JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1908.

VOL. XLII.

EDITED BY

THE HONORARY SECRETARIES.

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

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1908.

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AND

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OF THE

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(INCORPORATED 1881.)

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

TO AUTHORS.

Authors of papers desiring illustrations are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink, so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is $4\frac{1}{4}$ in. $\times$ $6\frac{3}{4}$ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

ERRATA.

Page 12, second line from bottom, 'rail level is 3,400,' should read 'rail level is 3,611.'

PUBLICATIONS.

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

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

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W. H. WEBB.

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

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

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Titles, &c..

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

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The Royal Society of N. S. Wales,

5 Elizabeth Street, Sydney.

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OF THE

Royal Society of New South Wales.

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

‡ Life Members.

Elected.		
1908		Abbott, George Henry, B.A., M.B., Ch. M., 'Kylemore,' 181 Stanmore-road, Petersham.
1877	P 5	Abbott, W. E., 'Abbotsford,' Wingen.
1895		Adams, J. H. M., Broughton Cottage, St. James' Rd., Waverley.
1904		Adams, William John, M. I. Mech. E., 163 Clarence-street.
1906		Adams, Walter E., Assistant Engineer, Sydney Harbour Trust, Circular Quay.
1890	P 2	Allan, Percy, M. Inst. C.E., Assoc. Am. Soc. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ld., Cement Works, Granville.
1905		Anderson, Charles, M.A., D. Sc., *Edin.*, 'Waratah,' Lower Ocean-street, Double Bay.
1903		Arnot, Arthur James, Assoc. M. Inst. C.E., M. I. Mech. E., M.I.E.E., Electrical Engineer, 83 Pitt-street.
1899	P 1	Atkinson, A. A., Chief Inspector of Collieries, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 13	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1894		‡Balsille, George, 'Lauderdale,' N.E. Valley, Dunedin, N.Z.
1896		Barff, H. E., M.A., Registrar, Sydney University.
1908	P 1	Barling, John, 'St. Adrians,' Raglan-street, Mosman.
1895	P 9	Barraclough, S. Henry, B.E., M.M.E., Assoc. M. Inst. C.E., M. I. Mech. E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Lecturer in Mechanical Engineering, Sydney University; p.r. 'Marmion,' Victoria-street, Lewisham.
1906		Basnett, Nathaniel James, Accountant, 'Loorose,' Punch-st., Mosman.
1894		Baxter, William Howe, Chief Surveyor, Existing Lines Office, Railway Department, Bridge-street.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1900		Bender, Ferdinand, Accountant and Auditor, 21 Elizabeth-street, North.
1905		Bignold, Hugh Baron, Barrister-at-Law, Chambers, Wentworth Court, 64 Elizabeth-street.
1906		Binnie, Herbert, 524 Kent-st.; p.r. 'Seabright,' Woollahra P

Elected

1905 Blakemore, George Henry, General Manager, Great Cobar Ld., Australian Club, Macquarie-street.

1888 ‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond*, Fremantle, West Australia.

1893 Blomfield, Charles E., B.C.E. *Melb.*, 'Woombi,' Kangaroo Camp, Guyra.

1898 Blunno, Michele, Licentiate in Science (Rome), Government Viticultural Expert, Department of Agriculture, Sydney.

1905 Board, Peter, M.A. *Syd.*, Under Secretary and Director of Education, Department of Public Instruction, Sydney.

1907 Bogenrieder, Charles, Mining and Consulting Engineer, 4 Clifton-street off Nicholson Road, Balmain.

1879 ‡Bond, Albert, 131 Bell's Chambers, Pitt-street.

1907 Boyd, Robert James, M.E., Assoc. M. Inst. C.E., 'Greenstead,' Park Road, Burwood.

1876 Brady, Andrew John, Lic. K. & Q. Coll. Phys. *Irel.*, Lic. R. Coll. Sur. *Irel.*, 3 Lyons Terrace, Hyde Park.

1891 Brennand, Henry J. W., B.A., M.B., Ch. M. *Syd.*, F.R.A.S., F.G.S., 'Wabun,' 310 Miller-street, N. Sydney.

1902 Brereton, Victor Le Gay, Solicitor, Royal Chambers, Hunter-street; p.r. 'Osgathorpe,' Gladesville.

1878 ‡Brooks, Joseph, F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.

1876 Brown, Henry Joseph, Solicitor, Newcastle.

1906 Brown, James B., Resident Master, Technical School, Granville; p.r. 'Kingston,' Merrylands.

1903 Bruck, Ludwig, Medical Publisher, 15 Castlereagh-street.

1898 ‡Burfitt, W. Fitzmaurice, B.A., B. Sc., M.B., Ch. M., *Syd.*, 357 Glebe Road, Glebe Point.

1890 Burne, Dr. Alfred, Dentist, 1 Lyons Terrace, Liverpool-street.

1907 Burrows, Thomas Edward, M. Inst. C.E., L.S., Metropolitan Engineer, Public Works Department; p.r. 'Balboa,' Fern-street, Randwick.

1880 Bush, Thomas James, M. Inst. C.E., Australian Gas-light Company, 153 Kent-street.

1904 Cambage, Richard Hind, F.L.S., Chief Mining Surveyor, p.r. Park Road, Burwood.

1907 Campbell, Alfred W., Medical Practitioner, 183 Macquarie-st.

1900 Canty, M., 'Rosemont,' 13 York-street, Wynyard Square.

1876 Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Rd., Edgecliffe.

1897 P 4 Cardew, John Haydon, M. Inst. C.E., L.S., 75 Pitt-street.

1901 Card, George William, A.R.S.M., F.G.S., Curator and Mineralogist to the Geological Survey, N.S.W., Deparsment of Mines.

1891 Carment, David, F.I.A. *Grt. Brit. & Irel.*, F.F.A, *Scot.*, Australian Mutual Provident Society, 87 Pitt-st. *Hon. Treasurer.*

1903 Carslaw, H. S., M.A., D. Sc., Professor of Mathematics, Sydney University, Glebe.

1879 P 1 ‡Chard, J. S., Licensed Surveyor, Armidale.

1908 Chauleur, Paul, Hon. Secretary and Treasurer of the French Chamber of Commerce, Officier d'Académie (France), 2 Bond-street Chambers.

1907 Cobham, Allan Blenman, 'Garthowen,' Myahgah Road, Mosman.

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1896	P 2	Cook, W. E., M.C.E. *Melb.*, M. Inst. C.E., Water and Sewerage Board, North Sydnsy.
1904	P 2	Cooksey, Thomas, Ph. D., B. Sc. *Lond.*, F.I.C., Second Government Analyst; p.r 'Clissold,' Calypso Avenue, Mosman.
1876		Codrington, John Frederick, M.R.C S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, Fuller's Road, Chatswood.
1906		Colley, David John K., Superintendent Royal Mint, Sydney.
1876		Colyer, J. U. C., 'Malvern,' Collingwood and Seymour-streets, Drummoyne.
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1892	P 1	Davis, Joseph, M. Inst. C.E., London.
1907		Davys, Hubert John, c/o Messrs. Clutterbuck Bros. & Co., Builders' Exchange, Castlereagh-street; p.r. 'La Bohéme,' Marshall-street, Manly.
1885	P 3	Deane, Henry, M.A., M. Inst. C.E., F.L.S., F. R. Met. Soc., F.R.H.S., Equitable Building, George-st.; p.r. 'Blanerne,' Wybalena Road, Hunter's Hill. *Vice-President.*
1877		Deck, John Feild, M.D. Univ. *St. Andrews*, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 203 Macquarie-st.; p.r. 92 Elizabeth-st., Ashfield.
1899	P 1	De Coque, J. V., c/o Messrs. Gibbs, Bright & Co., 37 Pitt-st.
1894		Dick, James Adam, B.A. *Syd.*, M.B., C.M. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., F.I.C., 97 Pitt-street.
1880		Dixson, Thomas Storie, M.B. *Edin.*, Mast. Surg. *Edin.*, 151 Macquarie-street.
1906		Dixson, William, 'Abergeldie,' Summer Hill.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Eltham,' Edgecliffe Road.
1899	P 1	Duckworth, A., F.R.E.S., A.M.P. Society, 87 Pitt-street; p.r. 'Trentham,' Woollahra.
1873	P 2	Du Faur, E., F.R.G.S., 'Flowton,' Turramurra.
1908		Dun, William S., Palæontologist, Department of Mines.
1906		Epps, William, Secretary, Royal Prince Alfred Hospital, Camperdown, Sydney.
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Elected		
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1876		Evans, George, Fitz Evan Chambers, Castlereagh-street.
1877		‡Fairfax, Edward Ross, *S. M. Herald* Office, Hunter-street.
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1868		Fairfax, Sir James R., Knt., *S. M. Herald* Office, Hunter-st.
1887		Faithfull, R. L., M.D. *New York* (Coll. Phys. & Surg.), L.R.C.P. L.S.A. *Lond.*, 18 Wylde-street.
1902		Faithfull, William Percy, Barrister-at-Law, Australian Club.
1881		Fiaschi, Thos., M.D., M.Ch. *Pisa*, 149 Macquarie-street.
1888		Fitzhardinge, Grantly Hyde, M.A. *Syd.*, District Court Judge, 'Red Hill,' Beecroft.
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1902		Fleming, Edward G., A.M.I.E.E., 16 O'Connell-street.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 141 Macquarie-st.
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1904		Fraser, James, M. Inst. C.E., Engineer-in-Chief for Existing Lines, Bridge-street; p.r. 'Arnprior,' Neutral Bay.
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1879		Gerard, Francis, 'The Grange,' Monteagle, near Young.
1859		Goodlet, J. H., 'Canterbury House,' Ashfield.
1906		Gosche, Vesey Richard Consul for Nicaragua, 15 Grosvenor-st.
1906		Gosche, W. A. Hamilton, Electrical Engineer, 40 and 42 Clarence-street.
1897		Gould, Senator, The Hon. Sir Albert John, 'Eynesbury,' Edgecliffe.
1907		Green, W. J., Chairman, Hetton Coal Co., Athenæum Club.
1899		Greig-Smith, R., D.Sc. *Edin.*, M.Sc. *Dun.*, Macleay Bacteriologist, Linnean Society's House, Ithaca Road, Elizabeth Bay.
1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c., c/o W. Tarleton, 93 Pitt-street.
1899	P 2	Gummow, Frank M., M.C.E., Vickery's Chambers, 82 Pitt-st.
1891	P 12	Guthrie, Frederick B., F.I.C., F.C.S., Chemist, Department of Agriculture, 136 George-street, Sydney. *Hon. Secretary.*
1880	P 3	Halligan, Gerald H., F.G.S., 'Riversleigh,' Hunter's Hill.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1887	P 7	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; Government Analyst, Health Department, Macquarie-street, North. *President.*
1905	P 1	Harker, George, D.Sc., 35 Boulevarde, Petersham.

