelling downwards. The cap-piece having been unscrewed and the thermometers withdrawn, the highest temperature registered was found to be 97° Fah.

In spite of the tube having remained for twenty-seven hours under the great hydrostatic pressure it must have sustained at a depth of 2,733 feet, not a drop of water had found its way into the tube, a fact, which speaks for itself as to the excellence of the work done by the plumber, Mr. James Gilchrist, of 174a Pitt Street, Sydney.

On the following day the experiment was repeated, the tarred rope alone being used with a weight of only about thirty pounds, including that of the tube. This time the tube was withdrawn after it had remained down the bore one hour. The stoppage of the tube in the bore at a depth of 2,733 feet, was this time distinctly perceptible, and so the cause of the kinking of the piano wire on the previous occasion was explained.

The maximum temperature registered by the three overflow thermometers was 96° Fah. The maximum and minimum thermometer was found to have been shattered, probably through the jarring of the tube against the sides of the borehole. The lower temperature recorded on the occasion of the third experiment as compared with that of the second, was probably due to the tube carrying the thermometers and the sheet lead wrapped round it, (in order to increase its weight) having slightly chilled the water at the point where the temperature was taken, and the time allowed (one hour), before the tube was withdrawn having been too short to admit of the water around the tube in the bore resuming the normal temperature of the surrounding rock.

The above experiments were conducted without any special precautions having been taken against convection currents. It is impossible, however, that convection currents would obtain to such an extent as to materially alter the temperature in a bore-hole only four inches in diameter from 2,400 feet to 2,929 feet, and five inches in diameter from 2,400 feet to the surface. If therefore 97° Fah. be assumed to be the correct temperature of the earth's crust at Port Jackson at a depth of 2,733 feet, (and the authors do not think there is likely to be an error of more than half a degree in the temperature above quoted), the mean surface temperature being 63° Fah., as determined by Mr. H. C. Russell, the rate of increase in temperature down to a level of 2,733 feet would be 1° Fah. for every eighty feet, after the zone of mean temperature, at about thirteen feet below the surface, has been passed. The temperature therefore at the depth at which the coal seam was struck, 2,917 feet, should be 2·3° Fah. higher than that registered at 2,733 feet, that is 99·3° Fah.

At the Metropolitan Colliery near Sydney, the rate of increase of temperature was found to be approximately 1° Fah. for every seventy-eight feet. This result however, can be considered as only approximate. Experiments were also made with a view of ascertaining whether the water in the deeper portions of the harbour may have had any chilling effect locally on that portion of the earth's crust nearest the bore, so as to depress the isogeotherms. The temperature however of the water in the harbour at the greatest depths near Cremorne, varying from forty-five feet to sixty-three feet, was uniform at 68° Fah. The experiment was made on December 6th, 1893. The abnormally low rate of increase in temperature in the earth's crust downwards at Cremorne cannot therefore be attributed to any chilling effect of the water in the harbour. More observations will be needed before any definite conclusions can be arrived at. The comparatively low temperature at the horizon of the coal seam will obviously materially lessen the cost of ventilation, as compared with what it would have been, had the rate been 1° for every sixty-three feet, as has so often been experienced in other countries under somewhat similar conditions.

VI. *Possibility of Working the Seam,*—With the efficient ventilation which can be secured by means of the most modern ventilating fans, there does not appear to be any reason to doubt that the temperature of the mine workings under the harbour at Sydney, can be reduced to 80° or even less. At the Metropolitan Colliery, Helensburgh, with a Schiele fan twenty feet in diameter working at the top of the upcast shaft, a ventilation of about 350,000 cubic feet per minute is said to be obtained, and the condition of the air in the mine is very satisfactory. The depth of the coal below high watermark at Cremorne—about 2,774 feet is undoubtedly great, but it is not by any means the greatest depth at which coal has been worked. Thus in England at the Ashton Moss pit, at Dukinfield, the workings were carried to a depth of 2,850 feet, while in Belgium at a Colliery near Charleroi a depth of 3,411 feet was attained.*

It may therefore be reasonably expected that the difficulties of working the coal under Sydney harbour can all be overcome with the aid of the most improved appliances for ventilating and hoisting. The only other question to be considered, viz., whether the trade that may be looked for in the near future will be sufficient to pay interest on the capital required to develop the mine, is a commercial rather than a scientific one, and is therefore outside the limits of this paper.

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* *Vide* Prestwich's Geology, 1888, Vol. II., p. 100.

ON ARTESIAN WATER IN CONNECTION WITH IRRIGATION.

By W. A. DIXON, F.I.C., F.C.S.

[*Read before the Royal Society of N. S. Wales, December 6, 1893.*]

FOLLOWING on the interesting paper by Prof. David on Artesian Water, I have ventured to put down a few remarks in their connection with irrigation. This is required, because very loose and wild ideas as to the results likely to be achieved float through the minds of many people, and often find expression through the press.

Prof. David states as his opinion, that the water which now rises in our artesian bores has hitherto been flowing to the sea by underground channels, and that the rise of water to the surface is caused by the friction of the material of the porous beds on the water, the outlet to the sea being much below the level of the land surface, He also says that the intake area at the outcrop of the Cretaceous beds is about two hundred square miles (so far as the drainage into New South Wales is concerned I understand). The rainfall on this area is about twenty-two inches per annum on the average, and it is stated by Mr. Russell, (Jour. Roy. Soc. N.S.W. Vol. XXIII., pp. 57 – 63), that probably half this rainfall percolates into the soil.

It must not be thought that because vegetation exists with a rainfall of eight inches per annum, and flourishes with three times that amount, that even the larger quantity applied to the ground by irrigation would produce the same effect. When rain falls the atmosphere is saturated with moisture and evaporation is checked, but successful irrigation is practised when the air is dry and evaporation at its greatest, so that it is best applied thoroughly to small areas instead of to large ones merely watered. The cost of laying out channels is kept at a minimum, as is also the loss by aporation relatively to the crop.

The quantity of water used for efficient irrigation is very large, as, for example, in Italy the hay land gets twelve floodings each six inches deep during the summer six months, of which one-third to one-half is retained by the land, the remainder being utilized to similarly flood land at a lower level. The land thus gets seventy-two inches, and if one-third of this, viz., twenty-four inches is retained by the soil, this is two inches more than the fall on our catchment. In some other countries more is used.

Supposing that half of the rainfall which passes into the soil could be made available it would only irrigate something under 60,000 acres. If the cause of the upward pressure is as stated, long before this maximum was reached the bores would cease to be artesian.

It seems more probable that only about one-fifth of the rainfall on the catchment area could be made available after allowing for loss by streams, evaporation, and the requirements of vegetation locally, and the unavoidable escape through the old channels to the sea. This reduces the *available* catchment area to forty square miles, giving water enough to irrigate 25,000 acres. This area would produce 75,000 tons of hay per annum by growing grasses of the largest yield, such as Timothy, taking the result as the same as that of Italy, viz., three tons per acre. Mr. Coglan gives the yield of hay in New South Wales as 1·73 tons per acre and the area as 131,153 acres, so that the total crop at present is, say 227,000 tons. Other crops could of course be raised instead, but hay would probably be the most valuable on the spot for conversion into live stock.

Water for irrigation is not required all the year round, so that it would be necessary to construct reservoirs to contain and store it when it is not required. It is evident that no advantage can arise by closing down the bores either completely or partially, as the water would then simply find its way to the sea by the old channels instead of on to the land. The only possible advantage of closing would be that of giving other bores a chance of getting pressure, but this would only happen if the wells were too numerous, and would make no difference in the area that could be irrigated. Probably half the water would have to be stored, and the reservoirs would require, for the irrigation of 25,000 acres, a capacity of 6,806,250,000 gallons, or one hundred and twenty-one million cubic yards. This is a work of some magnitude and with ditches and other capital work would cost at least £5,000,000, or £200 per acre, the interest on which alone would come to £2 6s. 8d. per ton on the hay.

In Mr. Boultbee's report on artesian bores published in the beginning of 1892, the flow of water is stated to be 10,750,000 gallons per day, but these figures are misleadingly large when used in connection with irrigation, when the water has to be measured in inches of depth on the surface. Put into this form it would be twenty-four inches per annum on 7,230 acres or the rainfall on twelve and one-third square miles on the catchment area, or nearly one-third of supply available.

I would be glad to find that the results are better, but they are those derivable from the information available and can only be increased by enlarging the catchment or the rainfall. As I said in the discussion on Prof. David's paper a month ago, we must be sure of our supply. It seems folly to build castles in the air at present, and to dream as some people seem to do of cultivating millions of acres and settling hundreds of thousands of agriculturists on the soil.

Addendum to Mr. Ray's paper (pp. 101 - 167) on the Languages of the New Hebrides.

III. Malekula ; dialects—1. *Port Sandwich* (additional);

Sun—meriu
Moon—rambatsi
Star—matsoi
Night—ur-e-marin
Wind—ean
Water—vai
Sea—ras, tes
Land—ur
Smoke—basu-amp
Pig—boas, baramban
Shark—bag'co
Banana—buts
Breadfruit—barap

Yam—dram
Taro—buagk
Road—buse
Club—mbat
Food—hanian
Father—ramagk
Man—arar
Child—ruari
Female—rambaik
Wife—sua
Bad—e-samb
Great—mbau
Small—kikei

Numerals.

One—tsika
Two—e-u
Three—e-roi
Four—e-vats
Five—e-rim
Six—ma-tsukai
Seven—hou-e-u
Eight—wu-roi
Nine—wu-vats
Ten—sungeav

III. Malekula ; dialects—5. *Uripiv Island*, off Port Stanley, on the north-east coast.

Sun—ial
Moon—il
Night—ata-mu-bog
Wind—lig
Rain—us
Water—nui
Sea—ndis
Land—vanua, ure
Smoke—us
Pig—birbir *(fem.)*
Shark—bai
Cocoanut—ni
Breadfruit—betiv
Yam—dram
Taro—buak

Road—sel
Club—nai
Boat—ndrav
Food—hanin
Father—tata
Man—tsinib
Male—oroman
Child—natu
Female—nevseven
Wife—nevseven
Chief—numal
Name—ise
Good—eres
Bad—isits
Great—elep

Small—walili
Holy—on
Barter—mboili
Bury—tevini

Numerals.

One—i-tes
Two—e-ru
Three—i-tul
Four—i-wits
Five—e-lim
Six—o-won
Seven—a-mbut
Eight—o-wil
Nine—e-su
Ten—e-snavil

Corrigenda.

Page 107, line 7, for *gembw* read *gcmbw.*
„ 109, „ 18, 26, for *Taian* read *Iaian.*
„ 110, „ 42, *for* make *read* mace.
„ 111, „ 42, *add* bata, 'rain.'
„ 112, „ 35, *read* mbuka-wagca, 'fire'; line 42, *dele* waga.
„ 113, „ 11, *add* boas, 'pig.'
„ 114, „ 41, *read* ui, vui; ian, en.
„ 114, „ 42, *read* pika-rowo, 'animal-fly.'
„ 116, „ 34, *for* matig', *read* noki.
„ 116, „ 41, *for* pil *read* mapinai.
„ 118, „ 1, *for* nithjan *read* nithjan-ne-fana.
„ 118, „ 11, *for* buts *read* mbat.
„ 120, „ 32, *for* tagala *read* tagata, 'man.'
„ 124, „ 7, *for* pioroa *read* piowa; line 31, *read* kanouri.
„ 125, „ 34, *read* memea; line 41, *read* gala, gir.
„ 126, „ 42, *for* numere *read* nunurai.
„ 127, „ 26, *add* tunu, 'barter.'
„ 127, „ 28, *transfer* gangan *to line* 29.
„ 128, „ 41, *for* nilaun *read* laun; line 42, *read* lalaun.
„ 129, „ 26, *for* humei *read* himei.
„ 133, „ 13, *dele* †; page 138, line 26, *for* thigo *read* thig.
„ 142, „ 22, *for* sege *read* segi.
„ 145, „ 20, *for* batin-venua *read* batin-fenu.
„ 151, „ 7, *for* gouta *read* gonta.
„ 157, „ 7, *read* , properly *not* properly,
„ 159, „ 12, *for* vahai *read* avahi.

Also, in the Comparative Vocabulary, in line 41 throughout, wherever *kw* occurs substitute *c*; in line 42 throughout, read *g* for *c*; in line 43 throughout, read *c* for *g*.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW SOUTH WALES.

WEDNESDAY, MAY 3, 1893.

ANNUAL GENERAL MEETING.

Prof. WARREN, M. Inst. C.E., Wh. Sc., President, in the Chair.

Sixty members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ending 31st March, 1893, was presented by the Hon. Treasurer, and adopted:—

GENERAL ACCOUNT.

Receipts.	£	s.	d.	£	s.	d.
Subscriptions — One Guinea	182	14	0			
Subscriptions — Two Guineas	443	2	0			
Subscriptions — Arrears	24	3	0			
Subscriptions — Advances	2	2	0	652	1	0
Entrance Fees				58	16	0
Parliamentary Grant on Subscriptions received during 1892				500	0	0
Rent of Hall				32	0	6
Sundries				13	11	10
Total Receipts				1256	9	4
Balance on 1st April, 1892				38	11	7
				£1295	0	11

Payments.	£	s.	d.	£	s.	d.
Advertisements	30	15	0			
Assistant Secretary	250	0	0			
Books and Periodicals	128	17	1			
Bookbinding	73	18	1			
Freight, Charges, Packing, &c....	9	13	7			
Furniture and Effects	68	5	6			
Gas	29	6	6			
Housekeeper	10	0	0			
Insurance	9	10	0			
Office Boy	25	9	2			
Petty Cash Expenses	14	1	0			
Postage and Duty Stamps	55	4	0			
Printing	39	11	0			
Carried forward	£744	10	11			

Payments—*continued.*	£ s. d.	£ s. d.
Brought forward	744 10 11	
Printing and Publishing Journal	292 19 7	
Prize Essay Award	25 0 0	
Rates	25 6 3	
Refreshments and attendance at Meetings ...	19 8 0	
Repairs	9 19 0	
Stationery	11 18 8	
Sundries	21 9 6	
Total Payments		1150 11 11
Transfer to Building and Investment Fund...		84 16 0
Balance on 31st March, 1893		59 13 0
		£1295 0 11

BUILDING AND INVESTMENT FUND.

Receipts.	£ s. d.
Transfer from General Account	84 16 0
Interest on Fixed Deposit	38 10 0
Amount of Fund on 1st April, 1892	769 10 1
	£892 16 1

	£ s. d.
Fixed Deposit in Union Bank	892 16 1
	£892 16 1

CLARKE MEMORIAL FUND.

Receipts.	£ s. d.
Interest on Fixed Deposit	15 15 0
Amount of Fund on 1st April, 1892	315 1 8
	£330 16 8

	£ s. d.
Fixed Deposit in Union Bank	330 16 8
	£330 16 8

ABERCROMBY FUND.

Receipts.	£ s. d.
Amount received from the Hon. Ralph Abercromby to be offered as Prizes for Competitive Essays on various phases of Australian weather	100 0 0

	£ s. d.
Fixed Deposit in Union Bank	100 0 0

Audited, P. N. TREBECK. A. LEIBIUS, *Honorary Treasurer.*
S. MACDONNELL. W. H. WEBB, *Assistant Secretary.*
Sydney, 12th April, 1893.

Messrs. P. N. Trebeck and J. T. Wilshire were appointed Scrutineers for the election of officers and members of Council.

A ballot was then taken, and the following gentlemen were duly elected officers and members of Council for the current year :—

Honorary President:

HIS EXCELLENCY SIR R. W. DUFF, P.C., G.C.M.G.

President:

PROF. T. P. ANDERSON STUART, M.D.

Vice-Presidents:

C. W. DARLEY, M. INST. C.E.	H. C. RUSSELL, B.A., C.M.G., F.R.S.
PROF. LIVERSIDGE, M.A., F.R.S.	PROF. WARREN, M. INST. C.E., WH. SC.

Hon. Treasurer:

A. LEIBIUS, PH. D., M.A., F.C.S.

Hon. Secretaries:

Prof. T. W. E. DAVID, B.A., F.G.S.	J. H. MAIDEN, F.L.S., F.C.S.

Members of Council:

H. DEANE, M.A., M. INST. C.E.	J. A. McDONALD, M. INST. C.E.
JAMES GRAHAM, M.A., M.D.	CHARLES MOORE, F.L.S., F.Z.S.
W. M. HAMLET, F.C.S., F.I.C.	E. F. PITTMAN, ASSOC. R.S.M., F.G.S.
LAWRENCE HARGRAVE.	PROF. THRELFALL, M.A.
F. B. KYNGDON.	H. G. A. WRIGHT, M.R.C.S.E., &c.

The following gentlemen were duly elected ordinary members of the Society :

Henderson, John, Civil Engineer ; North Sydney.

McKay, William J. Stewart, B.Sc. M.B., Ch.M.; Sydney.

Nangle, James, Architect ; Newtown.

Orr, Alexander, Analytical Chemist ; Sydney.

Owen, Percy Thomas, Lieut., Assistant Engineer, Military Works ; Sydney.

Smith, Charles Walter, Civil Engineer ; Sydney.

Smith, Henry George, Laboratory Assistant, Technological Museum ; Sydney.

The certificates of two new candidates were read for the second time, and of ten for the first time.

The names of the Committee-men of the different Sections were announced :—

Section H.—Medical.

Chairman—Hon. Dr. H. N. MacLaurin, M.L.C., M.A.

Secretaries—Dr. G. E. Rennie and Dr. Huxtable.

Committee—Dr. Fiaschi, Prof. Anderson-Stuart, M.D., Dr. W. Chisholm, Dr. James Graham, Dr. P. Sydney Jones.

Three Meetings will be held, viz.—June 16th, August 18th and October 20th 1893, at 8·15 p.m.

Section K.—Engineering.

Chairman—H. Deane, M.A., M. Inst. C.E.

Secretary—J. A. McDonald, M. Inst. C.E.

Treasurer—D. M. Maitland.

Committee—Cecil W. Darley, M. Inst. C.E., Professor Warren, M. Inst. C.E., J. W. Grimshaw, M. Inst. C.E., W. F. How, Assoc. M. Inst. C.E., J. M. Smail, M. Inst. C.E.

Meetings held on the Third Wednesday in each month, at 8 p.m.

Fifty volumes, four hundred and thirty-three parts, one hundred and twenty-eight pamphlets, twenty-four reports, three atlases of maps, three hydrographic charts and one photograph received as donations since the last meeting, were laid upon the table and acknowledged.

The following letter was read from Prof. Ralph Tate, F.G.S., Adelaide University, acknowledging the award of the Clarke Medal for 1893 :—

The University, Adelaide,
January 10, 1893.

Gentlemen,—It is with unqualified pleasure that I acknowledge the very high honour which you have conferred upon me by the award of the Clarke Memorial Medal.

I care not to disguise the fact that I have been ambitious to win this prize, but I had hardly hoped to have been thought worthy of it at so early date, as on reviewing my Australian work I recognize only an aggregate of small and diverse efforts, but as you are aware, the role of the scientific pioneer, or that of a promoter of scientific investigation in an almost unexplored country, is not conducive to a concentration of purpose likely to evolve an *opus magnum*. Therefore, I will not regard your estimable favour in the light of a retiring allowance but as an incentive to continue those investigations, to which you have alluded, to some measure of completeness as far as time and opportunity will allow.

Yours faithfully,
RALPH TATE.

To the President and Members of Council of the Royal Society of N.S.W.

Also one from William Huggins, D.C.L., LL.D., F.R.S., F.R.A.S., &c., London :—

90 Upper Tulse Hill, London, S.W.,
17 December, 1892.

My Dear Sir,—It is indeed a very high gratification to me to receive the unexpected news of the very high honour which the Royal Society of New South Wales has conferred upon me.

So welcome and distinguished a recognition of what little I have been able to do for science, from your Society which represents the highest intellect and science of the Colony, is indeed a tribute which I am proud to receive. Next to the delight of any new conquest however small, in the realms of Nature, the most acute pleasure which a worker in science can receive comes from the recognition and approval of his fellow workers.

May I ask you to convey to the Society my best thanks and the expression of my very high appreciation of the honour conferred upon me. With many thanks to yourself for the kind words in which you have conveyed the news of the honour done me.

I remain yours very truly,
WILLIAM HUGGINS.

To the Honorary Secretary of the Royal Society of New South Wales.

Prof. Warren, M. Inst. C.E., Wh. Sc., then read his address.

A vote of thanks was passed to the retiring President, and Prof. T. P. Anderson Stuart, M.D., was installed as President for the ensuing year.

Prof. Stuart thanked the members for the honour conferred upon him, and hoped to prove himself worthy of their confidence.

Mr. Russell proposed a vote of thanks to Mr. F. B. Kyngdon for his valuable services as Honorary Secretary for so long, and who had been compelled to resign office on account of his removal from Sydney; the vote was carried unanimously.

WEDNESDAY, JUNE 7, 1893.

Prof. T. P. Anderson Stuart, M.D., President in the Chair.

Thirty-seven members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two new candidates were read for the third time, of ten for the second time, and of one for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Noyes, Edward, Civil Engineer ; Sydney.

Roberts, W, S. De Lisle, Civil Engineer ; Sydney.

Thirty-five volumes, one hundred and eighty-nine parts, four pamphlets, nine reports, and fourteen meteorological charts received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Flying-machine Motors and Cellular Kites," by Lawrence Hargrave. Some remarks were made by the President.

2. "Notes and analysis of a Metallic Meteorite from Moonbi, near Tamworth, New South Wales," by John C. H. Mingaye, F.C.S., M.A.I.M.E.

Remarks were made by Prof. T. W. E. David, Rev. J. Milne Curran, and the Author.

3. "Plants with their habitats, discovered to be indigenous to this Colony since the publication of the Handbook of the Flora of New South Wales; chiefly furnished by Baron von Mueller, from unpublished Herbarium Notes," by Charles Moore, F.L.S., &c.

4. "Description of a new Myrtaceous tree indigenous to New South Wales *Eugenia parvifolia*," by Charles Moore, F.L.S.

5. "On the Whip-worm of the Rat's Liver," by Thomas L. Bancroft, M.B. *Edin.*, (Communicated by J. H. Maiden, F.L.S., &c.) Some remarks were made by the President.

6. " Small Whirlwinds," by Hugh Charles Kiddle.

A discussion ensued in which the following gentlemen took part, viz., Mr. H. C. Russell, Rev. S. Wilkinson, Messrs. W. F. Bell, C. W. Darley, W. S. Campbell, C. A. Benbow, Prof. T. W. E. David, L. Hargrave, and P. N. Trebeck.

Exhibits :

Mr. H. C. Russell, C.M.G., F.R.S., exhibited several beautiful photographs of star clusters and the Milky Way, taken with the large star camera at the Observatory. The largest cluster—one of the finest in the heavens—had been photographed with the double object of showing its beauty and seeing if there were any nebula connected with the stars. Long exposure of six and eight hours were given without sign of any nebula; but where Herschel estimated 200, there were considerably more than 2,000. Several of the other photographs exhibited were taken with the object of still further exploring the depths of the Milky Way, and the result was surprising. The earlier photographs taken at Sydney with a smaller instrument were very perfect; in fact, the best of the kind that had been published. As a means of showing the difference between these earlier and later photographs, it might be stated that in one space where one of the earlier photographs showed forty-three stars, the later one taken in May last, showed 1,166, or twenty-seven times as many, and the scale was so large that each star stood separate from its neighbours. The smaller scale had two serious drawbacks—first, the stars were so crowded together that it was impossible to see separate stars that it was now known ought to have been visible; and, secondly, the crowding of the stars helped to mislead the eye by presenting apparent lines, curves, and forms which were not found when the stars were conveniently separated and clearly shown, as in the later photographs.

Mr. L. Hargrave showed a new 2·8lb. steam screw motor, of about one-quarter horse power.

WEDNESDAY, JULY 5, 1893.

Prof. T. P. Anderson Stuart, M.D., President, in the Chair.

Twenty-seven members and six visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of ten new candidates were read for the third time, of one for the second time, and of six for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Allman, Edward McCarthy, Civil Engineer ; Mudgee.
Beal, Latham Osborn ; New Zealand.
Blomfield, Charles E., B.C.E. *Mel.* ; Sydney.
Bowman, John, Civil Engineer ; Homebush.
Brownless, Anthony Colling, M.B. et Ch. B. *Mel.* ; Sydney.
Cameron, John MacDonald, F.G.S., F.C.S., F.I.C., Deputy Master Royal Mint ; Sydney.
Hope, Joseph, Civil Engineer ; North Sydney.
Purser, Cecil, M.B., Ch. M. *Syd.;* Sydney.
Rygate, Philip W., M.A., et B.E. *Syd.;* Sydney.
Townsend, George W., Civil Engineer ; Sydney.

Six volumes, seventy-seven parts, nine reports, sixteen pamphlets and six charts, received as donations since the last meeting were laid upon the table and acknowledged.

The following letter from Baron von Mueller was read :—

24 June, 1893.

It is my mournful duty, dear Prof. Liversidge, to convey my profound condolence to the Royal Society of New South Wales at the death of its distinguished member and Past-President, Dr. Leibius. This *triste* intelligence comes to me with sudden sadness, in as much as I was not even aware of any serious ailing of his. Much will he be missed by us, for he was not only a sterling man of knowledge, but also a genial sympathetic friend, as I experienced myself, and all the more as I had so little claim on his generosity.

If his friends unite to erect a monument at his grave, I will readily contribute.

With regardful remembrance, yours,
FERD. VON MUELLER.

The President referred to the great loss the Society had sustained by the death of Dr. Leibius, who had served it so long and so faithfully in the various offices of Honorary Secretary, President, Honorary Treasurer and Member of Council, and stated that a letter of sympathy had been forwarded by the Council to Mrs. Leibius and family in their bereavement.

The following papers were read :—

1. "On the Languages of the New Hebrides," by Mr. SIDNEY H. RAY.

2. "Unrecorded genera of the Older Tertiary Fauna of Australia, including diagnoses of some new genera and species," by Prof. Ralph Tate, F.G.S., F.L.S., Hon. Memb.
3. "On an approximate method of finding the forces acting in Magnetic Circuits," by Prof. Richard Threlfall, M.A., assisted by Florence Martin, Student in the University of Sydney. Some remarks were made by Mr. H. C. Russell.

Exhibit :

Mr. L. O. Beal exhibited and described some specimens of granite with markings attributed to glacial action.

WEDNESDAY, AUGUST 2, 1893.

Prof. T. P. Anderson Stuart, M.D., President, in the Chair.

Thirty-eight members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of one new candidate was read for the third time, of six for the second time, and of one for the first time.

The following gentleman was duly elected an ordinary member of the Society :—

Spencer, Thomas Wm. Loraine, Resident Engineer, Roads and Bridges ; Muswellbrook.

Thirty-six volumes, one hundred and thirty-seven parts, eight reports, ten pamphlets, five meteorological charts and one photograph received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Notes on the Bingera Diamond Field," by the Rev. J. Milne Curran, F.G.S. Some remarks were made by Prof. Liversidge.
2. "Preliminary Note on the occurrence of a chromite-bearing rock from the Pennant Hills Quarry near Parramatta," by Prof. T. W. E. David, B.A., F.G.S., W. F. Smeeth, M.A., B.E., Assoc. R.S.M., and J. A. Watt, M.A.
3. "Note on the occurrence of Barytes at the Five Dock Sandstone Quarry," by Prof. T. W. E. David, B.A., F.G.S.

4. "Note on the occurrence of Calcareous Sandstone allied to Fontainebleau Sandstone from Rock Lily near Pittwater," by Prof. T. W. E. David, B.A., F.G.S.

Exhibits:

Photographs and specimens of diamonds by Rev. J. Milne Curran, F.G.S.; the Moonbi Meteorite by J. C. H. Mingaye, F.C.S. and specimens, microscopic sections and micro-photographs relating to the papers read by Prof. David.

WEDNESDAY, SEPTEMBER 6, 1893.

H. C. Russell, B.A., C.M.G., F.R.S., Vice-President, in the Chair.

Twenty-nine members and six visitors were present.

The Chairman said that before the business of the evening was gone on with he wished to announce a fact in which those present would, no doubt, be greatly interested. That this was the two hundredth meeting of the Society, which he hoped would go on for a good many more hundreds.

The minutes of the preceding meeting were read and confirmed.

The certificates of six new candidates were read for the third time, of one for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Clark, Charles Dagnall, M.B. *Lond.;* Sydney.
Cobbett, Pitt, Professor of Law; Sydney University.
Cohen, Algernon A., M.B., M.D. *Aberd.*, M.R.C.S. *Eng.;* Sydney.
Martin, Charles James, B.Sc., M.B. *Lond.*, M.R.C.S. *Eng.*, Demonstrator of Physiology; Sydney University.
Millard, Reginald Jeffery, M.B., Ch.M. *Syd.;* Parramatta.
Money, Angel, M.D., F.R.C.P. *Lond.;* Sydney.

Fifty-five volumes, ninety-four parts, ten reports, nine pamphlets and two photographs received as donations since the last meeting were laid upon the table and acknowledged.

The Chairman announced that a bust of the late Professor Hoffman of Berlin, had been presented to the Society by Mrs. Leibius.

The following papers were read :—

1. (*a*) "On the origin of Moss Gold"; (*b*) "On the condition of Gold in Quartz and Calcite Veins"; (*c*) "On the origin of Gold Nuggets"; (*d*) "On the Crystallization of Gold in Hexagonal Forms"; (*e*) "Gold Moiré-métallique," by Prof. LIVERSIDGE, M.A., F.R.S., &c. Remarks were made by Mr. P. N. Trebeck and the Chairman.

2. "Results of observations of Comet VI. (Brooks) 1892 at Windsor, New South Wales," by JOHN TEBBUTT, F.R.A.S. &c.

3. "The treatment of Manufactured Iron and Steel for constructional purposes" by WILLIAM FIELD HOW, Assoc. M. Inst. C.E., M. I. Mech. E., Wh. Sc.

Some remarks were made by Prof. Warren, and the Chairman stated that this paper would be further discussed by the Engineering Section on Sept. 20, 1893.

EXHIBITS.

Prof. LIVERSIDGE exhibited a combination laboratory lamp, retort, and filter stand, provided with bunsen, argand, fishtail and blowpipe jets, all with ground joints, screws being liable to corrode. Besides this he showed an example of the purple-coloured alloy of gold, 78%, and aluminium 22%, as recently described by Prof. Roberts-Austen; also, a specimen of the purple alloy of copper and antimony.

The Rev. J. MILNE CURRAN showed "nature prints" of the Widmanstatten figures on a slice of the Moonbi meteorite. The plates were printed direct from the iron meteorite itself.

WEDNESDAY, OCTOBER 4, 1893.

Prof. T. P. ANDERSON STUART, M.D., President, in the Chair.

Forty-seven members and three visitors were present.

The certificate of one new candidate was read for the third time, of two for the second time, and of two for the first time.

The following gentleman was duly elected an ordinary member of the Society :—

Smeeth, William Frederick, M.A., B.E., F.G.S., A.R.S.M., Demonstrator in Geology; Sydney University.

Eighteen volumes, one hundred and twenty-nine parts, two pamphlets, five reports, and one geological map, received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Rock paintings by the Aborigines in caves on Bulgar Creek near Singleton" by R. H. Mathews, L.S.

   A discussion ensued in which the following gentlemen took part, viz., Messrs. D. M. Maitland, Prof. David, Judge Docker, C. Moore, J. Trevor Jones, B. H. Purcell, G. R. Cowdery, W. M. Hamlet, W. D. Campbell, and the President.

2. "Notes on Artesian Water in Australia," by Prof. T. W. E. David, B.A., F.G.S.; illustrated by lantern views.

   Some remarks were made by the President, Messrs. F. B. Gipps and P. N. Trebeck, when it was resolved that the discussion be postponed to the next meeting.

Exhibits :—

By E. F. Pittman, A.R.S.M., Government Geologist, Carborundum, a newly discovered abrasive, stated to have the hardness of the diamond, and a collection of agates cut and polished, from New South Wales.

By Professor David, petrological specimens from the Ipswich Coal Measures, Queensland.

WEDNESDAY, NOVEMBER, 1, 1893.

Prof. T. P. Anderson Stuart, M.D., President, in the Chair.

Forty-seven members and six visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two new candidates were read for the third time, of two for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Taylor, James, B. Sc., A.R.S.M., Government Metallurgist; Sydney.

Wright, John, Civil Engineer; Sydney.

Forty-eight volumes, seventy-seven parts, twenty-one reports and six pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "Notes on Artesian bores at Bunda Bunda Station in Queensland," by the Hon. W. H. Suttor, M.L.C.
2. "On the probability of extraordinarily high spring tides about the December solstice of 1893," by John Tebbutt, F.R.A.S., &c.
3. "On Meteorite No. 2 from Gilgoin Station," by H. C. Russell, B.A., C.M.G., F.R.S.
4. "Pictorial Rain Maps," by H. C. Russell, B.A., C.M.G., F.R.S.
5. "Note on the occurrence of a new Mineral at Broken Hill," by Edward F. Pittman, A.R.S.M., Government Geologist.

Prof. T. W. E. David, B.A., F.G.S., in opening the discussion upon the paper read by him at the previous meeting on "Artesian Water in Australia," exhibited and described a model designed to account for the various levels of Artesian flows. The following gentlemen took part in the discussion :—Messrs. F. B. Gipps, G. H. Knibbs, H. C. Russell, J. W. Grimshaw, James Wilson, H. G. McKinney, W. M. Hamlet, W. A. Dixon, Prof. Liversidge, Lewis Whitfeld, the President, and Prof. David.

Mr. E. F. Pittman exhibited and described some specimens and photographs of some of the rarer minerals occurring in the Australian Broken Hill Consols Mine.

Prof. Liversidge exhibited a collection of Tasmanian Minerals.

WEDNESDAY, DECEMBER 6, 1893.

Prof. T. P. Anderson Stuart, M.D., President, in the Chair.

Fifty-one members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two new candidates were read for the third time, of two for the second time, and of four for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Bowman, Reginald, M.B., et Ch. M. *Edin.*, M.R.C.S. *Eng.*; Parramatta.

Sinclair, Russell, M.I.M.E., &c., Consulting Engineer; Sydney.

It was resolved that Messrs. P. N. Trebeck and W. C. W. Bartels be appointed Auditors for the current year.

Fifteen volumes, ninety-three parts, seven reports and twenty pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read:—

1. "On the occurrence of Triassic plant remains in a shale bed near Manly," by B. DUNSTAN, F.G.S. Some remarks were made by Prof. David. B.A., F.G.S.
2. "The orbit of the double star h 5014," by R. P. SELLORS, B.A.
3. "Occurrence of Evansite in Tasmania," by HENRY G. SMITH.
4. "On the separation of gold, silver, and iodine from sea-water by Muntz metal sheathing," by Prof. LIVERSIDGE, M.A., F.R.S. Some remarks were made by Mr. W. A. Dixon.
5. "Notes on the Cremorne Bore," by Prof. T. W. E. DAVID, B.A., F.G.S., and E. F. PITTMAN, A.R.S.M., F.G.S. Remarks were made by Messrs. J. T. Wilshire, — Roberts, E. F. Pittman and H. C. Russell.
6. "The Progress and position of Irrigation in New South Wales," by H. G. McKinney, M.E., M. Inst. C.E.
7. "On Artesian Water in connection with Irrigation," by W. A. DIXON, F.I.C., F.C.S. [Taken as read.]