Elected		
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1887	P 20	‡Hargrave, Lawrence, Wunulla Road, Woollahra Point.
1884	P 1	Haswell, William Aitcheson, M.A., D. Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. 'Mimihau,' Woollahra Point.
1900		Hawkins, W. E., Solicitor, 88 Pitt-street.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1900	P 3	Helms, Richard, Experimentalist, Department of Agriculture.
1906		Henning, Edmund Tregenna, B.E. *Syd.*, 'Passy,' Hunter's Hill.
1899		Henderson, J., F.R.E.S., Manager, City Bank of Sydney, Pitt-st.
1899		Henderson, S., M.A., Assoc. M. Inst. C.E., Equitable Building, George-street.
1884	P 1	Henson, Joshua B., Assoc. M. Inst. C.E., Hunter District Water, Supply and Sewerage Board, Newcastle.
1905		Hill, John Whitmore, Architect, 'Willamere,' May's Hill, Parramatta.
1876	P 2	Hirst, George D., F.R.A.S., 379 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, 147 Macquarie-st.
1892		Hodgson, Charles George, 157 Macquarie-street.
1901		Holt, Thomas S., 'Sutherland House,' Sylvania.
1905		Hooper, George, Registrar, Sydney Technical College; p.r. 'Branksome,' Henson-street, Summer Hill.
1905		Hoskins, George J., M. I. Mech. E., Burwood Road, Burwood.
1907		Hoskins, George Herbert, St. Cloud,' Burwood-rd., Burwood.
1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 63 Pitt-street.
1906		Howle, Walter Creswell, Medical Practitioner, Pambula, New South Wales.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Acting Chief Inspector of Mines, Geological Surveyor, Department of Mines.
1904		Jenkins, R. J. H., Fisheries Commissioner, 'Pyalla,' 13A Selwyn-street, Moore Park.
1905	P 5	Jensen, Harold Ingemann, D. Sc., Macleay Fellow of the Linnean Society of New South Wales, 'Roslyn,' Plunkett-street, Drummoyne.
1907		Johnson, T. R., M. Inst. C.E., Chief Commissioner of New South Wales Railways.
1902		Jones, Henry L., Assoc. Am. Soc. C.E., 14 Martin Place.
1884		‡Jones, Llewellyn Charles Russell, Solicitor, Falmouth Chambers, 117 Pitt-street.
1867		Jones, Sir P. Sydney, Knt., M.D., *Lond.*, F.R.C.S. *Eng.*, 16 College street, Hyde Park; p.r. 'Llandilo,' Boulevard, Strathfield.
1876	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., Stephen Court, 81 Elizabeth-street; p.r. Kallara.
1907		Kaleski, Robert, Agricultural Expert, Holdsworthy, Liverpool.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873	P 2	Keele, Thomas William, M. Inst. C.E., Commissioner, Sydney Harbour Trust, Circular Quay; p.r. Llandaff-st., Waverley.
1906		Keenan, Rev. Bernard, D.D. etc., 'Royston,' Rose Bay.
1887		Kent, Harry C., M.A., F.R.I.B.A., Bell's Chambers, 129 Pitt-st.

Elected		
1903	P 1	Kennedy, Thomas, Assoc. M. Inst. C.E., Public Works Department.
1901		Kidd, Hector, M. Inst. C.E., M. I. Mech. E., 'Craig Lea,' 15 Mansfield-street, Glebe Point.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Public Works Department, Newcastle.
1896		King, Kelso, 120 Pitt-street.
1892		Kircaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.G.S. *Irel.*, 1 Lyons Terrace, Hyde Park.
1881	P 18	Knibbs, G. H., F.R.A.S., Memb. Internat. Assoc. Testing Materials; Memb. Brit. Sc. Guild; Commonwealth Statistician, Melbourne.
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1906		Lee, Alfred, Merchant, 'Glen Roona,' Penkivil-st., Bondi-
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1901		Little, Robert, 'The Hermitage,' Rose Bay.
1872	P 57	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S., Hon. F.R.S. *Edin.*, Assoc. Roy. Sch. Mines, *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon, Fel. Roy. Historical Soc. *Lond.*; Mem. Phys. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France;* Corr. Mem. Edin. Geol. Soc.; New York Acad. of Sciences; Roy. Soc. *Tas.*; Roy. Soc., *Queensland;* Senckenberg Institute, *Frankfurt;* Société d' Acclimat., *Mauritius;* Foreign Corr. Indiana Acad. of Sciences; Hon. Mem. Roy. Soc., *Vict.*; N. Z. Institute; K. Leop. Carol. Acad., *Halle a/s;* The United University Club, Suffolk-st., Pall Mall, London W.
1906		Loney, Charles Augustus Luxton, M. Am. Soc. Refr. E., Equitable Building, George-street.
1884		MacCormick, Alexander, M.D., C.M *Edin.*, M.R.C.S. *Eng.*, 185 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1868		MacDonnell, William J., 4 Falmouth Chambers, 117 Pitt-st.
1903		McDonald, Robert, J.P., Under Secretary for Lands, p. r. 'Wairoa,' Holt-street, Double Bay.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H, *Cantab.*, Hospital for Insane, Gladesville.
1906		McIntosh, Arthur Marshall, Dentist, 'Dalmore,' Albert Avenue, Chatswood.
1891	P 2	McKay, R. T., Assoc. M. Inst. C.E., 'Tranquilla.' West-st., North Sydney.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch. M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, Equitable Building, George-street,
1904		McKenzie, Robert, Sanitary Inspector, (Water and Sewerage Board), 'Stonehaven Cottage,' Bronte Road, Waverley.

Elected		
1880	P 9	McKinney, Hugh Giffin, M.E., Roy. Univ. *Irel.*, M. Inst. C.E., Australian Club, Macquarie-street.
1903		McLaughlin, John, Solicitor, Clement's Chambers, 88 Pitt-st.
1876		MacLaurin, The Hon. Sir Henry Normand, M.L.C., M.A. M.D., L.R.C.S. *Edin.*, LL.D. *St. Andrews*, 155 Macquarie-street.
1901	P 1	McMaster, Colin J., Chief Commissioner of Western Lands; p.r. Wyuna Road, Woollahra Point.
1894		McMillan, Sir William, 'Logan Brae,' Waverley.
1899		MacTaggart, J. N. C., M.E. *Syd.*, Assoc. M. Inst. C.E., Water and Sewerage Board District Office, Lyons Road, Drummoyne.
1882	P 1	Madsen, Hans F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 18	Maiden, J. Henry, J.P., F.L.S., Hon. Fellow Roy. Soc., S. A.; Hon. Memb. Nat. Hist. Soc., W.A.; Netherlands Soc. for Promotion of Industry; Philadelphia Coll. Pharm.; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc., Lond.; Corr. Memb. Pharm. Soc. Great Britain; Bot. Soc. Edin.; Soc. Nac. de Agricultura (Chile); Soc. d' Horticulture d' Alger; Union Agricole Calédonienne; Soc, Nat. etc., de Chérbourg; Roy. Soc. Tas.; Inst. Nat. Genévois; Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1906		Maitland, Louis Duncan, Dental Surgeon, 6 Lyons' Terrace, Liverpool-street.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1897		Marden, John, B.A., M.A., LL.B. *Melb.*, LL.D. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1908		Marshall, Frank, B.D.S. *Syd.*, Dental Surgeon, 141 Elizabeth-st.
1875	P 25	Mathews, Robert Hamilton, L.S., Assoc. Etran. Soc. d'Anthrop. de Paris; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem. Anthrop. Soc,, Vienna; Cor. Mem. Roy. Geog. Soc. Aust.,Queensland; 'Carcuron,' Hassall-st., Parramatta.
1908		Meares, Frederick Thomas Devenish, c/o Messrs. Crossley Bros. Ld., 37 Wynyard Square.
1903		Meggitt, Loxley, Manager Co-operative Wholesale Society, Alexandria.
1896	P 7	Merfield, Charles J., F.R.A.S., Mitglied der Astronomischen Gesellschaft, Observatory, South Yarra, Melbourne.
1905		Miller, James Edward, Barton-street, Cobar.
1889	P 8	Mingaye, John C. H., F.I.C., F.C.S., Assayer and Analyst to the Department of Mines, Government Metallurgical Works, Clyde; p.r. Campbell-street, Parramatta.
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1876		Myles, Charles Henry, 'Dingadee,' Everton Rd., Strathfield.
1893	P 1	Nangle, James, Architect, 'St. Elmo,' Tupper-st., Marrickville.
1901		Newton, Roland G., B.A. *Syd.*, 'Walcott,' Boyce-st., Glebe Point.
1891		‡Noble, Edwald George, Public Works Department, Newcastle.
1893		Noyes, Edward, Assoc. Inst. C.E., Assoc. I. Mech. E., c/o Messrs. Noyes Bros., 109 Pitt-street.

Elected		
1903		Old, Richard, Solicitor, 'Waverton,' Bay Rd., North Sydney.
1896		Onslow, Lt. Col. James William Macarthur, Camden Park, Menangle.
1875		O'Reilly, W. W. J., M.D., M. Ch., Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street, Hyde Park.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1883		Osborne; Ben. M., J.P., 'Hopewood,' Bowral.
1906		Oschatz, Alfred Leopold, Teacher of Languages, 46 High-st., North Sydney.
1903		Owen, Rev. Edward, B.A., All Saints' Rectory, Hunter's Hill.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1906		Pawley, Charles Lewis, Dentist, 137 Regent-street.
1901		Peake, Algernon, Assoc. M. Inst. C.E., 25 Prospect Road, Ashfield.
1899		Pearse, W., Union Club; p.r. Moss Vale.
1877		Pedley, Perceval R., 227 Macquarie-street.
1899		Petersen, T. Tyndall, Member of Sydney Institute of Public Accountants, Copper Mines, Burraga.
1879	P 7	Pittman, Edward F., Assoc. R. S. M., L.S. Under Secretary and Government Geologist, Department of Mines.
1896		Plummer, John, 'Northwood,' Lane Cove River; Box 413 G.P,O.
1881		Poate, Frederick, Lands Office, Moree.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887	P 5	Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, D. Sc., *Syd.*, Professor of Physics, Sydney University.
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon 235 Macquarie-street.
1893		Purser, Cecil, B.A., M.B., Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1901	P 1	Purvis, J. G. S., Water and Sewerage Board, 341 Pitt-street.
1908		Pye, Walter George, M. A., B. Sc., Nield Avenue, Paddington.
1876		Quaife, F. H., M.A., M.D., Mast. Surg. *Glas.*, 'Hughenden,' 14 Queen-street, Woollahra. *Vice-President.*
1890	P 1	Rae, J. L. C., 'Endcliffe,' Church-street, Newcastle.
1865	P 1	‡Ramsay, Edward P., LL D. *St. And.*, F.R.S.E., F.L.S., 8 Palace-street, Petersham.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 159 Macquarie-street.
1906		Redman, Frederick G., P. and O. Co., Pitt-street.
1902		Richard, G. A., Mount Morgan Gold Mining Co., Mount Morgan, Queensland.
1906		Richardson, H. G. V., Equitable Chambers, Lismore.
1892		Rossbach, William, Assoc. M. Inst. C.E., Public Works Department, Sydney.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, 147 Macquarie-st.
1905	P 1	Ross, Herbert E., Equitable Building, George-street.

Elected		
1904	P 2	Ross, William J. Clunies, B. Sc. *Lond. & Syd.*, F.G.S., Lecturer in Chemistry, Technical College, Sydney.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-street, and Union Club.
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 369 George-street; p.r. 'Mahuru,' Fairfax Road, Bellevue Hill.
1893		Rygate, Philip W., M.A., B.E. *Syd.*, Assoc. M. Inst. C.E., Phœnix Chambers, 158 Pitt-street.
1905		Scheidel, August, Ph. D., Managing Director, Commonwealth Portland Cement Co., Sydney; Union Club.
1899		Schmidlin, F., 83 Elizabeth-street, Sydney.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., University, Sydney.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1877	P 4	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1904	P 1	Sellors, R. P., B.A. *Syd.*, 'Cairnleith,' Military Road, Mosman.
1908		Sendey, Henry Franklin, Manager of the Union Bank of Australia, Ld., Sydney, Union Club.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Inspecting Engineer, Existing Lines Office, Bridge-street.
1905		Simpson, D. C., M. Inst. C.E., N.S. Wales Railways, Redfern; p.r. 'Omapere,' Lane Cove Road, North Sydney.
1900		Simpson, R. C., Technical College, Sydney.
1882		Sinclair, Eric, M.D., C.M. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain; p. r. Cleveland-street, Wahroonga.
1893		Sinclair, Russell, M.I. Mech. E., etc., Vickery's Chambers, 82 Pitt-st.
1891	P 3	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1907		Smith. Guy P., 'Earlscourt,' Glenferrie, Melbourne.
1893	P 36	Smith, Henry G., F.C.S., Assistant Curator, Technological Museum, Sydney.
1907		Smith, Horace Alexander, F.S.S., 'Yalaroi,' Moruben Road, Mosman.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1896		Spencer, Walter, M.D. *Brux.*, Ch. D., M.R.C.S., L.R.C.P. *Eng.*, Corresponding Member, Royal College of Medicine, Chief Medical Officer Sydney Rescue Work Society; 'Milton,' Edgeware Road, Enmore. *Vice-President.*
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., Cumberland Heights, Parramatta.
1900		Stewart, Professor J. D., M.R.C.V.S., University of Sydney; p.r. Cowper-street, Randwick.
1903		Stoddart, Rev. A. G., The Rectory, Manly.
1883	P 4	Stuart, T. P. Anderson, M.D., LL.D. *Edin*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay. *Vice-President.*
1901	P 2	Süssmilch, C. A,, Technical College, Sydney.
1907		Sutherland, David Alex., F.I.C., Equitable Building, George-st.