EXHIBITS :

Mr. J. W. BOULTBEE, Officer-in-Charge of the Water Conservation Branch, Department of Mines, New South Wales, exhibited samples of produce grown at the Barringun and Native Dog Artesian Bore farms, also a number of photographs of Artesian Bores in different parts of the Colony.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

ENGINEERING SECTION.

At the preliminary meeting held on April 12th, the following officers were elected for the 1893 Session :—Chairman : Mr. H. DEANE, M. Inst. C.E. Hon. Secretary : Mr. J. A. McDONALD, M. Inst. C.E. Hon. Treasurer : D. M. MAITLAND, L.S. Committee: Mr. C. W. DARLEY, M. Inst. C.E., Mr. J. W. GRIMSHAW, M. Inst. C.E., Mr. W. F. HOW, Assoc. M. Inst. C.E., Mr. J. M. SMAIL, M. Inst. C.E., Professor WARREN, M. Inst. C.E.

It was resolved that the subscription to the Printing Fund be raised to £1 1s.

Monthly meeting held May 17, 1893.

Mr. H. DEANE, in the Chair.

Twenty-five members present.

The evening was devoted to a discussion in connection with the printing of Mr. BURGE's paper on "Light Railways," and the discussion on Mr. HOUGHTON's paper on the "Economical Use of Steam," which was opened by Professor Warren, and continued by Messrs. Grimshaw and Haycroft, and further adjourned until next meeting.

Monthly meeting held June 21st, 1893.

Mr. DEANE, in the Chair.

Twenty-five members present.

The Chairman alluded to the death of Dr. Leibius and mentioned the great services he had rendered to the Society, as Honorary Secretary, President, and Hon. Treasurer; and also announced the retirement of Mr. McDonald from the position of Honorary Secretary, and that the Committee had nominated Mr. Grimshaw for that position. The nomination was approved and Mr. Grimshaw elected.

The adjourned discussion on Mr. HOUGHTON'S paper on the "Economical Use of Steam," was resumed by Messrs. How and Grimshaw, and Professors Threlfall and Warren, and replied to by Mr. Houghton.

The adjourned discussion on Mr. BURGE'S paper on "Light Railways for New South Wales," was opened by the Author and continued by Mr. Parkinson, and then adjourned to the next meeting.

Monthly meeting held July 19th, 1893.

Professor WARREN, in the Chair.

Twenty-six members present.

The Chairman stated that the Committee had nominated Mr. Houghton, to fill the vacancy caused by the retirement of Mr. McDonald; the nomination was approved and Mr. Houghton appointed.

The adjourned discussion of Mr. BURGE'S paper on "Light Railways for New South Wales," was resumed by Messrs. Cowdery, Vandevelde, How and Thow, Col. Wells, Messrs. Noyes, Grimshaw and Professor Warren, and adjourned to next meeting.

Mr. How exhibited photographs of the types of engines he referred to, and Mr. VANDEVELDE exhibited photographs of the "Dechanville" system of light railways.

Monthly meeting held August 16th, 1893.

Mr. DEANE in the Chair.

Twenty-eight members present.

The discussion on Mr. BURGE'S paper on "Light Railways for New South Wales," was resumed by communications from Mr. Renwick, Engineer-in-Chief of Railways, Victoria, and Mr. Trevor Jones being read, and continued by Messrs. Allen, Fischer, Poole, Middleton, Firth, Thow, Vandevelde, and the Chairman, and replied to by Mr. Burge.

Monthly meeting held September 20th, 1893.

Mr. DEANE in the Chair.

Twenty-one members and visitors present.

The discussion on Mr. HOW'S paper on "The Treatment of Manufactured Iron and Steel for Constructional Purposes," was continued by Messrs. Thow, Houghton, Grimshaw, H. Hunt, Mansfield, Farr, Cowdery, Noyes, Col. Wells and the Chairman. Mr. How then replied.

Monthly meeting held October 18th, 1893.

Mr. DARLEY in the Chair.

Nine members present.

A paper by Mr. HAYCROFT, on "Highway Construction and matters pertinent thereto," was read and the discussion adjourned.

Monthly meeting held November 15th, 1893.

Mr. DEANE in the Chair.

Sixteen members present.

The discussion of Mr. HAYCROFT'S paper on "Highway Construction and matters pertinent thereto," was opened by Col. Wells, and continued by Messrs. Statham, Smail, Trevor Jones, W. S. Wells, Cowdery, Grimshaw, and the Chairman, and was adjourned to next meeting to give Mr. Haycroft an opportunity of replying.

Mr. Trevor Jones then explained the nature of his paper "A Hydrostatic Paradox," and the diagrams; further discussion was adjourned to next meeting.

Monthly meeting held December 20th, 1893.

Mr. Deane in the Chair.

Thirteen members present.

Mr. Haycroft replied to the discussion of his paper on "Highway Construction and matters pertinent thereto."

Mr. Selman read his paper on "Oil Engines," and the discussion was opened by Mr. C. W. Darley. Messrs. Houghton, How, Grimshaw, and J. A. Griffith, took part. As the paper required carefully reading through before it could be fully discussed it was decided to adjourn it to the next meeting, but before doing so Mr. Selman replied to the remarks made.

It was resolved that Mr. Trevor Jones' paper "A Hydrostatic Paradox" be postponed to the next meeting.

During the Session thirty-one (31) members have subscribed £32 9s. to the Printing Fund, and the disbursements for printing amounts to £23 16s., a further expenditure of £1 7s. 4d. for type writing having also been incurred.

MEDICAL SECTION.

At the provisional meeting held on April 21st 1893, the following officers were elected:—Chairman: Hon. Dr. MacLaurin, LL.D., M.L.C. Committee: Drs. Fiaschi, Anderson Stuart, Chisholm, Sydney Jones, J. Graham. Secretaries: Drs. L. R. Huxtable and G. E. Rennie.

It was announced that the New South Wales Branch of the British Medical Association intended to approach the Council of the Royal Society in the hope of obtaining certain concessions, with a view to the establishment of a Medical Library; a Committee consisting of Dr. Sydney Jones, Prof. Anderson Stuart, and Dr. HUXTABLE was appointed to draw up a report upon the matter.

It was decided that in lieu of the monthly meetings of the Section only three meetings be held during the year at suitable intervals.

First meeting, June 23, 1893, at 8·15.

Hon. Dr. MACLAURIN in the Chair.

This was the largest meeting of the Section ever held.

Dr. SYDNEY JONES exhibited a patient suffering from myxoedema.

Dr. JAMES GRAHAM read a paper on "Peripheral Neuritis" as it occurs more specially as an endemic disease amongst the Chinamen of Sydney.

Prof. J. T. WILSON read a paper on "Recent Investigations on the Structure and Development of the Nervous System." The paper was illustrated by numerous diagrams and microscopical specimens. The discussion on the papers was adjourned until July 21st.

The recent additions to the University Museum of Anatomy and Pathology were on view during the evening.

Adjourned meeting, July 21, 1893. at 8·15.

Hon. Dr. MACLAURIN in the Chair.

At this meeting, Prof. J. T. WILSON completed his remarks on "Recent Investigations on Structure and Relation of Nerve Fibres, etc."

At the discussion which followed, Drs. SHEWEN, SYDNEY JONES, ANGEL MONEY, STEEL, WILKINSON, C. J. MARTIN, and the Chairman took part.

Second meeting, October 18, 1893, at 8·15.

Dr. FIASCHI ex-Chairman, in the Chair.

Dr. C. J. MARTIN, B.Sc., read a paper on "Recent Development of the question of the Coagulation of the Blood," illustrated by some experiments on animals.

Dr. MARTIN was accorded a very hearty vote of thanks for his interesting paper and for the trouble he had taken in preparing the experiments.

Third meeting October 20, 1893, at 8·15.

Hon. Dr. MACLAURIN in the Chair.

Drs. CRAGO and MORGAN MARTIN exhibited a female patient suffering from myxoedema.

Dr. F. N. MANNING and Dr. BLAXLAND also exhibited a female case of myxoedema.

Dr. C. J. MARTIN, B.Sc., showed a case of sporadic cretinism, in which, he in conjunction with Dr. RENNIE had performed thyroid grafting with marked beneficial results. Dr. MARTIN also read notes of the case, and exhibited photographs and temperature charts.

Dr. G. E. RENNIE read a paper on Myxoedema.

Dr. F. N. MANNING made some very interesting and suggestive remarks on sporadic cretinism.

The Chairman made a few remarks, and this closed the meetings for the year.

As on a previous occasion the recent additions to the University Museum of Anatomy and Pathology were on view during the evening.

ADDITIONS
TO THE
LIBRARY OF THE ROYAL SOCIETY OF NEW SOUTH WALES.

DONATIONS—1893.

(The Names of the Donors are in *Italics.)*

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EXCHANGES AND PRESENTATIONS

MADE BY THE

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* Exchanges of Publications have been received from the Societies and Institutions distinguished by an asterisk.

Argentine Republic.

1 Cordoba ... ...*Academia Nacionale de Ciencias.
2 La Plata ... ...*Directeur-Général de Statistique de la Province de Buénos Ayres.
3 „ ... ...*Museo de La Plata. Provincia de Buenos Aires.

Austria—Hungary.

4 Agram (Zagrab) ...*Société Archéologique Croate.
5 Bistritz (in Siebenbürgen) *Direction der Gewerbeschule.
6 Cracow ... ...*Académie des Sciences.
7 Gratz ... ...*Naturwissenschaftliche Vereins für Steiermark in Graz.
8 Prague ... ...*Königlich Böhmische Gesellschaft der Wissenschaften.
9 Trencsin ... ...*Naturwissenschaftliche Verein des Trencsiner Komitates.
10 Trieste ... ...*Museo Civico di Storia Naturale.
11 „ ... ...*Società Adriatica di Scienze Naturali.
12 Vienna ... ...*Anthropologische Gesellschaft.
13 „ ... ...*Kaiserliche Akademie der Wissenschaften.
14 „ ... ...*K. K. Central-Anstalt für Meteorologie und Erdmagnetismus.
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17 „ ... ...*K. K. Gradmessungs Bureau.
18 „ ... ...*K. K. Naturhistorische Hofmuseum.
19 „ ... ...*K. K. Zoologisch-Botanische Gesellschaft.
20 „ ... ...*Section für Naturkunde des Osterreichischen-Touristen Club.

Belgium.

21 Brussels ... ...*Académie Royale des Sciences, des Lettres et des Beaux Arts.

22 Brussels ... ...*Musée Royal d'Histoire Naturelle de Belgique.
23 " ... ...*Observatoire Royal de Bruxelles.
24 " ... ...*Société Royale Malacologique de Belgique.
25 Liege ... ...*Société Géologique de Belgique.
26 " ... ...*Société Royale des Sciences de Liège.
27 Luxembourg ...*Institut Royale grand-ducal de Luxembourg.
28 Mons ... ...*Société des Sciences, des Arts et des Lettres du Hainaut.

Brazil.

29 Rio de Janeiro ...*Observatoire Impérial de Rio de Janeiro.

Chili.

30 Santiago ... ...*Sociedad Cientifica Alemana.

Denmark.

31 Copenhagen ...*Société Royale des Antiquaires du Nord.

France.

32 Bordeaux ... ...*Académie Nationale des Sciences, Belles-Lettres et Arts.
33 Caen ... ...*Académie Nationale des Saiences, Arts et Belles-Lettres.
34 Dijon ... ...*Académie des Sciences, Arts et Belles-Lettres.
35 Havre ... ...*Société Géologique de Normandie.
36 Lille ... ...*Société Géologique du Nord.
37 Marseilles ...*Faculté des Sciences de Marseille.
38 Montpellier ...*Académie des Sciences et Lettres.
39 Nantes ... ...*Société des Sciences Naturelles de l'Ouest de la France.
40 Paris ... ...*Académie des Sciences de l'Institut de France.
41 " ... ... *Annuaire Geologique Universel.*
42 " ... ... Bibliothèque de l'Université à la Sorbonne.
43 " ... ...*Depot des Cartes et Plans de la Marine.
44 " ... ...*Ecole d' Anthropologie.
45 " ... ...*Ecole Nationale des Mines.
46 " ... ... Ecole Normale Supérieure.
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48 " ... ... Faculté de Médecine de Paris.
49 " ... ...**Feuille des Jeunes Naturalistes.*
50 " ... ...*Institut Pasteur.
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63 PARIS ... ...*Société de Géographie.
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66 " ... ... Société Philotechnique.
67 " ... ...*Société Zoologique de France.
68 ST. ETIENNE ...*Société de l' Industrie Minérale.
69 TOULOUSE ...*Académie des Sciences, Inscriptions et Belles-Lettres.
70 VILLEFRANCHE-SUR-MER (Alp. Mar.) ... Laboratoire de Zoologie.

Germany.

71 BREMEN ... ...*Naturwissenschaftliche Vereine zu Bremen.
72 BERLIN ... ... Deutsche Chemische Gesellschaft.
73 " ... ...*Gesellschaft für Erdkunde.
74 " ... ...*Königlich Preussische Akademie der Wissenschaften.
75 " ... ...*Königlich Preussische Meteorologische Instituts.
76 BONN ... ...*Naturhistorischer Vereines der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück.
77 BRUNSWICK ...*Vereins für Naturwissenschaft zu Braunschweig.
78 CARLSRUHE ...*Grossherzoglich-Badische Polytechnische Schule.
79 " ...*Naturwissenschaftlicher Verein zu Carlsruhe.
80 CASSELL ... ...*Verein für Naturkunde.
81 CHEMNITZ ...*Naturwissenschaftliche Gesellschaft zu Chemnitz.
82 DRESDEN ... ...*Königliches Mineralogisch und Naturhistorisches Museum.
83 " ... ...*Offentliche Bibliothek.
84 " ... ...*Statistische Bureau des Ministeriums des Innern zu Dresden.
85 " ... ...*Vereins für Erdkunde zu Dresden.
86 ELBERFELD ...*Naturwissenschcftlicher Verein in Elberfeld.
87 FRANKFURT A/M...*Senckenbergische Naturforschende Gesellschaft.
88 FREIBERG (Saxony) Königlich-Sächsische Berg-Akademie.
89 FREIBURG (Baden)*Naturforschende Gesellschaft.
90 GIESSEN ... ...*Oberhessische Gesellschaft für Natur-und-Heilkunde.
91 GÖRLITZ ... ...*Naturforschende Gesellschaft in Görlitz.
92 GÖTTINGEN ...*Königliche Gesellschaft der Wissenschaften in Göttingen.
93 HALLE, A.S. ...*Kaiserliche Leopoldina—Carolina Akademie der Deutschen Naturforscher.
94 HAMBURG... ...*Deutsche Meteorologische Gesellschaft.
95 " ... ...*Deutsche Seewarte.
96 " ... ...*Geographische Gesellschaft in Hamburg.
97 " ... ...*Naturhistorische Museum.
98 " ... ...*Verein für Naturwissenschaftliche Unterhaltung in Hamburg.
99 HEIDELBERG ...*Naturhistorisch Medicinische Verein zu Heidelberg.
100 JENA ... ...*Medicinisch NaturwissenschaftlicheGesellschaft.
101 KÖNIGSBERG ...*Königliche Physikalisch-Okonomische Gesellschaft.

102 Leipzig (Saxony) *Königliche Sächsische Gesellschaft der Wissenschaften.
103 „ ... ...*Vereins für Erdkunde.
104 Lubeck ... ...*Naturhistorische Museum.
105 Marburg... ...*Gesellschaft zur Beförderung der gesammten Naturwissenschaften in Marburg.
106 „ ... ...*University.
107 Metz ... ...*Vereins für Erdkunde zu Metz.
108 Mulhouse ...*Société Industrielle de Mulhouse.
109 Munich ... ...*Königlich Bayerische Akademie der Wissenschaften in München.
110 „ ... ... Société Botanique Bavaroise.
111 Stuttgart ...*Königliches Statistische Landesamt.
112 „ ... ...*Verein für Vaterländische Naturkunde in Württemberg.
113 „ ... ...*Württembergische Vereins für Handelsgeographie.

Great Britain and the Colonies.

114 Birmingham ...*Birmingham and Midland Institute.
115 „ ...*Birmingham Philosophical Society.
116 Bristol ... ...*Bristol Naturalists' Society.
117 Camborne ...*Mining Association and Institute of Cornwall.
118 Cambridge ... Philosophical Society.
119 „ ... Public Free Library.
120 „ ...*Union Society.
121 „ ... University Library.
122 Halifax ... ...*Yorkshire Geological and Polytechnic Society.
123 Kew ... ...*Royal Gardens.
124 Leeds ... ...*Conchological Society.
125 „ ... ...*Leeds Philosophical and Literary Society.
126 „ ... ...*Yorkshire College.
127 Liverpool ...*Literary and Philosophical Society.
128 London ... ...*Aëronautical Society of Great Britain.
129 „ ... ... Agent-General (two copies).
130 „ ... ...*Anthropological Institute of Great Britain and Ireland.
131 „ ... ... British Museum.
132 „ ... ...*British Museum (Natural History).
133 „ ... ... Chemical Society.
134 „ ... ... Colonial Office, Downing Street.
135 „ ... ...*Geological Society.
136 „ ... ... Institute of Chemistry of Great Britain and Ireland.
137 „ ... ...*Institution of Civil Engineers.
138 „ ... ...*Institution of Naval Architects.
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140 „ ... ... Library, South Kensington Museum.
141 „ ... ...*Linnean Society.
142 „ ... ... London Institution.
143 „ ... ...*Lords Commissioners of the Admiralty.
144 „ ... ...*Meteorological Office.
145 „ ... ...*Mineralogical Society.
146 „ ... ... Museum of Practical Geology.
147 „ ... ... Patent Office Library.
148 „ ... ...*Pharmaceutical Society of Great Britain.