Elected		
1906		Taylor, Allen, (Lord Mayor) 'Ellerslie,' 85 Darlinghurst Road.
1906		Taylor, Horace, Registrar, Dental Board, 7 Richmond Terrace, Domain.
1905		Taylor, John M., M.A., LL.B. *Syd.*, 'Woonona,' 43 East Crescent-street, McMahon's Point, North Sydney.
1893		‡Taylor, James, B. Sc., A.R.S.M., 'Adderton,' Dundas.
1899		Teece, R., F.I.A., F.F.A., General Manager and Actuary, A.M.P. Society, 87 Pitt-street.
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, John Stuart, Solicitor, Athenœum Chambers, 11 Castlereagh-street.
1878		Thomas, F. J., Newcastle and Hunter River Steamship Co. 147 Sussex-street.
1879		Thomson, Hon. Dugald, M.H.R., Carabella-st., North Sydney.
1885	P 2	Thompson, John Ashburton, M.D *Brux.*, D.P.H. *Cantab.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt, A. J. Onslow, Camden Park, Menangle.
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., Locomotive Department, Eveleigh.
1894		Tooth, Arthur W., Kent Brewery, 26 George-street, West.
1879		Trebeck, P. C., F. R. Met. Soc., 12 O'Connell-street.
1900		Turner, Basil W., A.R.S.M., F.C.S., Wood's Chambers, Moore-st.
1905		Turner, John William, Director, Technical College, Sydney.
1883		Vause, Arthur John, M.R., C.M. *Edin.*, 'Bay View House,' Tempe.
1890		Vicars, James, M.C.E., City Engineer and Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1903	P 3	Vonwiller, Oscar U., B.Sc. Demonstrator in Physics, University of Sydney.
1876		Voss, Houlton H., J.P., Union Club, Sydney.
1906		Wade, James Scargill, Assoc. M. Inst. C.E., Legaspi, Island of Luzon, Phillipine Islands.
1898	P 1	Wade, Leslie A. B., M. Inst. C.E., Department of Public Works.
1907		Waley, F. G., Assoc. M. Inst. C.E., c/o Belambi Coal Co. Ltd., Bridge-street.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, Senator The Hon. J. T., 'Wallaroy,' Edgecliffe Road, Woollahra.
1901		Walkom, A. J., A.M.I.E.E., Electrical Branch, G.P.O., Sydney.
1991	P 1	Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Engineer-in-Chief, Harbour Trust, Circular Quay.
1903		Walsh, Fred., George and Wynyard-streets ; p.r. 'Walsholme,' Centennial Park, Sydney E.
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1898		Wark, William, Assoc. M. Inst. C.E., 9 Macquarie Place ; p.r. Kurrajong Heights.
1883	P 16	Warren, W. H., Wh. Sc., M. Inst. C.E., Mem. Am. Soc. C.E., Member of Council of the International Society for Testing Materials, Professor of Engineering, University of Sydney.

Elected		
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, Macquarie-st.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1908		Weatherburn, Chas. Ernest, M.A., B. Sc. *Syd*, B.A. *Cantab.*, 11 Myrtle-street.
1897		Webb, Frederick William, C.M.G., J.P., 'Livadia.' Manly.
1903		Webb, A. C. F., M.I.E.E., Vickery's Chambers, 82 Pitt-street.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Town Hall, Sydney.
1907		Weedon, Stephen Henry, C.E., 'Kurrowah,' Alexandra.street, Hunter's Hill.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1907		Welch, William, F.R.G.S., 'Roto-iti,' Boyle-street, Mosman.
1881		‡Wesley, W. H.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Qnantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, Sellinge,' Albert-st., Woollahra.
1907		Wiley, William, 'Kenyon,' Kurraba Point, Neutral Bay.
1876		Williams, Percy Edward, Commissioner, Government Savings Bank, Sydney.
1908		Willis, Charles Savill, M.B., Ch. M. *Syd.*, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H., Roy. Coll. P. & S. *Lond.*, Department of Public Health.
1901		Willmot, Thomas, J.P., Toongabbie.
1878		Wilshire, James Thompson, F.R.H.S., J.P., 'Coolooli,' Bennett Road, Neutral Bay.
1890		Wilson, James T., M.B., Ch. M., *Edin.*, Professor of Anatomy, University of Sydney.
1907		Wilson, William Claude, Assistant Engineer, Public Works Department, Sydney.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1906	P 3	Woolnough, Walter George, D. Sc., F.G.S., Demonstrator in Geology, University of Sydney.
1902		Wright, John Robinson, Lecturer in Art, Technical College, Harris-street, Sydney.

HONORARY MEMBERS.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1905		Cannizzaro, Stanislao. Professor of Chemistry, Reale Università Rome.
1900		Crookes, Sir William, F.R.S., 7 Kensington Park Gardens, London W.
1905		Fischer, Emil, Professor of Chemistry, University, Berlin.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., c/o Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.

Elected		
1901		Judd, J.W., C.B., LL.D., F.R.S., F.G.S., Professor of Geology, Royal College of Science, London; 30 Cumberland Road, Kew, England.
1908		Kennedy, Sir Alex. B. W., LL.D., F.R.S., 17 Victoria-street, Westminster, London S.W.
1903		Lister, Right Hon. Joseph, Lord, O.M., B.A., M.B., F.R.C.S. D.C.L., F.R.S., Hon. M. Inst. C.E., etc., 12 Park Crescent, Portland Place, London, W.
1908		Liversidge, Prof., M.A., LL.D., F.R.S., The United University Club, Suffolk-street, Pall Mall, London S.W.
1901		Newcomb, Professor Simon, LL.D., Ph. D., For. Mem. R.S. Lond., United States Navy, Washington.
1905		Oliver, Daniel, LL.D., F.R.S., Emeritus Professor of Botany, University College, London.
1894		Spencer, W. Baldwin, M.A., C.M.G., F.R.S., Professor of Biology, University of Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., B.Sc. F.R.S., F.L.S., late Director, Royal Gardens, Kew.
1908		Turner, Sir William, K.C.B., M.B., D.C.L., LL.D., Sc. D., F.R.C.S. *Edin.*, F.R.S., 6 Eton Terrace, Edinburgh, Scotland.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Old Orchard, Broadstone, Wimborne, Dorset.

Obituary 1908.

Ordinary Members.

1890		Haycroft, J. I.
1874		Lenehan, H. A.
1887		Munro, Dr. W. J.
1870		Renwick, Sir Arthur.
1886		Smith, W. A.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

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

Vice-President from 1866 *to* 1878.

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

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

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

1880 *Professor Thos. Huxley, F.R.S., The Royal School of Mines, London.

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

1882 *Professor James Dwight Dana, LL.D.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1901 *Edward John Eyre.

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

1903 *Alfred William Howitt, D. Sc. *Cantab.*, F.G.S., Hon. Fellow Anthropol. Inst. of Gt. Brit. and Irel.

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

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

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

Money Prize of £25.

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

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

The Society's Bronze Medal and £25.

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

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

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

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

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

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

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

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

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

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

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

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

PRESIDENTIAL ADDRESS.

By HENRY DEANE, M.A., M. Inst. C.E., etc.

[*Delivered to the Royal Society of N.S. Wales, May 6, 1908.*]

I HAVE taken for the subject of my address some railway matters—

Closer Settlement and Economical Construction of Railways.—Much has been said as to the necessity for encouraging closer settlement and bringing population in from outside Australia to help in accomplishing this end. There may be several reasons for encouraging and assisting immigration when the natural increase of the population of the country does not suffice to meet the want. First of all there is the question of defence. We have such large uninhabited and sparcely inhabited tracts, that it is not unreasonable to expect that these areas may excite the cupidity of the yellow skinned nations to the north and north-west of us, and the only way to counteract that tendency, is to provide for the settlement of the land by desirable white people, preferably of our own race, who would thus be able to help in the defence of the country.

Another advantage in closer settlement is that, at any rate within certain limits, living is cheaper and more comfortable as produce is brought nearer to hand by railway; as villages and towns spring up and opportunities for social intercourse multiply, wealth increases and the well being of the community advances. The United States of America and Canada are notable examples of the rapid growth of population and its advantages. Towns spring up and business grows: people established in the country accumulate wealth, while those arriving see a similar chance for themselves in the future. It goes without saying that the cost

of government should be less in proportion as population increases, and thus the whole community should be the gainer.

Closer settlement could not take place without railways, and when this question presents itself, the need for more railways has also to be considered. As pastoral lands become cut up and devoted to agricultural purposes, thereby inducing a larger population, the produce per acre increases in bulk, there is a larger amount of freight to be transported, and the revenue to be derived therefrom justifies the construction of railways, where previously they would not pay. Wool being a high priced article valued by the pound, may be conveyed very considerable distances by road without the cost of carriage acting as a serious deterrent to its production. On the other hand, because a pound or two only may be produced on an acre, it certainly does not pay to run parallel railways too close to one another, probably 50 miles is about the limit to which it would pay to bring railways into proximity, and therefore parallel lines may perhaps be economically placed about 100 miles apart. When it comes to closer settlement, and instead of the land carrying one sheep to two or more acres the soil is cultivated and so made to carry from 10 to 20 bushels of wheat per acre, it pays to extend the railway system and put in parallel lines at closer intervals. The value of wheat or other crops does not permit of long cartage by road of more than about 15 miles, so that to serve the wheat districts the railway should be laid out so as to approach each spot within a radius of say, 15 miles, that is to say that parallel lines should not be more than double that distance or 30 miles apart.

In laying out a scheme of railways we have also to bear in mind that there is another kind of traffic to be provided for. The climate of our country is so precarious that while

some areas are enjoying favourable seasons others may be suffering from intense drought, as is the fact at the present time. It is incumbent, therefore, that cross country lines should be taken in hand so that stock may be conveyed from one district to another by the nearest route, and that the carrying of fodder cheaply from favoured parts into others suffering from drought may be facilitated.

If such railways can be constructed economically, a greater mileage can be built for the same money. Economy is thus all the more desirable, but in this case cheapness must not be sought in reduction of gauge, as no break should be tolerated where stock has to be carried. The changing of stock from one car to another is not only difficult, but in some cases highly detrimental.

Economy in construction is of vital importance where traffic is light and the returns small, and this principle holds not only in the remote interior but also nearer at hand. We have along the coast tracts pining, as it were, for better communication, and yet because the country is rough and intersected by rivers, and construction therefore costly, they have not yet been put in hand. In such districts the cartage is expensive on account of the steep and hilly character of the roads, and yet railways have been hitherto considered impracticable, because the cost is supposed to be prohibitive. It is not every district that can be favoured as the Richmond River has been, with a railway costing £14,000 per mile or more. But need the cost of making such lines be prohibitive? Certainly it may be so if sharp curves may not be used, but the difference in the conditions of a district supporting a main line with large traffic and those of a branch only with small traffic should be borne in mind. When the railway was laid over the Blue Mountains, 8 chain curves were adopted, but as the traffic increased and larger and heavier engines came into use,

these curves were found objectionable on account of resistance and wear and have for the most part been cut out. For branch lines however, the adoption of such curves in question is quite right, in fact much sharper curves may be inserted, as has been shown on the line recently constructed by me for the Commonwealth Oil Corporation Ltd., from the Western Railway into the Wolgan Valley, but I will refer to this later on.

What I want to emphasise is, not that lines should not be made with the best curves and grades possible, but that the desire for these is often out of all proportion to the necessities of the case. It is a good thing to be able to travel fast and with big loads, but when speed is not required and there are no big loads to carry, as is generally the case at the opening up of the country, it would be folly to incur unnecessary expense, and yet it would be a mistake to altogether prohibit the construction of railways, simply because the cost of putting in the best grades and curves is excessively heavy. Any railway must be better than none.

To take an example, I think most people will agree with me that it would be a shame to indefinitely postpone the construction of the much discussed connection with the rich Dorrigo country, simply because the cost of making a line suitable for express trains to run on would be prohibitive. What is wanted there is a cheap line; whether on the narrow gauge or on the standard gauge remains to be seen, and this end cannot be reached without sharp curves and perhaps steep grades, and it is for the rolling stock engineers to provide locomotives to suit the country, inasmuch as the country cannot be adapted to the usual type of rolling stock.

I remember reading somewhere a definition of an engineer as a man who could do with one dollar what any

fool could do with two, and certain it is that apart from difficult design, economy of construction is a matter that engineers should pride themselves on. They like to have the opportunity of spending large sums of money when this is necessary, on account of the magnitude or difficulty of the operations, but big schemes will cost less if proper engineering skill is applied, and it is the business of the engineer to keep down cost through intelligent application of brains.

Although I am urging economy in railway making, I wish it to be distinctly undersrood that I am not speaking of mere cheapness, although in some cases if money is short even that may be true economy. To judge of what is meant by the use of this word, it is well to search the dictionary and look for the derivation of the term, I find in the edition of Webster nearest to hand, under *economy:*

"1. The management, regulation and government of a family or the concerns of a household."

That is as everyone knows the original meaning of the Greek compound word from which our own word is derived. The next meaning given implies a more general use applied to other concerns outside.

"2. The management of pecuniary concerns or the expenditure of money."

"3. A frugal and judicious use of money; frugality in the necessary expenditure of money."

And then the lexicographer goes on to say:—

"It differs from *parsimony* which implies an improper saving of expense."

There are other derived meanings, but they do not concern us. What we wish to do when we want to practise economy is to get the cheapest thing, which will thoroughly serve the purpose, not necessarily the cheapest of all, but

the cheapest with the limitation that it must thoroughly serve the purpose, and if durability is wanted and is obtainable with what is absolutely the cheapest, then it is in accordance with this limitation. I might point out that economy does not always exclude attention to questions of comfort or even luxury. These may be the conditions of the problem set and with these in view as necessities of the case, economy may still be studied. One of the conditions of a problem in the design of a railway may be that high speed is a *sine qua non.* This does not exclude the consideration of economy, as it is quite certain that there is scope for extravagance if the work is carried out regardless of cost and outside the necessities of the case. If low speed only is required, a condition of things obtaining at the present time on many longer and shorter branches of our railway system, it would be foolish to spend money in excessive strength, curves of large radius and easy gradients, when the end would be met by cheaper construction. Of course the same conditions are not always present, and what would be proper expenditure in one case would be extravagance in another, and on the other hand what would be parsimony in one case would be reasonable economy in another.

The question of what money there is available often affects the design, and expenditure may be thus limited by want of adequate funds. When this is the case it cannot be helped. One must put up with it. One must cut one's coat according to one's cloth. Engineers cannot always exercise what they would think to be true economy because they cannot always get enough money. This is not infrequently the case even where State expenditure is concerned, and shortness of funds may arise at times not only from the reluctance of Parliament to vote the means required, but on other occasions on account of the unwillingness of the British public to lend the money. An example of the

former case in times past may be referred to, when from ignorance or parsimony it was actually proposed to extend the railway system after Penrith and Picton had been reached on the western and southern railways respectively, by means of a horse tramway at £4,000 per mile instead of a railway, and a great fight ensued when my predecessor in office, backed up by the late Governor Young and some other far-seeing men, eventually gained the day and succeeded in persuading Parliament that a horse tramway would not meet the case, but that a proper railway must be made even if it involved 1 in 30 grades, 8 chain curves and zigzags. Here the adoption of the tramway would have been very false economy.

When the construction of a railway was finally decided upon, two estimates were submitted by the Engineer-in-Chief, one for £8,000 per mile with sharp curves and grades, the other I think £25,000 per mile. There is no doubt that in this case it was right to choose the cheaper line—circumstances did not warrant the higher expenditure.

During the construction of the line over the Blue Mountains and beyond, the contractors had actually to be requested not to proceed too fast, as there might not be enough money in the Treasury to meet their claims. Here was a case where the British public were not ready to supply the money needed.

If those extensions were only now under consideration we should lay them out in a different manner. They were not built as we should construct a main line to-day, yet, at that time, with the difficulty of getting money at all, it was true economy to spend as little as possible. From the point of view of the traffic to be carried, about 40 tons per day, cheapness was most desirable, but even that involved a very large total expenditure, and we must give great credit to the people's representatives when they voted the

money, and it showed great confidence in the future of this part of Australia. The conditions of those times, when the traffic across the mountains was only 40 tons per day, were very diffierent from those existing at the present day, when at times, in spite of improved curves, heavier rails, duplications, and heavier engines, the Railway Department can with difficulty cope with the enormous passenger and goods traffic that has sprung up.

Some notable examples of the same principle adopted of beginning economically and afterwards reconstructing and improving may be found in America. The world famed Pennsylvania Railway has been relocated on some portions of its main line three times, and on the Southern Pacific System, the centre of which is San Francisco, a sum of $100,000,000 has been recently spent in shortening portions of the line and cutting out heavy grades and sharp curves.

What has been said with regard to the early extension of the main lines is now applicable to some of the branches proposed at the present time. The traffic was small, but the country had to be opened up. There is this difference however, that the branches in question can scarcely be expected to develop into main arteries of traffic, and therefore principles of economy, not to speak of cheapness, are less open to objection than in the case of original main line extensions. The late Mr. Eddy was very keen on the subject of economy, and it was through his support and recommendation that the cost of country extensions was reduced and the principles of the so called pioneer or earth ballasted lines have received so much consideration. There are many districts crying out, as it were, for better communication. These districts cannot properly develop without a railway of some sort, and the question remains what style of construction should be adopted so that the much desired facilities may be given. There are two typical classes of

line to be considered, one of which includes extensions in the interior where the country is flat or at most rolling in character, and the other branch railways in the coast districts, where the spurs run up towards the dividing range with a steep slope, and where the adoption of easy grades and very flat curves would make the cost of the line almost prohibitive.