149 LONDON ... ...*Physical Society of London.
150 „ ... ...*Quekett Microscopical Club.
151 „ ... ...*Royal Agricultural Society of England.
152 „ ... ...*Royal Astronomical Society.
153 „ ... ...*Royal College of Physicians.
154 „ ... ...*Royal College of Surgeons.
155 „ ... ...*Royal Colonial Institute.
156 „ ... ...*Royal Geographical Society.
157 „ ... ...*Royal Historical Society.
158 „ ... ...*Royal Institution of Great Britain.
159 „ ... ...*Royal Meteorological Society.
160 „ ... ...*Royal Microscopical Society.
161 „ ... ... Royal School of Mines.
162 „ ... ...*Royal Society.
163 „ ... ... Royal Society of Literature.
164 „ ... ...*Royal United Service Institution.
165 „ ... ...*Sanitary Institute.
166 „ ... ... Society of Arts.
167 „ ... ... University of London.
168 „ ... ... War Office—(Intelligence Division).
169 „ ... ...*Zoological Society.
170 MANCHESTER ...*Literary and Philosophical Society.
171 „ ...*Manchester Geological Society.
172 „ ... Owens College.
173 NEWCASTLE-UPON-TYNE... ... *Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne.
174 „ ...*North of England Institute of Mining and Mechanical Engineers.
175 „ ... Society of Chemical Industry.
176 OXFORD ... ...*Bodleian Library.
177 „ ... ...*Radcliffe Library.
178 „ ... ...*Radcliffe Observatory.
179 PENZANCE ...*Royal Geological Society of Cornwall.
180 PLYMOUTH ...*Plymouth Institution and Devon and Cornwall Natural History Society.
181 WINDSOR ... ... The Queen's Library.

CAPE OF GOOD HOPE.

182 CAPE TOWN ...*South African Philosophical Society.

CEYLON.

183 COLOMBO ... ...*Royal Asiatic Society, (Ceylon Branch).

DOMINION OF CANADA.

184 HALIFAX (Nova Scotia) *Nova Scotian Institute of Science.
185 HAMILTON (Ont.)...*Hamilton Association.
186 MONTREAL... ...*Natural History Society of Montreal.
187 „ ... ...*Royal Society of Canada.
188 OTTAWA ... ...*Geological and Natural History Survey of Canada.
189 „ ... ... Ottawa Literary and Scientific Society.
190 QUEBEC ... ...*Literary and Historical Society.
191 TORONTO ... ...*Canadian Institute.
192 „ ... ...*University.
193 WINNIPEG... ...*Manitoba Historical and Scientific Society.

INDIA.

194 Calcutta ...*Asiatic Society of Bengal.
195 „ ... ...*Geological Survey of India.

IRELAND.

196 Dublin ... ...*Royal Dublin Society.
197 „ ... ...*Royal Geological Society of Ireland.
198 „ ... ...*Royal Irish Academy.

JAMAICA.

199 Kingston ... ...*Institute of Jamaica.

MAURITIUS.

200 Port Louis ...*Royal Society of Arts and Sciences.
201 „ ... Société d'Acclimatation de l' Ile Maurice.

NEW SOUTH WALES.

202 Sydney ... ...*Australian Museum.
203 „ ... ...*Department of Mines and Agriculture.
204 „ ... ...*Department of Public Instruction.
205 „ ... ...*Engineering Association of New South Wales.
206 „ ... ...*Free Public Library.
207 „ ... ...*Government Statistician.
208 „ ... ...*Linnean Society of New South Wales.
209 „ ... ...*Mining Department.
210 „ ... ...*Observatory.
211 „ ... ... N. S. Wales Government Railways Institute.
212 „ ... ...*Public Works Department.
213 „ ... ...*Royal Geographical Society of Australasia (New South Wales Branch).
214 „ ... ... School of Arts.
215 „ ... ...*Technological Museum.
216 „ ... ...*United Service Institution of New South Wales.
217 „ ... ...*University.

NEW ZEALAND.

218 Auckland ... ...*Auckland Institute.
219 Christchurch ... Philosophical Institute of Canterbury.
220 Dunedin ... ... Otago Institute.
221 Wellington ...*Colonial Museum.
222 „ ...*New Zealand Institute.
223 „ ...*Polynesian Society.

QUEENSLAND.

224 Brisbane ... ...*Acclimatization Society of Queensland.
225 „ ... ...*Geological Survey of Queensland.
226 „ ... ... Parliamentary Library.
227 „ ... ...*Queensland Museum.
228 „ ... ...*Royal Geographical Society of Australasia (Queensland Branch)
229 „ ... ...*Royal Society of Queensland.

SCOTLAND.

230 Aberdeen ... ...*University.
231 Edinburgh ...*Editor, *Encyclopædia Britannica,* (Messrs. A. and C. Black).

232	Edinburgh	...*Edinburgh Geological Society.
233	,,	...*Highland and Agricultural Society of Scotland.
234	,,	...*Royal Botanic Garden.
235	,,	...*Royal Observatory.
236	,,	...*Royal Physical Society.
237	,,	...*Royal Scottish Geographical Society.
238	,,	...*Royal Society.
239	,,	...*University.
240	Glasgow ...	...*Geological Society of Glasgow.
241	,, ...	...*Philosophical Society of Glasgow.
242	,, ...	...*University.
243	St. Andrews	... University.

SOUTH AUSTRALIA.

244	Adelaide ...	...*Geological Survey of South Australia.
245	,, ...	...*Government Botanist.
246	,, ...	...*Government Printer.
247	,, ...	...*Observatory.
248	,, ...	...*Public Library, Museum, and Art Gallery of South Australia.
249	,, ...	...*Royal Geographical Society of Australasia (South Australian Branch).
250	,, ...	...*Royal Society of South Australia.
251	,, ...	.. *University.

STRAITS SETTLEMENTS.

252	Singapore...	...*Royal Asiatic Society (Straits Branch.)

TASMANIA.

253	Hobart ...	...*Royal Society of Tasmania.
254	Launceston	...*Geological Survey of Tasmania.

VICTORIA.

255	Ballaarat	...*School of Mines and Industries.
256	Maryborough	... District School of Mines, Industries and Science.
257	Melbourne	.. *Field Naturalists' Club of Victoria.
258	,,	...*Government Botanist.
259	,,	...*Government Statist.
260	,,	...*Mining Department.
261	,,	...*Observatory.
262	,,	...*Public Library.
263	,,	...*Registrar-General.
264	,,	...*Royal Geographical Society of Australasia (Victorian Branch.)
265	,,	...*Royal Society of Victoria.
266	,,	...*University.
267	,,	...*Victorian Institute of Surveyors.
268	,,	...*Working Men's College.
269	Stawell ...	...*School of Mines, Art, Industry, and Science.

WESTERN AUSTRALIA.

270	Perth ...	...*Geological Survey of Western Australia.

Hayti.

271	Port-au-Prince ...	Société de Sciences et de Géographie.

Italy.

272 Bologna ... ...*Accademia delle Scienze dell'Istituto di Bologna.
273 " ... ... Università di Bologna.
274 Florence ... ...*Società Africana d' Italia (Sezione Fiorentina).
275 " ... ...*Società Entomologica Italiana.
276 " ... ...*Societá Italiana di Antropologia e di Etnologia.
277 Genoa ... ...*Museo Civico di Storia Naturale.
278 Milan ... ...*Reale Istituto Lombardo di Scienze Lettere ed Arti.
279 " ... ...*Società Italiana di Scienze Naturali.
280 Modena ... ...*R. Accademia di Scienze, Lettere ed Arti.
281 Naples ... ...*Società Africana d' Italia.
282 " ... ...*Società Reale di Napoli(Accademia delle Scienze Fisiche e Matematiche).
283 " ... ...*Stazione Zoologica (Dr. Dohrn).
284 Palermo ... ...*Reale Accademia Palermitana di Scienze Lettere ed Arti.
285 " ... ... Reale Istituto Tecnico.
286 Pisa ... ...*Società Toscana di Scienze Naturali.
287 Rome ... ...*Accademia Pontificia de Nuovi Lincei.
288 " ... ...*Biblioteca e Archivio Tecnico (Ministero dei Lavori Pubblico).
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293 Siena ... ...*R. Accademia dei Fisiocritici in Siena.
294 Turin ... ... Reale Accademia della Scienze.
295 " ... ...*Regio Osservatorio della Regia Università.
296 Venice ... ...*Reale Istituto Veneto di Scienze, Lettere ed Arti.

Japan.

297 Tokio ... ...*Asiatic Society of Japan (formerly in Yokohama).
298 " ... ...*Imperial University.
299 " ... ...*Seismological Society of Japan.

Java.

300 Batavia ... ...*K. Natuurkundige Vereeniging in Nederl Indië.

Mexico.

301 Mexico ... ...*Sociedad Cientifica "Antonio Alzate."

Netherlands.

302 Amsterdam ...*Académie Royale des Sciences.
303 " ... ...*Société Royale de Zoologie.
304 Harlem ... ...*Bibliothèque de Musée Teyler.
305 " ... ...*Colonial Museum.
306 " ... ...*Société Hollandaise des Sciences.

Norway.

307 Bergen ... ...*Museum.
308 Christiania ...*Köngelige Norske Fredericks Universitet.
309 " ...*Videnskabs-Selskabet i Christiania.
310 Tromso ... ...*Museum.

Roumania.

311 Bucharest ...*Institutul Meteorologic al Roumăniei.

Russia.

312 Helsingfors ...*Société des Sciences de Finlande.
313 Kieff ... ...*Société des Naturalistes.
314 Moscow ... ...*Société Impériale des Naturalistes.
315 „ ... ...*Société Impériale des Amis des Sciences Naturelles d' Anthropologie et d' Ethnographie à Moscow (Section d' Anthropologie).
316 St. Petersburg ...*Académie Impériale des Sciences.
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Spain.

318 Madrid ... ...*Instituto geografico y Estadistico.

Sweden.

319 Stockholm ...*Kongliga Svenska Vetenskaps-Akademien.
320 „ ...*Kongliga Universitetet.

Switzerland.

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United States of America.

326 Albany ... ...*New York State Library, Albany.
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328 Baltimore ...*Johns Hopkins University.
329 Beloit (Wis.) ...*Chief Geologist.
330 Boston ... ...*American Academy of Arts and Sciences.
331 „ ... ...*Boston Society of Natural History.
332 „ ... ... State Library of Massachusetts.
333 Brookville (Ind.)*Brookville Society of Natural History.
334 „ ... Indiana Academy of Science.
335 Buffalo (Ind.) ...*Buffalo Society of Natural Sciences.
336 Cambridge (Mass.)*Cambridge Entomological Club.
337 „ ...*Museum of Comparative Zoology at Harvard College.
338 Chicago ... ... Academy of Sciences.
339 Cincinnati ...*Cincinnati Society of Natural History.
340 Coldwater ... Michigan Library Association.
341 Davenport (Iowa)*Academy of Natural Sciences.
342 Denver ... ...*Colorado Scientific Society.
343 Fort Monroe (Va.)*United States Artillery School.
344 Hoboken (N.J.) ...*Steven's Institute of Technology.
345 Iowa City (Iowa) *Director Iowa Weather Service.
346 Jefferson City...*Geological Survey of Missouri.
347 Madison (Wis.)...*Wisconsin Academy of Sciences, Arts and Letters.
348 Minneapolis ...*Minnesota Academy of Natural Sciences.
349 Newhaven (Conn) *Connecticut Academy of Arts and Sciences.
350 New York ...*American Chemical Society.
351 „ ...*American Geographical Society.
352 „ ...*American Institute of Mining Engineers.

353	New York	...*American Museum of Natural History.
354	„	...*Editor *Journal of Comparative Medicine and Veterinary Archives.*
355	„	... Editor *Science.*
356	„	...*New York Academy of Sciences.
357	„	...*New York Microscopical Society.
358	„	...*School of Mines, Columbia College.
359	Palo Alto (Cal.)	...*Geological Survey of Arkansas.
360	Philadelphia	...*Academy of Natural Science.
361	„	...*American Entomological Society.
362	„	...*American Philosophical Society.
363	„	...*Franklin Institute.
364	„	...*Geological Survey of Pennsylvania.
365	„	...*Wagner Free Institute of Science.
366	„	...*Zoological Society of Philadelphia.
367	Rochester (N.Y.)	*Geological Society of America.
368	Salem (Mass.)	...*American Association for Advancement of Science.
369	„	...*Essex Institute.
370	St. Louis ...	...*Academy of Science.
371	„	...*Missouri Botanical Garden.
372	San Francisco	...*California Academy of Sciences.
373	„	...*California State Mining Bureau.
374	Scranton (Pa.)	...*The Colliery Engineer Co.
375	Washington	... American Medical Association.
376	„	...*Bureau of Education (Department of the Interior).
377	„	...*Bureau of Ethnology.
378	„	...*Chief of Engineers (War Department).
379	„	...*Chief of Ordnance (War Department).
380	„	...*Department of Agriculture, Library.
381	„	...*Department of Agriculture, Weather Bureau.
382	„	...*Director of the Mint (Treasury Department).
383	„	... Library (Navy Department).
384	„	...*National Academy of Sciences.
385	„	...*Office of Indian Affairs (Department of the Interior).
386	„	...*Philosophical Society.
387	„	...*Secretary (Department of the Interior).
388	„	...*Secretary (Treasury Department).
389	„	...*Smithsonian Institution.
390	„	...*Surgeon General (U.S. Army).
391	„	...*U. S. Coast and Geodetic Survey (Treasury Department).
392	„	...*U.S. Geological Survey.
393	„	...*U. S. National Museum (Department of the Interior).
394	„	... U.S. Patent Office.
395	„	...*War Department.

Number of Publications sent to		Great Britain ...	... 84
„	„	India and the Colonies	... 72
„	„	America	... 74
„	„	Europe	... 155
„	„	Asia, &c.	... 5
„	„	Editors of Periodicals	... 5
		Total ...	... 395

T. W. E. DAVID...... }
J. H. MAIDEN.......... } Hon. Secretaries.

The Society's House, Sydney, 31st December, 1893.

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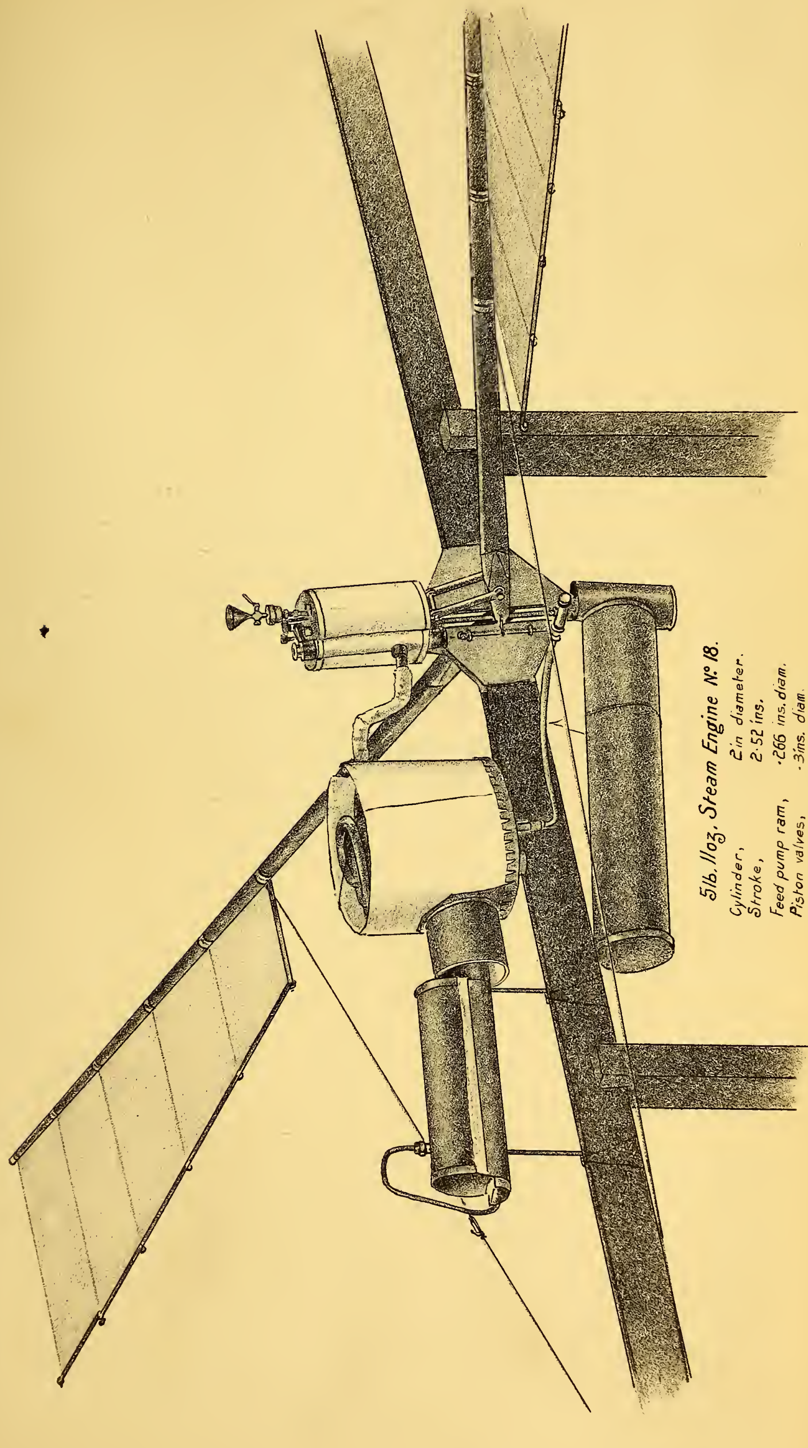
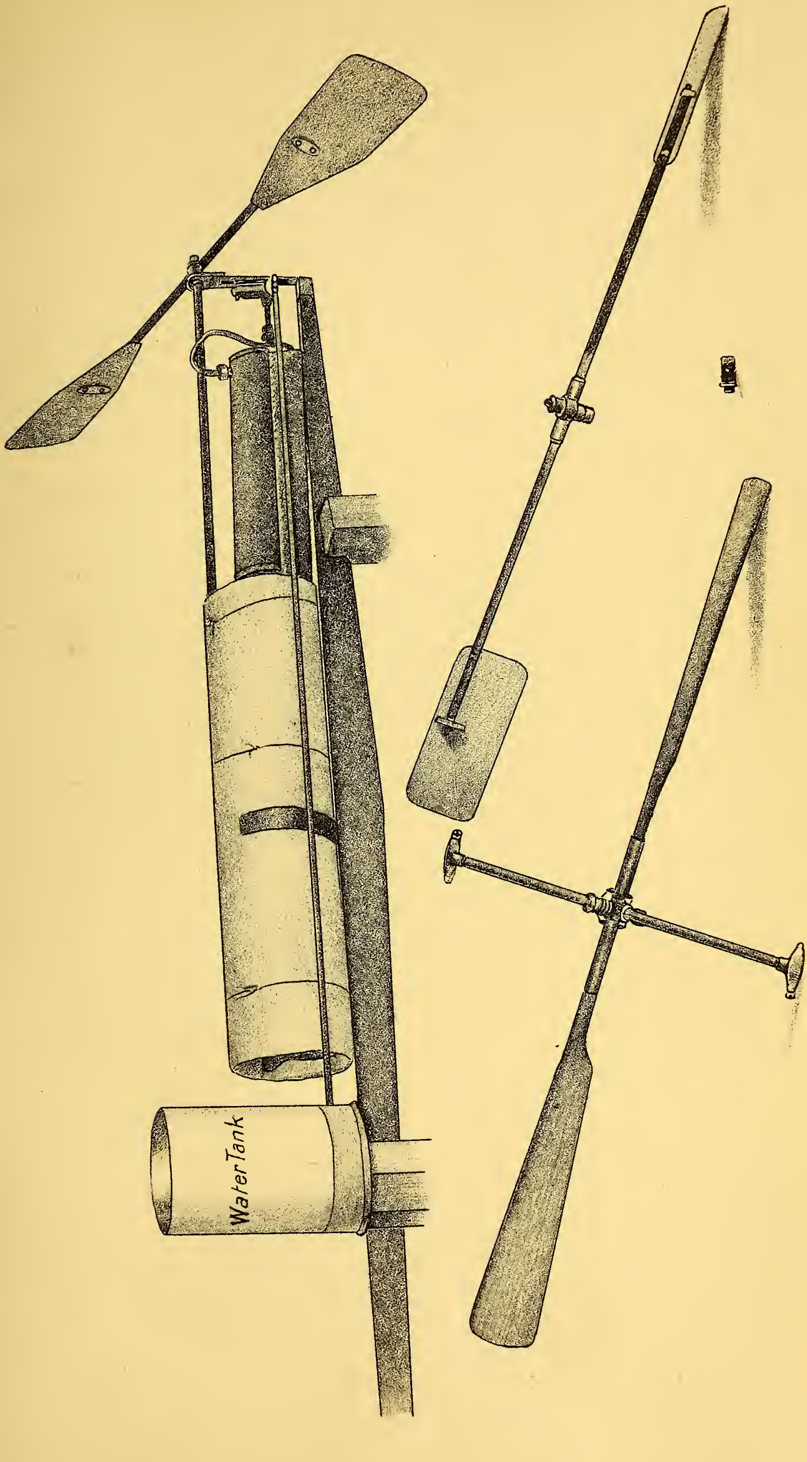
Sydney.
F. W. WHITE, PRINTER, MARKET-ST..
1894.



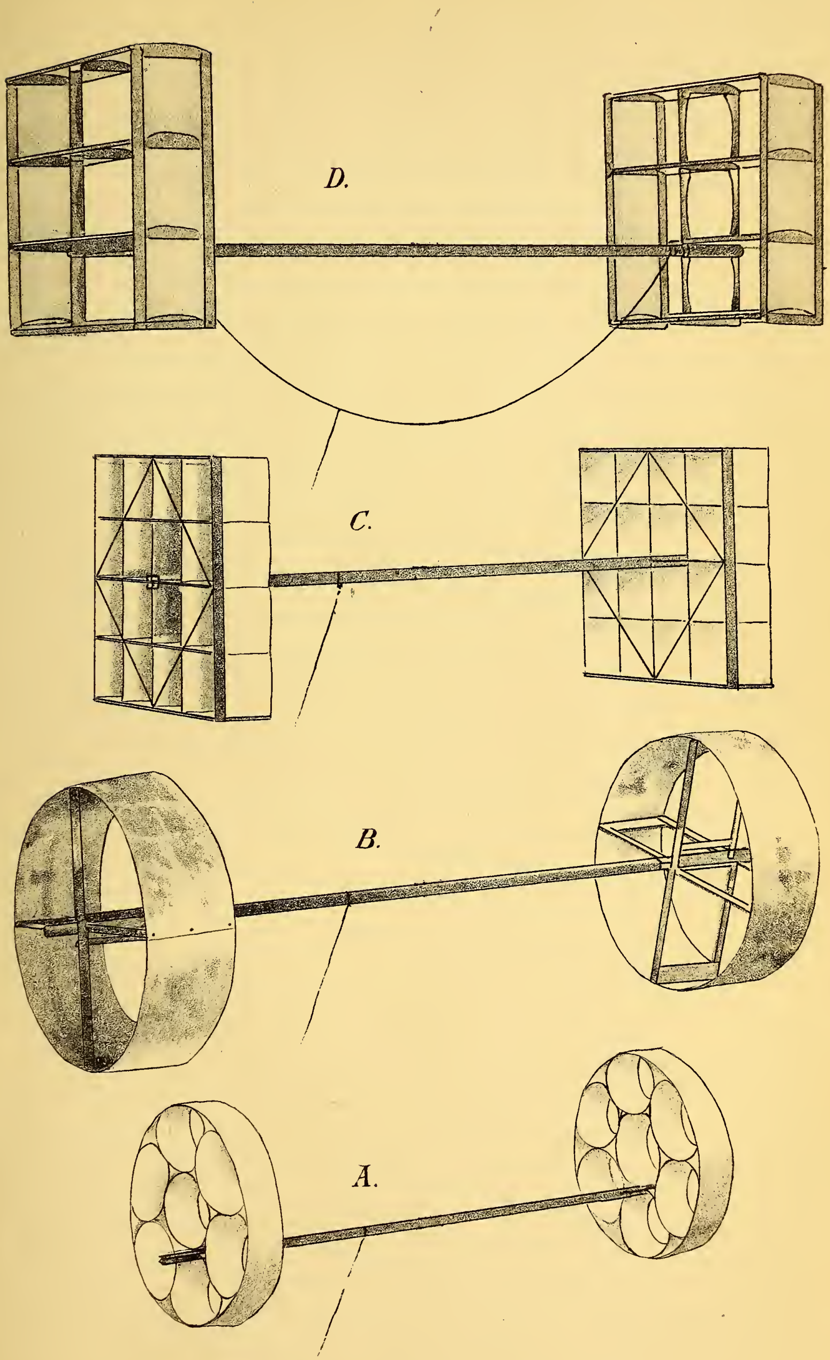
5lb. 11oz, Steam Engine No. 18.

Cylinder,	2in diameter.
Stroke,	2·52 ins.
Feed pump ram,	·266 ins. diam.
Piston valves,	·3 ins. diam.
Surface of Wings.	281 sq. ins.
Boiler,	21 Feet of copper pipe ·18 in. bore.

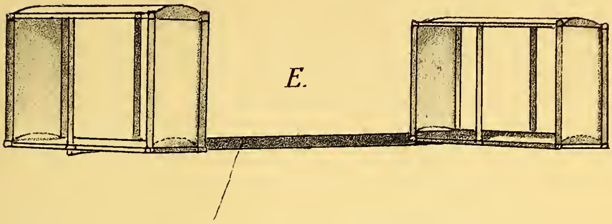
Law. Hargrave. Dec 1892.



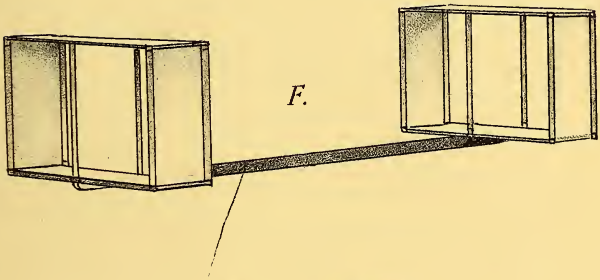
Screw Motors.

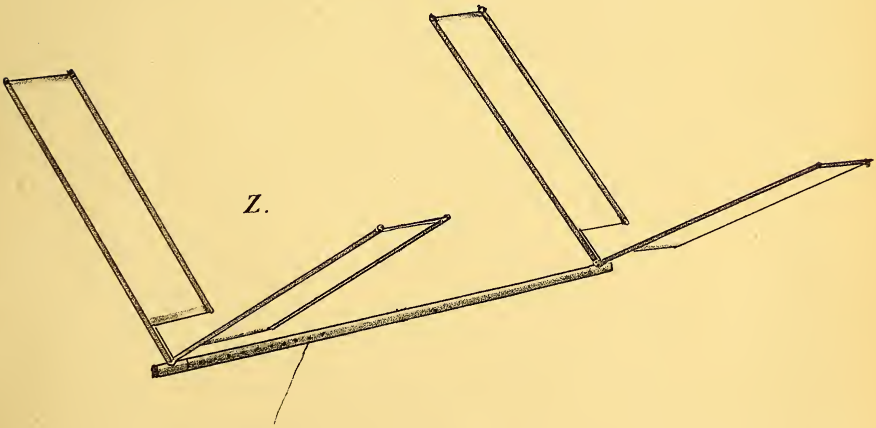


Cellular Kites. Feb. 1893



Cellular Kites. Feb. 1893





Photographed by the Rev. J. Milne Curran F.G.S.

Photographed by the Rev. J. Milne Curran. F.G.S.

Fig. 1.

Fig. 7.

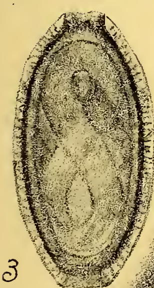


Fig. 3

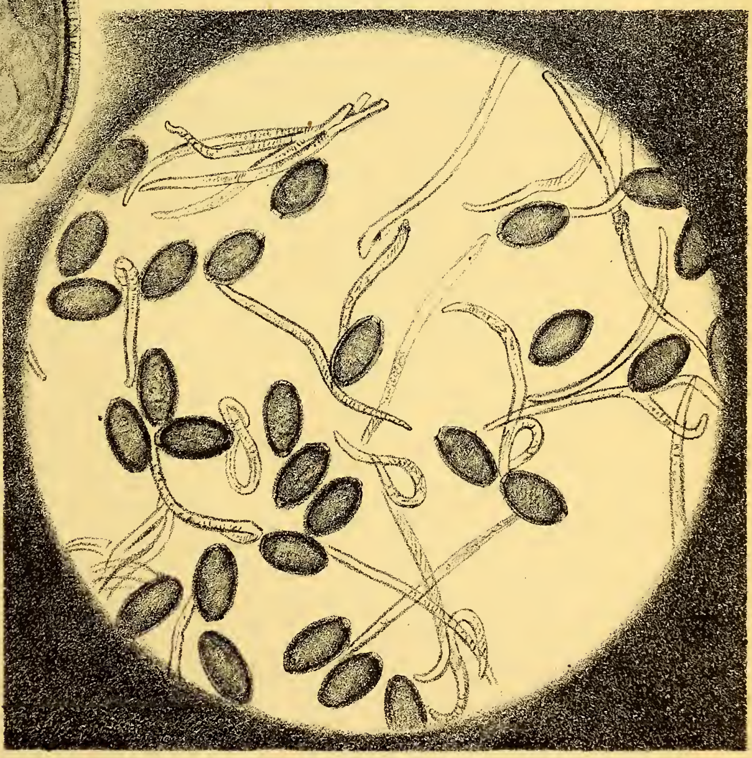


Fig. 2.

Lithographed from Photomicrographs.

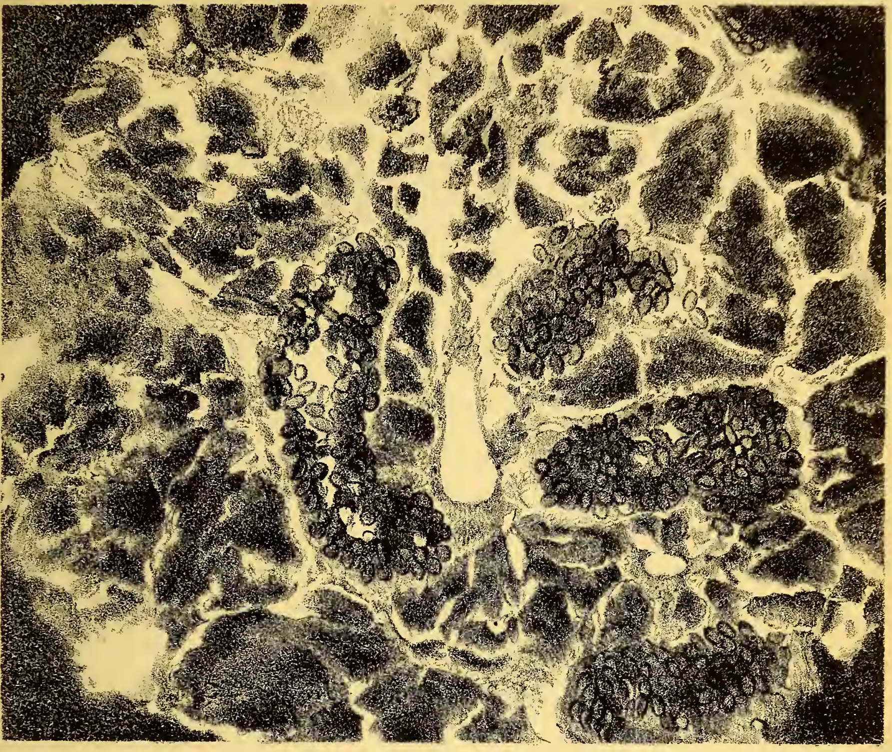


Fig. 4.