The first case is one about which there should be no difficulty in arriving at a decision. If it is a Government railway, I have no hesitation in saying that the standard gauge should be retained. If a private line and a works or mere mining or firewood line, a narrow gauge with lighter rails and rolling stock may have the advantage, especially if the prospects of traffic developing is small. If, however, it is intended to carry passengers and goods in connection with the existing system, and there is a probability of a considerable development of traffic, one ought to be very careful about advocating a narrow gauge line when one considers how near to the other in cost a standard line comes. Here it is not a question of curves; I admit that in some cases narrow gauge lends itself more readily to sharp curves, but the country here is level or nearly so. Let us compare the cost of the two gauges in their various component items of expenditure. We will assume that traffic is somewhat limited and loads are at present small, but shall we be benefited in this class of country by the adoption of a narrow gauge? Light rails can be used on the standard gauge as well as on a narrow gauge, and light rolling stock can be used in either case. The narrow gauge trucks are it is true smaller, but there must be more of them to provide the same total capacity. Similar station accommodation and shelter sheds are required for the same class of traffic for either gauge. If cheapness and scantiness of accommodation is good enough in one case, it is in the other. If the sidings are a little cheaper per yard to

construct on the narrow gauge, they must be longer to allow of the corresponding larger number of trucks and carriages. The narrow gauge locomotives have less haulage power and can only travel on the narrow gauge at lower speed, so there must be more of them. Should the lines be ultimately extended to some considerable distance, say 100 miles, passengers and goods can only travel at slow speed, whereas on the wider gauge a much higher speed can be reached with more comfort, at any rate to passengers, and less rolling stock and fewer trains will serve the same purposes as it is not delayed so long in travelling over the line, and each train can get over more ground in the day. Against the narrow gauge there is the nuisance of the break of gauge at the junction, and the more costly maintenance of the narrow line with its overhanging rolling stock. So that it resolves itself into this, there is a saving in width of construction amounting to a strip of earthworks the width of the difference in the two gauges, and there is the difference in the cost of the sleepers. From £200 to £600 per mile will cover the extra cost. Is it worth while avoiding this expense, when the extra maintenance and traffic expenses will probably more than absorb the saving in interest on capital cost?

The case of a line taken through hilly, not to say mountainous country, presents a somewhat different problem. The advocates of the narrow gauge can here make out a much better case, and I am quite prepared to agree that it is easier to arrange for a narrow gauge line, where the contours of the country present sharp angles. I am far from saying that a narrow gauge line should never be put down, but no one can have any doubt that every effort should be made to preserve the standard gauge when possible, and if the cost of laying the line with the customary grades and curves is prohibitive, then let these be made sharper and steeper and suitable rolling stock

purchased to meet the special case. You will understand that I am only advocating the use of sharp curves and steep grades on branch lines and short connections where high speeds are not a necessity. The Railway Department does not consider high speed a necessity on branch lines. Look up for instance the timetable, we find the following: — The distance between Manilla – Tamworth is 29 miles and trains take 3 hours for the journey; Moree – Inverell, 96 miles—6 hours, 15 min.; Lismore – Murwillumbah, 62 miles—3 hours, 50 minutes; Grafton – Casino, 85 miles—6 hours, 17 minutes; Narrandera – Finlay, 101 miles—7 hours 30 minutes. It may be said this slowness of speed is partly due to the trains being mixed ones, but if mixed trains are good enough for passengers, speed is evidently not wanted. I am expressing, however, no approval of mixed trains, which I think are most unpleasant inventions. I think that on what one may call second grade lines, that is interurban lines of high importance, but not between capitals, very flat curves are by no means a necessity and their introduction is often a waste of money.

As an illustration of what may be done with sharp curves, there is the line I have recently constructed for the Commonwealth Oil Corporation, Limited, running from the Great Western Line to Newnes, in the Wolgan Valley. At the end of April, 1906, Mr. D. A. Sutherland, Consulting Engineer and General Manager of that Company on the eve of leaving for England, asked me to see him on the subject of providing access by railway with the Company's Shale Deposits, stretching between the Wolgan and Capertee Valleys. Mr. Sutherland himself had been already over the ground, and had submitted a rough estimate for a line into the valley, which later on proved not to differ very widely from the actual cost. As the result of the interview, I undertook the laying out of a

suitable line, and the construction of the same after an estimate had been submitted.

The problem was this :—The junction thus proposed was at Clarence, 3,658 feet above the sea level ; a spur extended out north about 26 miles, the end of which overlooked the Wolgan Valley, the bottom of which proved by levelling to be about 1,750 feet above sea level. According to the programme laid out for the Company's operations, the output was to be on such a scale that with shale, oil, and r fined products taken into account, there would be a daily gross tonnage of at least 1,000 tons to convey over the line.

On my arrival on the scene, I found amongst the proposals there was one to run a railway to the end of the spur with a rope incline to the valley. This had been roughly worked out, but it was not decided whether the scheme should include a line of standard or narrow gauge. Mr. Sutherland himself favoured standard gauge throughout and the descent, if possible, into the valley by a locomotive lin In searching for this, I had the assistance of Mr. Marshall, formerly of my staff in the Railway Construction Branch, and afterwards in the South African Service. Mr. Marshall deserves the utmost credit for his energy and perseverance in working over this very difficult country. The result was that we managed by the introduction of 1 in 25 grades and 5 chain curves to get down from the ridge into the valley ; nothing flatter in the way of curves would have done it, and there was just room by the adoption of the grades mentioned, and by the insertion of a tunnel 20 chains long, to get sufficient length to squeeze through.

The difficulty of the problem may be gathered from the following data :—The best point for the junction was found at 86 m. 60 ch. where the rail level is 3,400, at 7 miles out a narrow part of the ridge has to be traversed where the

altitude is 3,960 feet above sea level. This is also the highest known part of the Blue Mountains. From that point to 19 miles the drop is 460 feet. From 19 miles to 28·40 the great descent is effected, the total from the summit at 7 miles to the terminus being 2,200 feet. This line 32 miles in length, laid with 75lb steel rails and with cuttings and embankments of full standard width, 18 feet and 17 feet respectively, has only cost about £120,000, not including rolling stock. There are some improvements such as platforms, station buildings, signalling arrangements still to introduce, and these will add somewhat to the cost, but the line is a cheap line and a substantial one, and without the grades and curves adopted could scarcely have been constructed at all, unless the use of spiral tunnels and heavy earthworks had been freely resorted to. A comparison, not a very fair one perhaps for the Wolgan Line, can be made with the Homebush – Hawkesbury section of the Northern Line. In the latter case the ruling grade is 1 in 40, and the sharpest curves on the descent to the Hawkesbury are of 11 chains radius. The length is about 29 miles. The drop from the summit to the Hawkesbury is only 700 feet. The total cost, deducting Ryde Bridge and portion of the tunnels for comparison was about £320,000. Had it been imperative in the case of the Wolgan Line to make the ruling grades and maximum curvature the same as on this section of the Northern Line, the cost would have been enormous and prohibitive. From the latest estimates made, and in consideration of the coke traffic likely to arise, the net tonnage to be conveyed over the line will probably be about 1,000 tons daily, which can easily be negotiated on a standard gauge line, but not on a narrow gauge line.

Some look upon steep grades and sharp curves as unmixed evils. As regards the first, it means that heavier locomotives must be used to carry the same load, which if

the rails are sufficiently strong is the best way of meeting the difficulty, for the cost of train staff remains the same. For sharp curves something more may be required, namely, special rolling stock. It is to be noted that the four-wheeled wagons of the N.S.W. Railway Department traverse 5 chain curves without difficulty. In Victoria, some years ago, Mr. Rennick, formerly Engineer-in-Chief of the Victorian Railways, made some tests which showed that all the Victorian carriages and wagons would travel safely round three chain curves at a speed of 20 miles per hour and many of the locomotives would also. In 1894, I visited the United States of America and travelled over the Southern Pacific roads. I found a good many curves of $16^\circ = 5{\cdot}3$ chains radius, and at Leadville there was one of $22^\circ = 3{\cdot}85$ chains radius. The train I was in was drawn by an eight wheeled coupled locomotive. In 1904, when travelling on the Canadian Pacific Railway, we traversed a curve of $3\frac{1}{2}$ chains radius slowly but safely, drawn by a similar locomotive. To-day curves of 5 chains radius are negotiated on the Ceylon Railways with their gauge of 5 feet 6 inches, by means of six wheeled coupled locomotives with bogie in front. There is plenty of side play allowed, the middle wheels have thin flanges, and the connecting rod and slide rod pins are barrelled. It is not pretended that there is no wear and tear to rails and flanges. Undoubtedly there is, but locomotives of English type are persistently made with too great rigidity, and far too little play in their axles for quite common curves, and even when provided with bogies in front, or pony trucks and radial axles, there is reason to believe that these excellent mechanical contrivances are not always kept in such an efficient state as to allow them to work to advantage, and there is grinding and wear and tear in consequence, and danger of derailments. Look at what a well worn contractor's engine will do, up and down, in

and out, over crooked lines and bad joints without going off the road. Why? Because all the joints are loose. Not a very nice state of things you will say, but there is evidently safety in loose joints nevertheless.