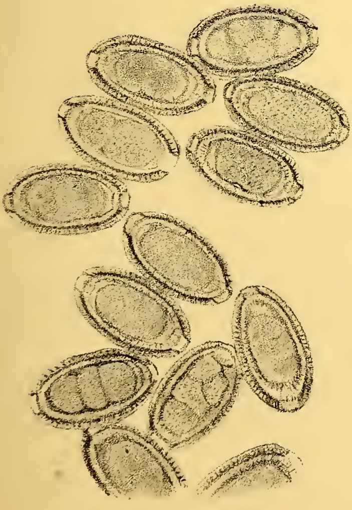
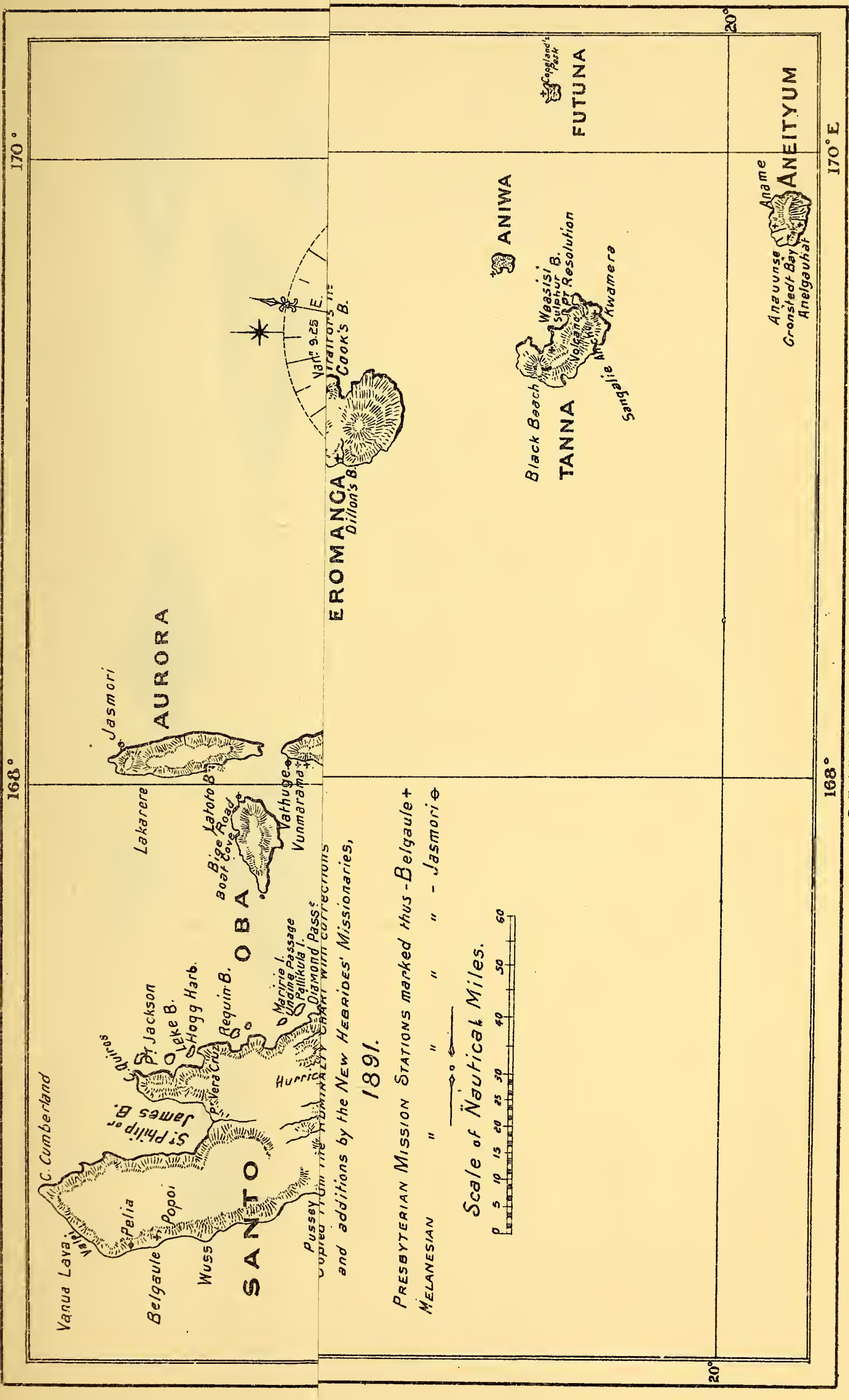
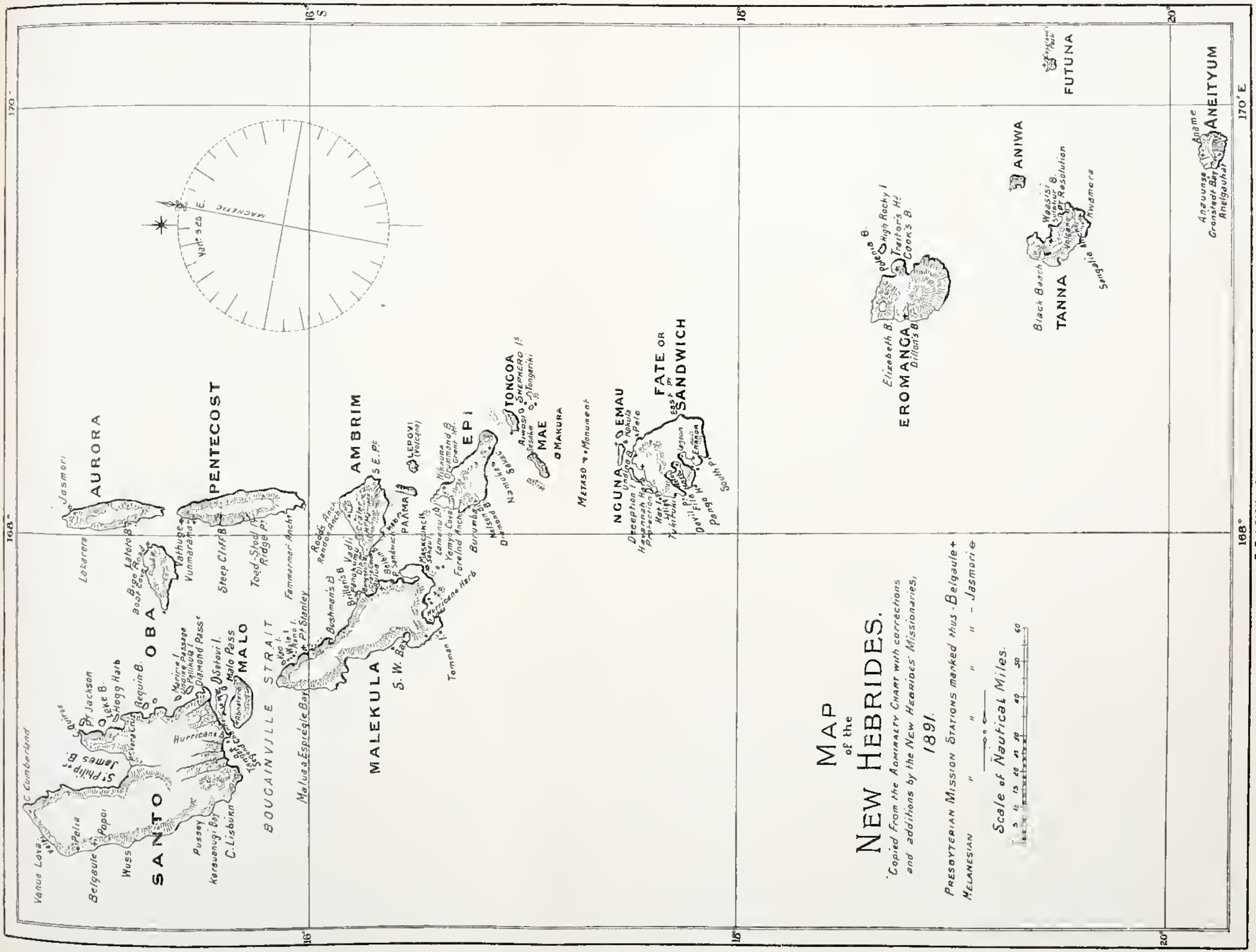
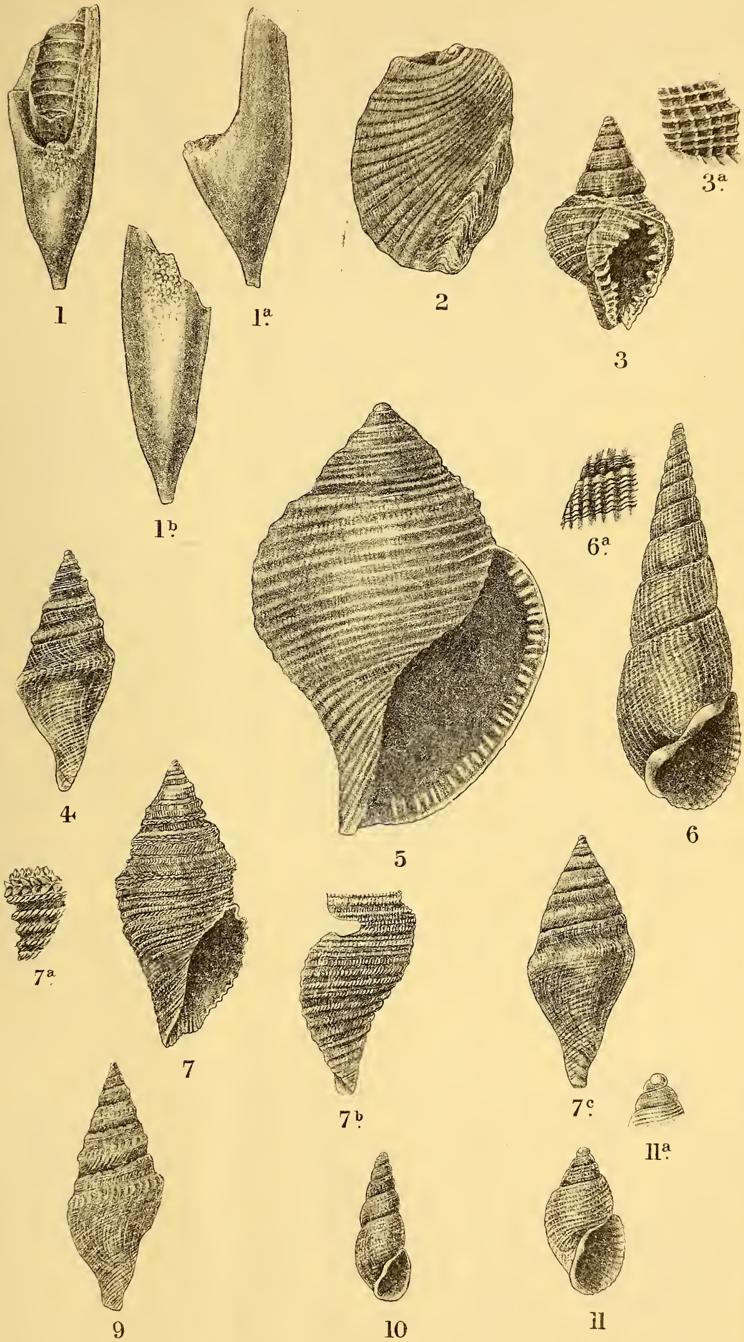


Fig. 5. Lithographed from Photomicrographs. Fig. 6.



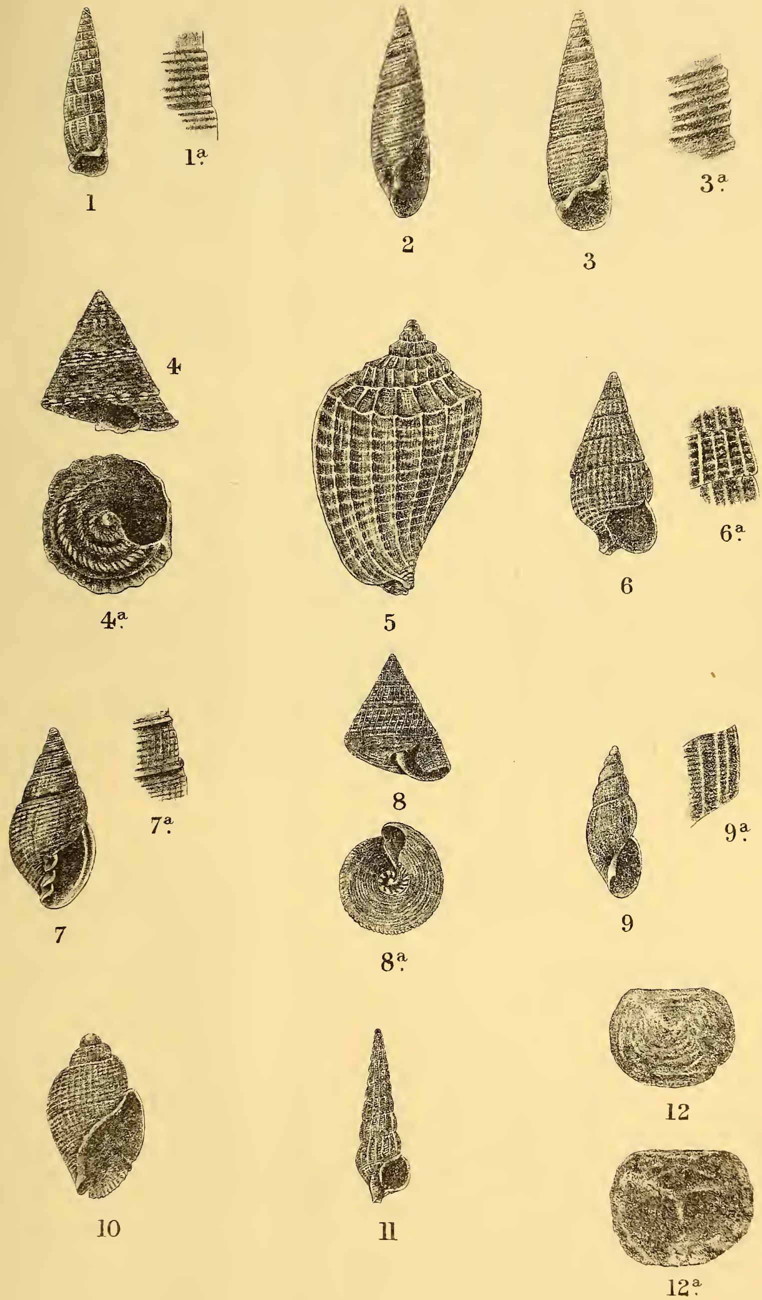
S. T. LEIGH & Co Lith. Sydney


MAP of the NEW HEBRIDES.
Copied from the Admiralty Chart with corrections and additions by the New Hebrides' Missionaries, 1891.
Presbyterian Mission Stations marked thus - Belgaule+
Melanesian " " " - Jasmorie
Scale of Nautical Miles.
SANTO
MALO
OBA
AURORA
PENTECOST
BOUGAINVILLE STRAIT
MALEKULA
AMBRIM
PAAMA
LEPOVI (Volcano)
EPI
TONGOA
SHEPHERD Is
MAE
MAKURA
NGUNA
EMAU
FATE OR SANDWICH
EROMANGA
TANNA
ANIWA
FUTUNA
ANEITYUM
168°
170° E
S. T. LEIGH & Co Lith Sydney



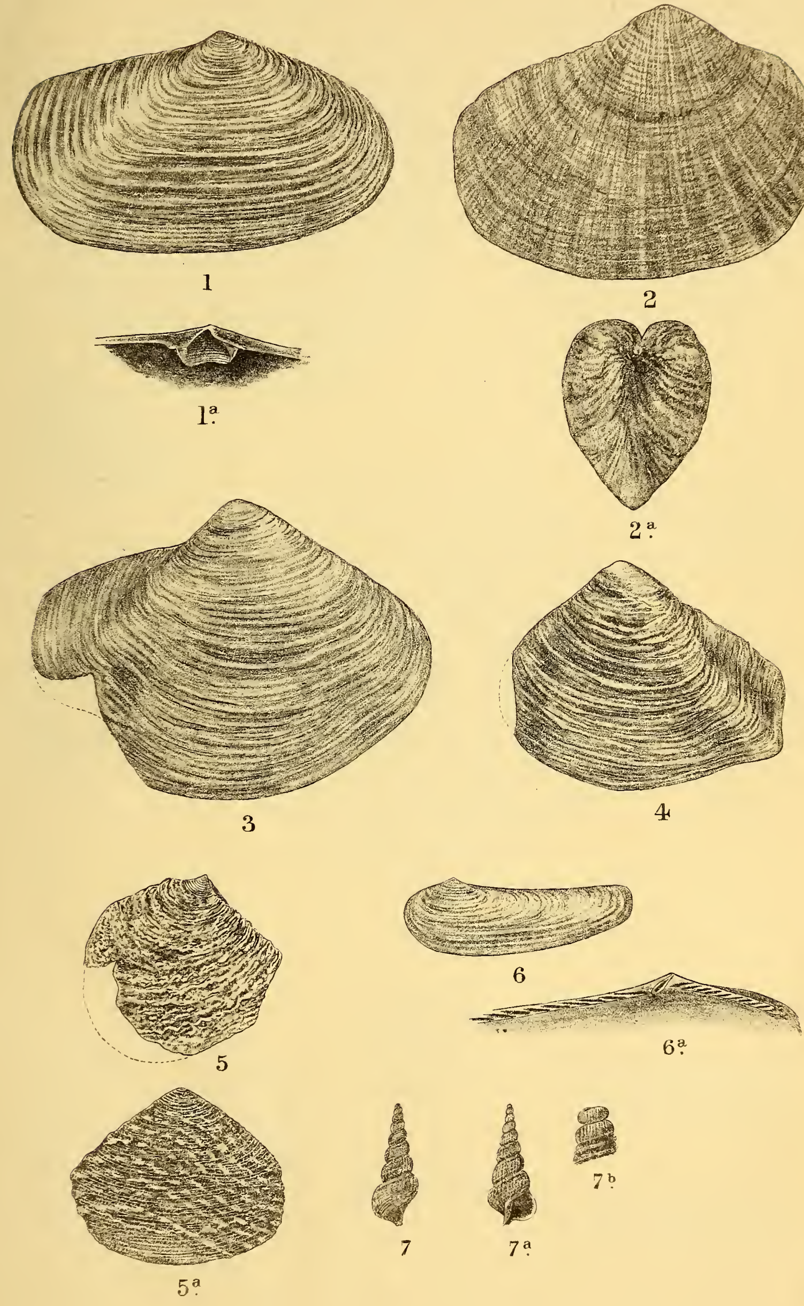
H. B. lith.

HUSSEY & GILLINGHAM. LITH ADELAIDE



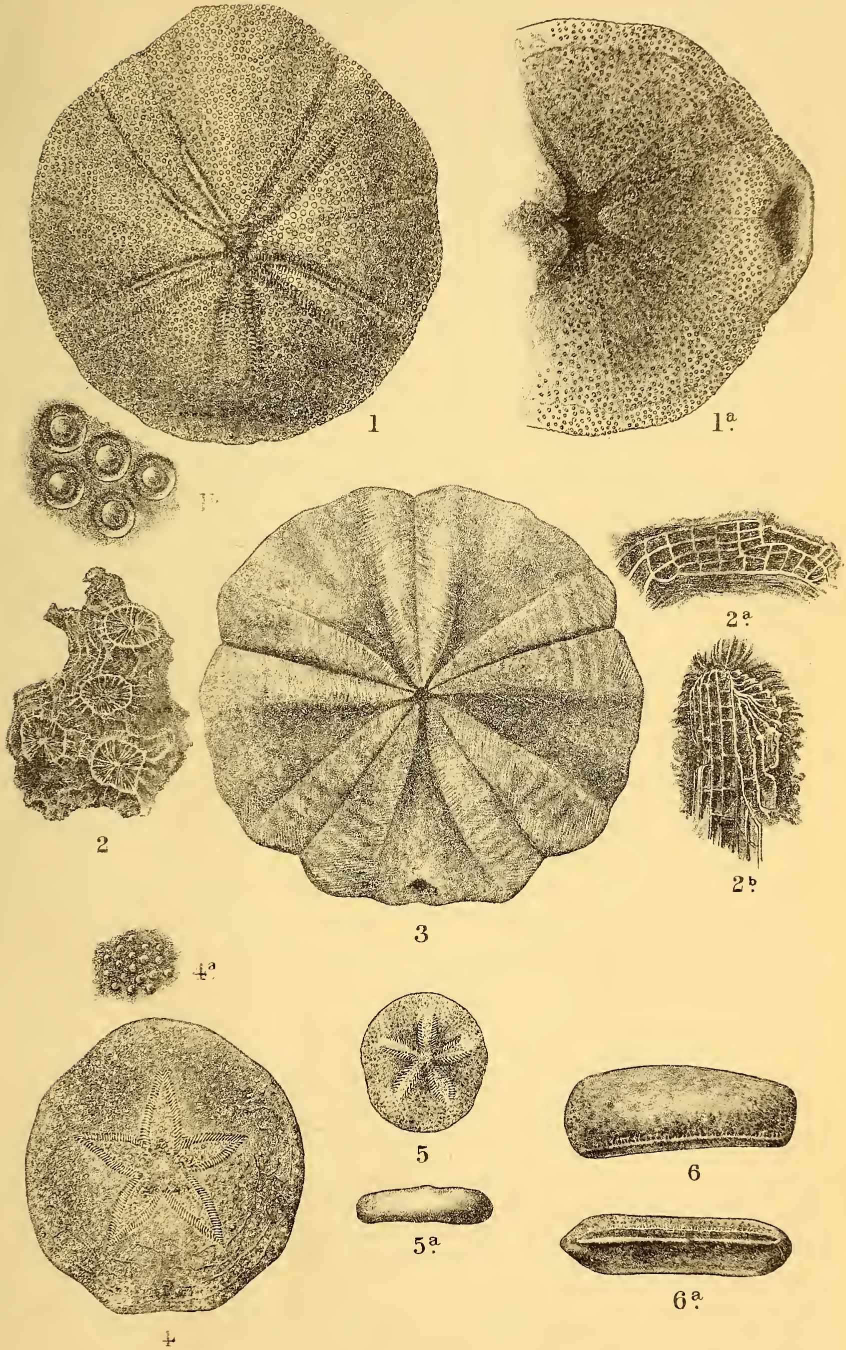
H. B. lith.