American engineers lay themselves out for flexibility, and in fact there is an adaptability about American practice which is to be highly commended. I am not referring to their workmanship and material, which unfortunately often leave much to be desired, but to the application of right principles and to their broadmindedness and rejection of everything narrow. This leads in the end to progress. When in America in 1894, I observed that the curves previously mentioned, were negotiated by locomotives of the consolidation type, while on the continent of Europe articulated locomotives of the Mallet and other types were used. Practice seems to have got reversed, for while within the last few years Mallet articulated engines have been built by the Baldwin Co. and the American Loco. Co., I found that, on the continent of Europe, there were less of the Mallet, Hagan or Meyer type than formerly, and that the tendency was to revert to the ordinary locomotive not articulated, flexibility being however given where required by some such method as the Gölsdorf, allowing for lateral shifting of wheels and axles as required to accommodate themselves to curves. With this contrivance it is stated that a 10 wheeled coupled locomotive, for standard gauge, can readily traverse 5 chain curves.

In England at the present time, Kitson of Leeds, Beyer and Peacock, and others, are building articulated locomotives with two pairs of cylinders and a single boiler, the former having supplied a number for Rhodesia and elsewhere, while the North British Locomotive Co. have been building locomotives of the Fairlie type for Mexico. I may say that all the firms I have referred to in Great Britain,

America, and the continent of Europe including Henschell of Cassel, the Hanoverian Locomotive Co., and Swiss Locomotive Co. of Winterthur, are quite prepared to compete in supplying the needs of such a line as that of the Commonwealth Oil Corporation Ltd., for the Wolgan Valley Railway and its hard conditions. A type which has been strongly recommended is the Garrett type, made by Beyer, Peacock and Co.

One type of locomotive I have not mentioned yet; that is the Shay geared locomotive made by the Lima Locomotive Co. of Lima, Ohio, U.S.A. A great deal has been heard of this locomotive during the last eighteen months, and I do not now propose to say more than that it is a great puller—no doubt it is slow as well as sure, but where the heavy grades can be grouped, its design is such as to give it advantages over ordinary types. On the level it is not so advantageous because its speed is limited, but on heavy grades it is in its element and can readily stop and start on maximum grades with maximum loads, and this cannot be said of every other locomotive.

With regard to wear of rails on curves, there is now a good deal of experience on the subject. Where rolling stock of the ordinary type is used wear on sharp curves must always be very considerable, but it can be greatly diminished if the rolling stock is of a suitable design, and still more so if guard rails are placed at a proper distance from the inner rail, so as to catch the inside of the wheel flanges and prevent the wheel flanges on the other side grinding against the outer rail. But where, through the adoption of sharp curvature the wear is rather heavy, the cost of renewals is far more than outbalanced by the interest on the saving effected on the original cost of construction. To take an example:—by the adoption of say 5 chain curves on a particular mountain line, the cost of

earthworks and waterways may be reduced by an average of £8,000 per mile. We will assume that the line is 20 miles long, and that one quarter of it consists of sharp curves, that these curves are check railed, and that in spite of this the rails have to be renewed every four years, which with properly designed engines, I might say in parenthesis, is making the case worse than it really is. The extra checking of the curves might possibly cost £500 per mile, and a quarter of the length being thus laid, the average on the whole length will be £125 per mile, that is to say, the average saving of cost of earthworks and waterways on the whole line will be £8,000 per mile less £125, that is to say, £7,875 per mile, or for 20 miles £157,500, the interest on which at 4% = £6,300 per annum, which is the annual saving due to cheaper construction. Against this we have permanent way rails 5 miles to be renewed every four years, say £5,000 = £1,000 per annum. Thus the net saving is £5,300 per annum, which sum would be vastly in excess of what is required to cover the cost of turning up and renewing locomotive tyres, etc.

Wear of rails is more or less proportioned to resistance to traction, but is increased in places by brake action. Observations show that it is not proportioned to curvature, as the sharper curves wear more in proportion than flatter ones, that is at least on main lines. It is largely a question of wheel base, and given a certain wheel base there must be a limit to the curvature round which a vehicle will travel. As sharper curves are used it is clear that resistance must increase out of all proportion, when nearing the limit. Probably when not near the limit, resistance and wear may be approximately proportional to curvature. Wellington has investigated the subject at great length, but it cannot be doubted that in a country like this, where the conditions do not correspond with those in the United States of America and where other types of locomotives are used,

and four wheeled stock is the more common type, more experiments are required to throw light on the question.

Mr. Fraser, Engineer-in-Chief for Existing Lines N.S.W. Railways, Mr. Pagan, Chief Engineer of Queensland, and Mr. Norman, Chief Engineer of Victorian Existing Lines, have furnished me with some valuable information on the subject of wear of rails, and Mr. Pagan of the remedy which he adopted.

Mr. Fraser says:—"As verbally requested a few days ago, I have to inform you that the wear of rails on sharp curves is now somewhat heavy in this State. On the main western line (Mountain section) we had before the 8 chain curves were cut out, 80 ℔. rails worn clean out in 5 months, but on the 12 chain curves to which the minimum radius has been improved, we got a life, when working single line, of two years, and since the traffic has been reduced by double line working the line has been increased to three years. On the North Coast line between Cowan and the Hawkesbury River, rails on 11 chain curves on the steep gradient have been worn out in 13 months, and this is practically the present life of 80 ℔. rails on these particular curves. On the Illawarra line, between Waterfall and Helensburgh, 80 ℔. rails on 10 chain curves have a life of approximately three years, the traffic though heavy being mainly slow. On the main Western line, between Bowenfels and Bathurst, we are now renewing 80 ℔. rails on 12 chain curves, which have had a life of two years only, but the traffic on that section is both heavy and fast.

"The foregoing will show that approximately the life of 80 ℔. rails on curves of 12 chain radius and under on single main lines, where the traffic is heavy and fast, varies from 1 $\frac{1}{12}$ to two years. Renewals on curves upwards of 12 chains radius are not heavy—the difference in wear being very marked as compared with what we class as sharp

curves. Rails on curves of 14 chains radius laid in over 10 years ago are still in good order, so that it is evident that a small decrease in curvature very greatly increases the rail life under the rolling stock we have in general use."

The information furnished by Mr. Norman tends to show the importance of using hard or tough rails. In the case of a curve at South Yarra where American rails from Maryland were used, the wear was less than one-fourth of those of some Barrow rails laid down at Kew. The particulars are as follows—in both cases 100 ℔. rails were used. The rails on the South Yarra curve of 908 feet radius lost on the average 3·18 ℔. per lin. yard for 52 months wear with a traffic of about 22,900,000 tons, whereas those at Kew which were on a curve of 792 feet radius showed a wear of 3·82 ℔. per lin. yard for 21 months, for a traffic of 7,905,500. Reducing the wear to the same period and traffic we find the wear of the South Yarra rails per year and for 10,000,000 tons was ·06 ℔s., whereas that of the Barrow rails was ·27 ℔s. The difference in curvature alone would not account for this.

Mr. Pagan shows the advantage to be gained by the use of guard rails. Prior to the introduction of guard rails on the main range the average life of the outer rail on curves of the radii mentioned, was as follows:—

5	chain curves,	16 months
5½	,,	18 ,,
6	,,	21 ,,
8	,,	28 to 30 months

The following are the results of putting guard rails on 5 chain curves. They depend largely on grade, and it is evidently that part of the wear is due to brake action:—

Grade 1 in 110, 11 years
,, 1 ,, 75, 4 years
,, 1 ,, 75, 5 years 8 months

Grade 1 in	55,	4 years
,, 1 ,,	60,	5 years 2 months
,, 1 ,,	60,	4 to 7 years, dependent on fastening
,, 1 ,,	97,	5 years 2 months
,, 1 ,,	105,	4 years

The greatest amount of wear on the guard rails is $\frac{1}{8}$ inch.

Automatic Couplings and Buffers.—It is a pity that when commencing railway construction in Australia the American style of coupling and buffer combined could not have been adopted. It not only is automatic and much safer therefore for the shunter, who avoids the risk of death by being squeezed between the buffers. It does away with the use of the latter, which are in the way on sharp curves. If a commencement had to be made again I have little doubt that the American coupling would be adopted with a larger sprinkling of American rolling stock and rails laid flat. The time has probably arrived when in the older countries buffers will begin to fall into disuse. The English Board of Trade having issued an order that automatic couplers must be introduced within a certain time, experiments have been made in Great Britain with an automatic coupler on the American style, and when I was over there in 1904–5, ten express trains on the east coast route were thus fitted up and running. The same system was being tried on the Great Central Railway. On the Continent of Europe I found a union of Railway Managers had been formed, and it was at the time the firmly expressed intention to introduce the automatic central coupler and buffer and abolish side buffers. To this end, intermediate or transitional combined couplings were designed, by which carriages could be coupled up on either system, and side buffers were used which could be put out of the way if not wanted. That is similar to what was done en the east coast route in Great Britain, above referred to, and it is to be noted that it was not only in

one country of Europe that the idea was developing, but France, Germany, Spain, Italy, Switzerland and Russia appeared to be taking part, and the matter has been brought before the International Congress. This style of coupling without the use of side buffers conduces to flexibility on sharp curves, for on sharp curves side buffers are liable to pass one another and get interlocked. It would be a great advantage to be able to run main line rolling stock over sharp curves, and if this system of coupling were adopted there would be no difficulty in transferring any of the N.S.W. bogie stock from the North Coast Line when completed, on to such a line as the Dorrigo, even if it included 2 or 3 chain curves, provided always that the necessary rotary movement of the bogie was arranged for, and proper width allowances in platform and other structures made.