HUSSEY & GILLINGHAM LITH. ADELAIDE



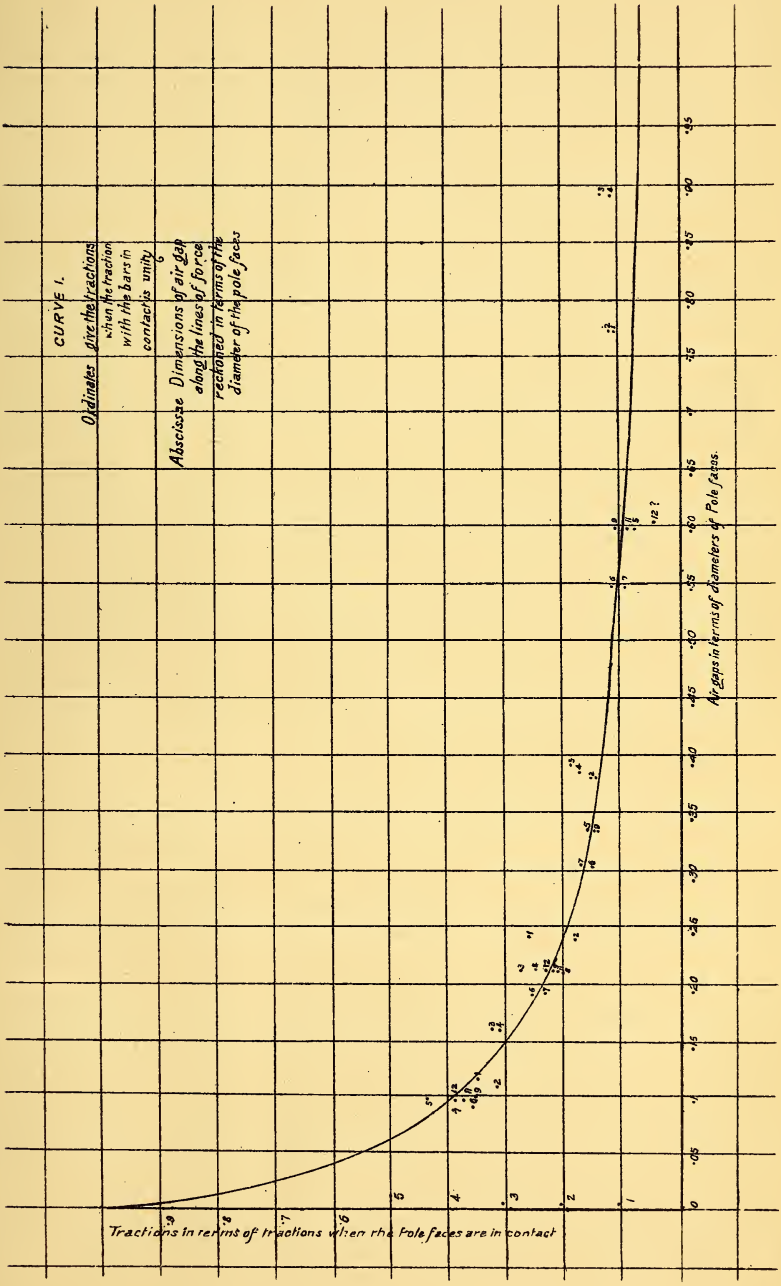
H.B. lith

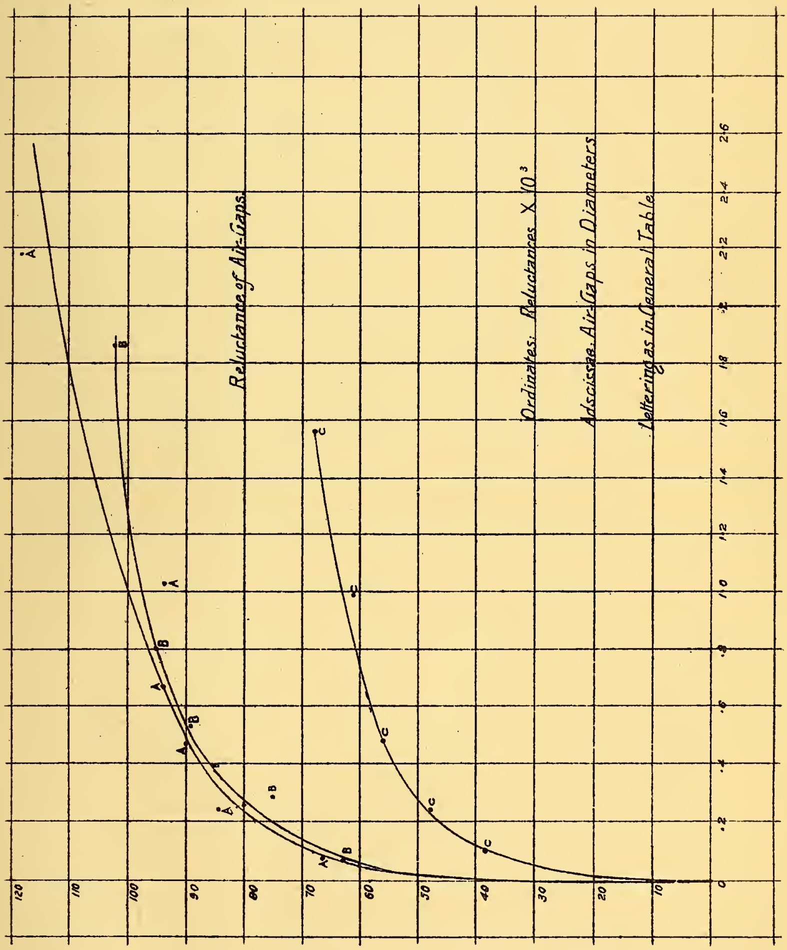
HUSSEY & GILLINGHAM, LITH. ADELAIDE



H.B. lith.

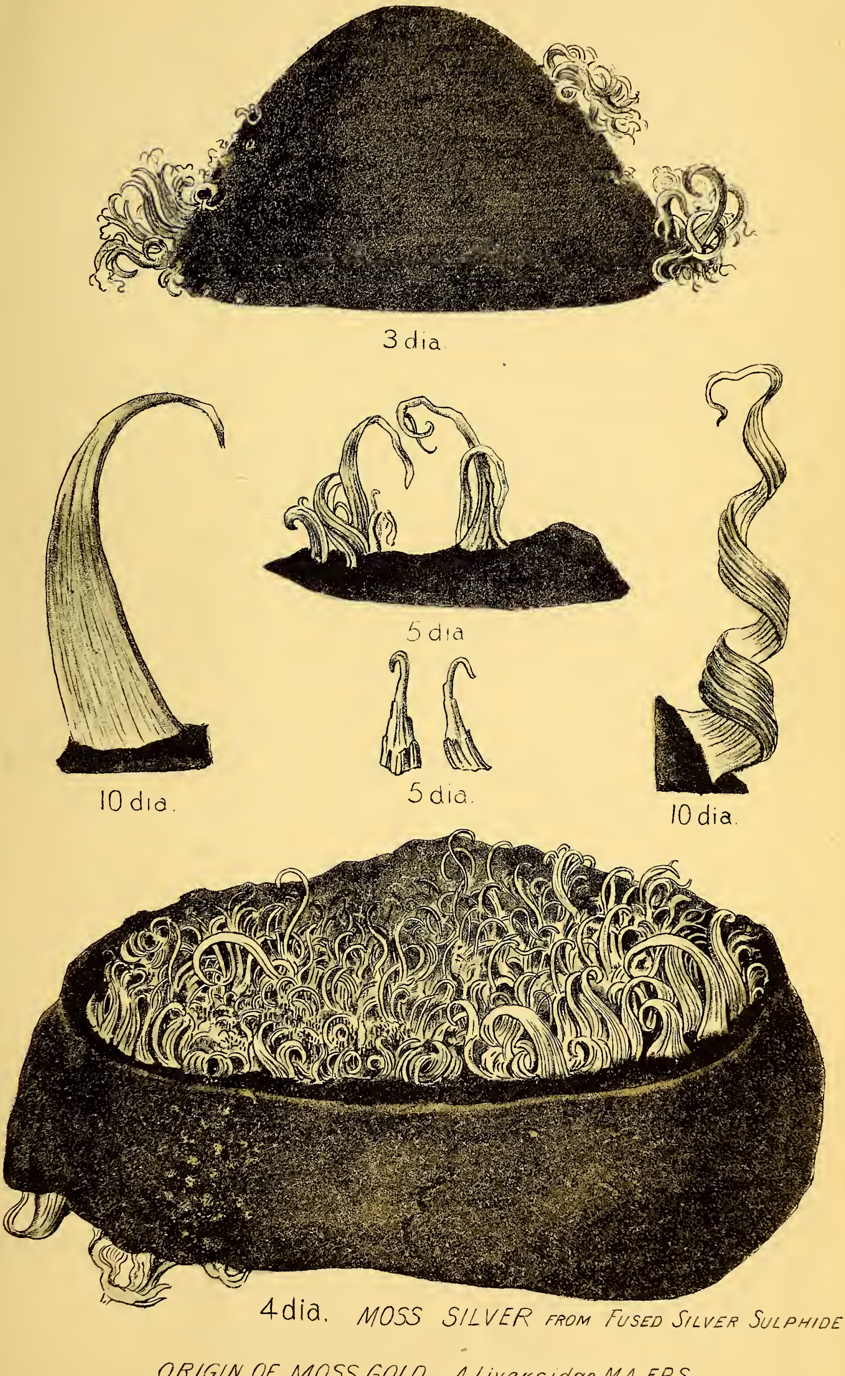
Hussey & Gillingham. Lith Adelaide


CURVE I.
Ordinates give the tractions when the traction with the bars in contact is unity
Abscissae Dimensions of air gap along the lines of force reckoned in terms of the diameter of the pole faces
Air gaps in terms of diameters of Pole faces.
Tractions in terms of tractions when the Pole faces are in contact


Reluctance of Air-Gaps.
Ordinates: Reluctances X 10³
Adscissae: Air-Gaps in Diameters
Lettering as in General Table
0
10
20
30
40
50
60
70
80
90
100
110
120
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
A
B
C

ORIGIN OF MOSS GOLD. A. Liversidge MA. F.R.S.

MOSS GOLD (enlarged) from Auriferous Mispickel. Lucknow.



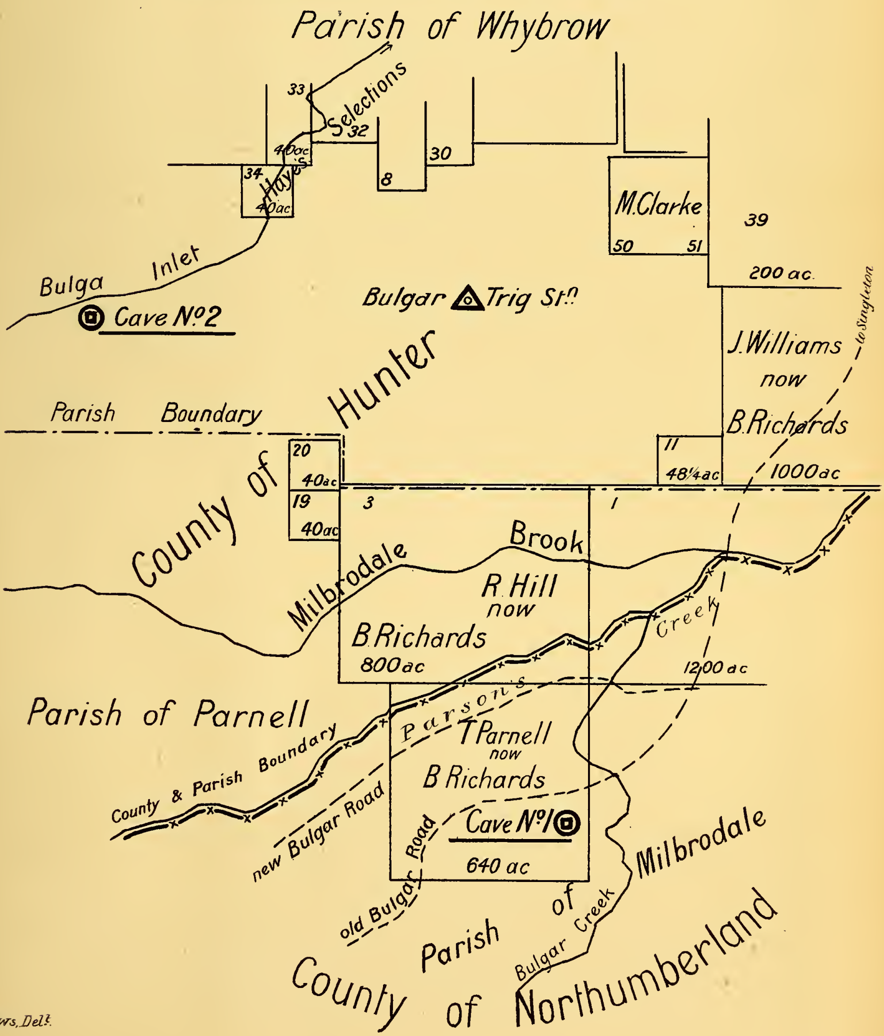
MOSS SILVER FROM FUSED SILVER SULPHIDE

ORIGIN OF MOSS GOLD. A Liversidge M.A. F.R.S.

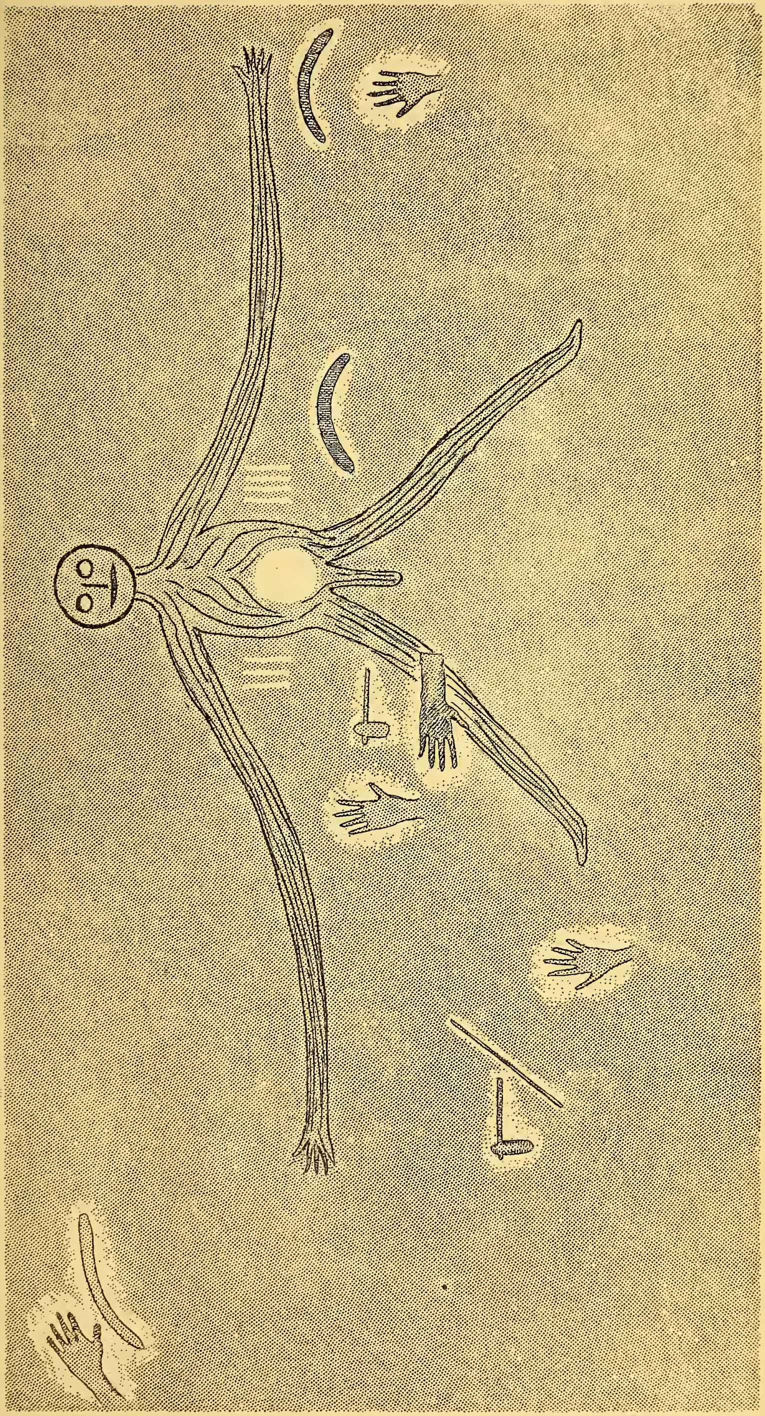
PLAN

showing Position of Caves
Parishes of Whybrow & Milbrodale
near Singleton

Scale — 80 Chains to an Inch



R.H. Mathews, Delt.



Drawings by Aborigines in Cave No 1.

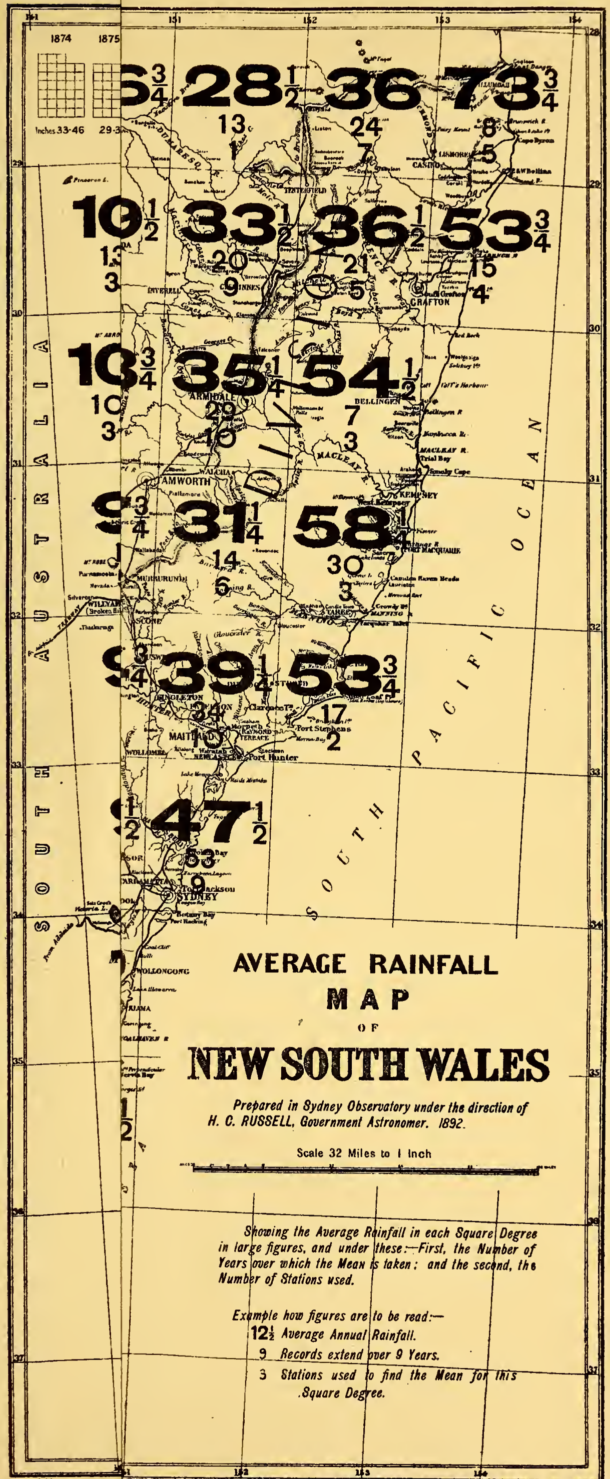
Scale:- 3 feet to an Inch

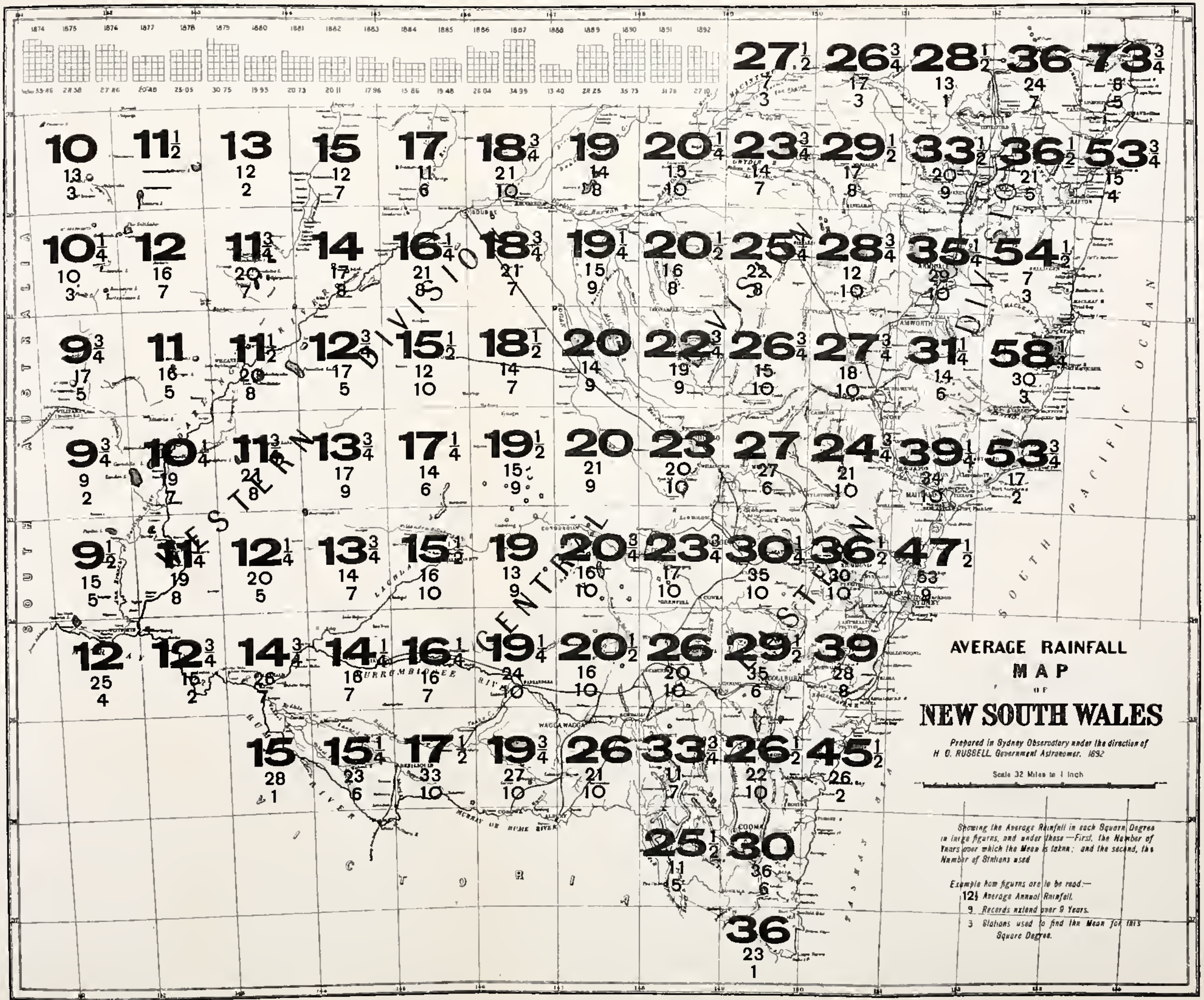
R.H. Mathews, Delt.

Drawings by Aborigines in Cave No. 2.

Scale:— 3 feet to an Inch.

R.H. Mathews, Delt.


AVERAGE RAINFALL
MAP
OF
NEW SOUTH WALES
Prepared in Sydney Observatory under the direction of
H. C. RUSSELL, Government Astronomer. 1892.
Scale 32 Miles to 1 Inch
Showing the Average Rainfall in each Square Degree in large figures, and under these:—First, the Number of Years over which the Mean is taken; and the second, the Number of Stations used.
Example how figures are to be read:—
12½ Average Annual Rainfall.
9 Records extend over 9 Years.
3 Stations used to find the Mean for this Square Degree.
SOUTH PACIFIC OCEAN
SOUTH AUSTRALIA
SYDNEY
NEWCASTLE
MAITLAND
SINGLETON
PORT MACQUARIE
KEMPSEY
ARMIDALE
TAMWORTH
GRAFTON
INVERELL
TENTERFIELD
WOLLONGONG
1874
1875


AVERAGE RAINFALL
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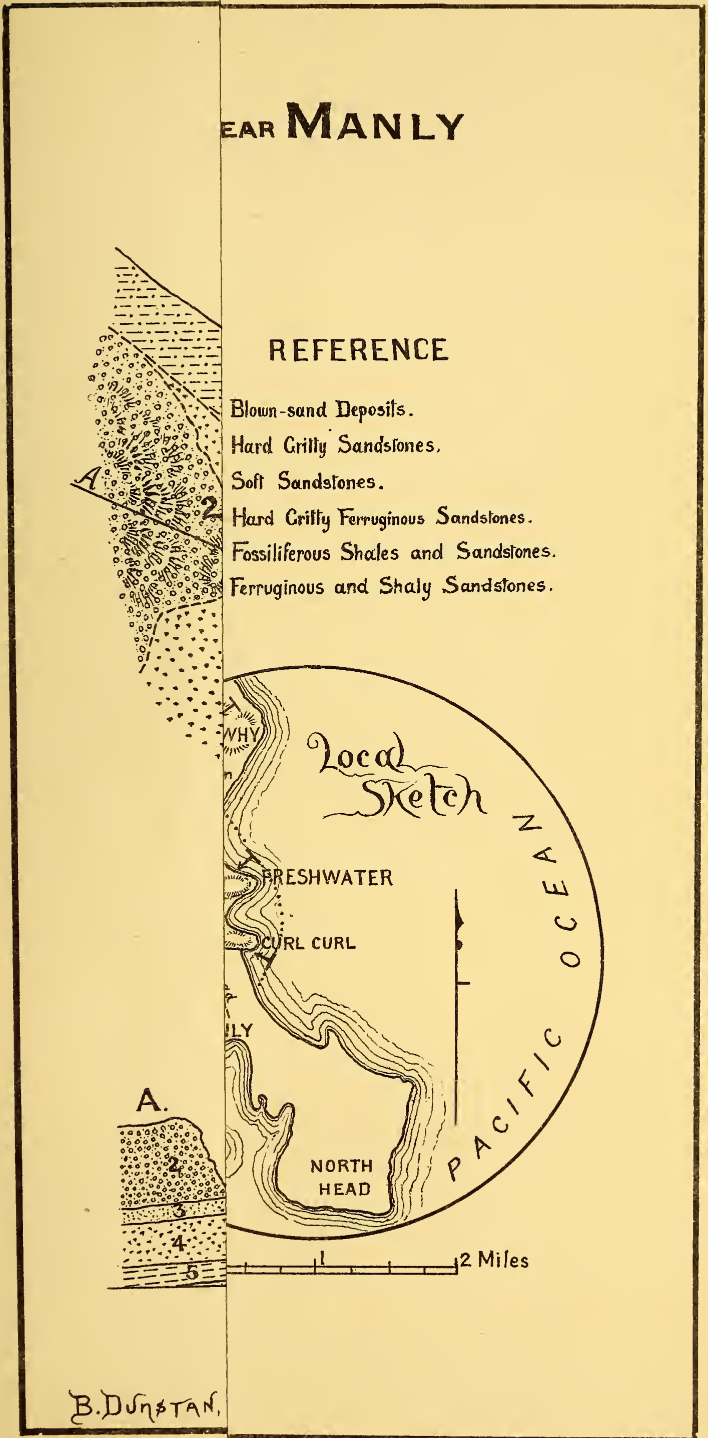
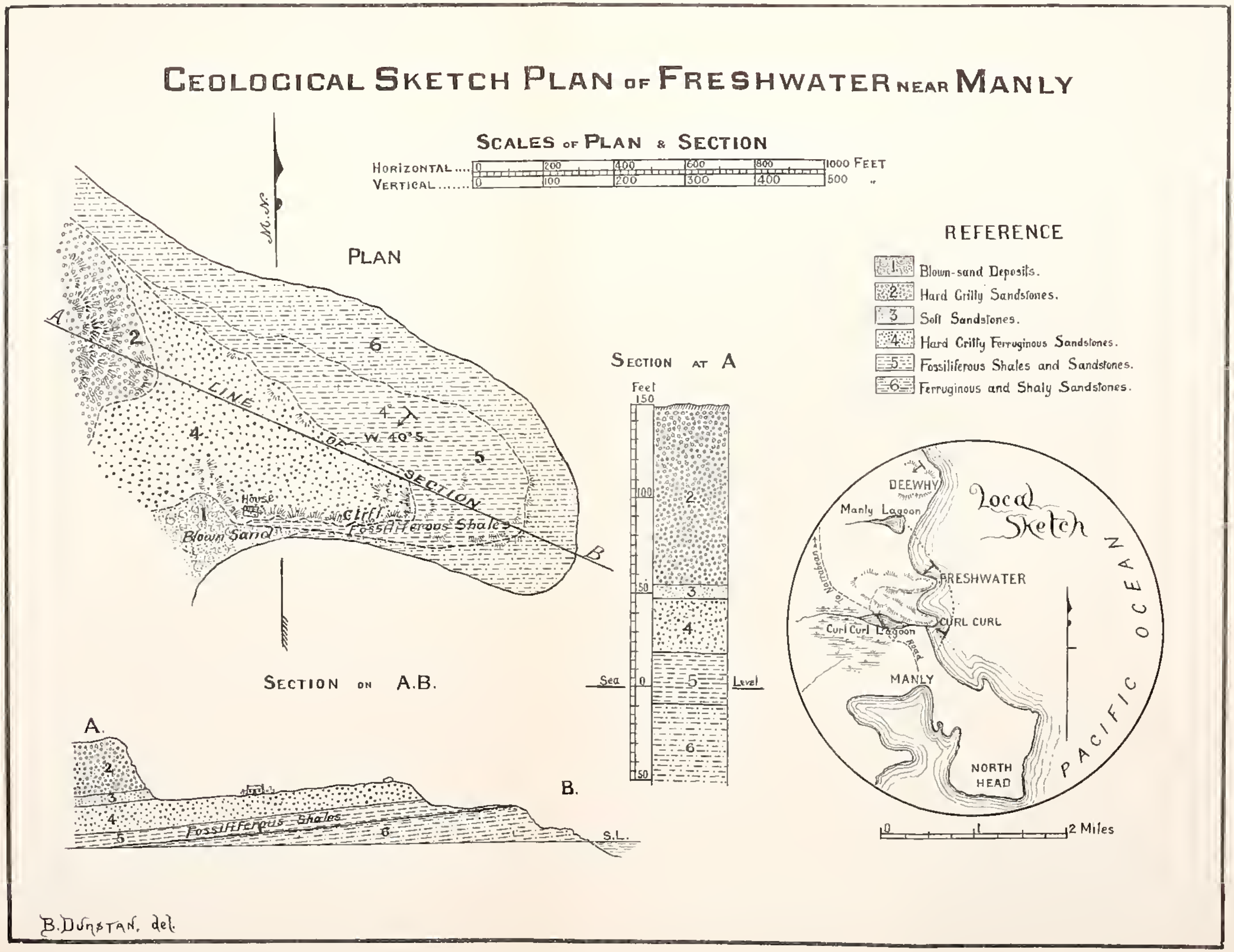
Scale 32 Miles to 1 Inch
Showing the Average Rainfall in each Square Degree in large figures, and under these—First, the Number of Years over which the Mean is taken; and the second, the Number of Stations used
Example how figures are to be read:—
12¼ Average Annual Rainfall.
9 Records extend over 9 Years.
3 Stations used to find the Mean for this Square Degree.
WESTERN DIVISION
CENTRAL DIVISION
EASTERN DIVISION
SOUTH PACIFIC OCEAN
SOUTH AUSTRALIA
VICTORIA


EAR MANLY
REFERENCE
Blown-sand Deposits.
Hard Gritty Sandstones.
Soft Sandstones.
Hard Gritty Ferruginous Sandstones.
Fossiliferous Shales and Sandstones.
Ferruginous and Shaly Sandstones.
A
2
Local Sketch
FRESHWATER
CURL CURL
NORTH HEAD
PACIFIC OCEAN
A.
2
3
4
5
1
2 Miles
B. DUNSTAN,


Geological Sketch Plan of Freshwater near Manly
Scales of Plan & Section
Horizontal ....
Vertical ....
0 200 400 600 800 1000 Feet
0 100 200 300 400 500 "
M.N.
Plan
A
B
Line of Section
2
4
5
6
1
4°
W. 40° S.
House
Cliff
Blown Sand
Fossiliferous Shales
Section at A
Feet
150
100
50
0
50
Sea
Level
2
3
4
5
6
Reference
1 Blown-sand Deposits.
2 Hard Gritty Sandstones.
3 Soft Sandstones.
4 Hard Gritty Ferruginous Sandstones.
5 Fossiliferous Shales and Sandstones.
6 Ferruginous and Shaly Sandstones.
Section on A.B.
A.
B.
2
3
4
5
6
Fossiliferous Shales
S.L.
Local Sketch
Deewhy
Manly Lagoon
Freshwater
Curl Curl
Curl Curl Lagoon
Road
To Narrabean
Manly
North Head
Pacific Ocean
0 1 2 Miles
B. Dunstan, del.

Vol. XXVII. 1893.

JOURNAL & PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

EDITED BY

THE HONORARY SECRETARIES.

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