Permanent Way Improvements.—When I was travelling through America in 1894, I found the different railway companies in the Eastern States vying with one another to get traffic, and with this object altering and improving their roads to permit of faster passenger trains and heavier freight trains. Curves were being flattened to a maximum curvature of 2°, which is a little over half a mile radius, and grades to ·5% or 1 in 200. Heavier rails were also being put down. In 1904 the lines in the west were now being improved (quite a remarkable alteration since 1894), curvature was being reduced and heavy grades cut out. The Southern Pacific Co. was spending £20,000,000 in improving and shortening their lines, one of the most extraordinary pieces of work being the short cut through Salt Lake.

These improvements are naturally undertaken as traffic increases, but although so much has to be rebuilt now, it is clear on consideration that had these same companies to start afresh with the sparse population of old times and

with limited capital, they would begin in the same way as originally, and the lines would be first laid down in the cheapest style. These facts should be kept in view when making our western connections for which there is an urgent need. They can be built in such a way as to be cheap at first, but to be capable of being strengthened up and improved afterwards.

Break of Gauge and Unification.—A few words must be devoted to the break of gauge question, for although so much has been said and written in the past, there still remains much to be said, and it will be so till the unification of the gauges is consummated. Perhaps it would not be out of place to put on record here a few facts setting forth the circumstances under which the discrepancy in the gauges has arisen. If reference is made to a lecture I delivered before the Sydney University Engineering Society in 1902, there will be found a short account of the early history of the introduction of railways in this State and of the gauge question. With regard to the latter the principal facts are as follows:—In 1848 it was decided that the future Australian gauge should be 4 feet 8 inches. In 1850 Mr. Sheilds who had been appointed as engineer to the recently formed Sydney Railway Co. urged the adoption of the Irish gauge 5 feet 3 inches. This was approved by the Home Government and became the legal gauge for Australia. Mr. Wallace, Engineer-in-Chief in succession to Mr. Shields, favoured a gauge of 4 feet 8½ inches, and this was passed in the New South Wales Legislature, and the Bill dealing with the matter was sent home for Royal approval. On receipt of it Earl Grey the Secretary for State, wrote out to Governor Fitzroy and urged the objections there were to adopting a different gauge, the result being that a reversion to the gauge of 5 feet 3 inches was attempted, and would have passed but that the company pointed out that they had already counted on the 4 feet 8½ inch gauge

being adopted and had ordered rolling stock accordingly. So it remained. In 1857 Mr. John Whitton then Engineer-in-Chief tried to induce the Government to alter the small length of line then made to that previously agreed to, namely, 5 feet 3 inches, but he failed to convince the Government of the wisdom of doing so.

There is no doubt that sooner or later the difficulties of unification will have to be faced. With the present time-tables the break of gauge is not a very serious matter for passengers by the express to Melbourne, and the greatest inconvenience is felt at Albury, when on the journey to Melbourne they have in winter to rise at an inconveniently early hour and on the journey in the opposite direction to wait up till near midnight before they can get to bed. Were there no break of gauge, passengers could wait to have breakfast at Benalla, and on the return journey could turn in about that point. It would also be possible to run through-trains at other times of the day. For instance it would be possible to arrange for an express to leave Sydney about 5 p.m. arriving in Melbourne at or before 10 a.m. next morning, which would suit business people very well. At present this cannot conveniently be done, as the time for passing Albury would be about 5 a.m.

It is most desirable that the inconvenience of the break between Sydney and Melbourne be abolished, and this can be effected or at least an amelioration found in various ways:

1. Lay down a separate line on the 4 feet 8½ inch gauge between Wodonga and Melbourne, by which the Sydney trains could run right through. This would be a perfectly effective proposal if room can be found at the stations en route.

2. Lay down a separate 4 feet 8½ inch line to Benalla only, and make that the changing station. This would get rid of the inconvenience of the present express timetable,

but would not so well allow for the convenience of the passengers by a possible train leaving Sydney at 5 p.m.

3. Introduction of a third rail, so that the same line would suit both gauges. The points and crossings seem to have been practically worked out by Mr. Brennan, and Mr. C. Wilkin of the Interlocking Department, has shown me a model to prove this. The heads of the rails have to be narrowed by planing, and at platforms, bridges, tunnels etc. the mean centre of the two roads has to be shifted out by half the difference of the two gauges, so that the required clearance may be effected. Mr. Wilkin assures me that he has made diagrams showing that this is quite workable.

4. Exchangeable bogies as used in Canada before the unification. This is applicable to all the newer passenger stock, but not to four-wheeled freight stock.

5. Moveable wheel gauge, effected either by a sliding telescopic axle, or by a divided axle as in Mr. A. R. Angus' system. Mr. Angus has informed me that he expects soon to be in a position to get tests made, which I consider absolutely necessary to prove the practicability of his system, however faultless otherwise the mechanical details of the apparatus may be. Mr. Angus claims that his system reduces friction on curves as the wheels can follow round independently of one another without having to slip. This is undoubtedly the case, but the greater part of the excessive wear and resistance is due to the stiff wheel base of the locomotives.

A traveller from Central Queensland to Adelaide has to wait over at Brisbane, Sydney and Melbourne. He has to encounter two breaks of gauge. That at Albury can be dealt with in one of the ways mentioned, that at Wallangarra can best be treated by the adoption of Mr. H. C. Stanley's via recta or separate short cut to Brisbane. The time will come when the traveller will expect to travel without these

long waits, and that will be especially the case when Perth is connected up, as it must eventually be, by the Transcontinental Railway. Partial unification or rather complete unification of the main route necessitating a separate main line for part of the distance or the introduction of a third rail will then be imperative.

Preservation of Timber.—The preservation of timber is a subject of the highest importance to railway engineers—so much timber is used not only for sleepers but also for bridge and other construction work. Timber can be treated by giving it a coat of some preservative liquid such as paint, tar, or other substance, but the surface treatment falls far behind any method of impregnation, of which creosote, chloride of zinc or mercury (corrosive sublimate) are the best known. The most recent method introduced into this country is "Powellising," and consists of treatment with molasses, by which the timber becomes thoroughly permeated. It is stated to be completely successful. Dry rot does not under the most adverse circumstances attack the timber thus treated, and white ants and other insect pests can be completely warded off by the addition of arsenic to the solution. Such a method should prove invaluable for sleepers, as not only does it render well known and approved timbers more durable, but it should enable classes of timber to be used which on account of liability to dry rot and attacks of insects are otherwise absolutely useless. I understand that the charge for treatment is somewhat high, in the case of sleepers about 1/- each. If this could be reduced to 6d. or even 3d., which may be eventually possible as the process must be a cheap one, the field of operations may become very wide.

Ferroconcrete Sleepers.—Within the last few years the price of timber sleepers has risen in this country, partly owing no doubt to rise in wages, but partly also to the

growing scarcity of the best kinds of timber and the remoteness of the forests from rail or wharf. In Germany and the continent of Europe steel sleepers are largely used. Although the first cost is high, when worn out they fetch about half the original price as scrap, so that they are not dear in the long run. Steel sleepers have been used in Australia, but not to any great extent nor with any great measure of success. Ferroconcrete sleepers of many designs have been brought into use but it cannot be said that much success has been achieved. The price has been against them, and, owing to the excessive vibration to which they are subject, they are very liable to disintegration. I still think that in spite of many failures, the sleeper of the future will be a ferroconcrete one, or at any rate this class of article will eventually successfully compete with other kinds. It would seem as if blocks of wood should be embedded in the sleeper to act as a rail bed, and so lend elasticity. Further experimenting is to be recommended, considering the large number of sleepers which will certainly be wanted in the near future if the Transcontinental and other long cross country lines come to be constructed.

Corrugation of Rails.—Corrugation of the surface of rails and the unpleasant noise and vibration thereby caused, has received much attention. It has generally been concluded that steam lines were exempt—except in the case of the Indian experience—and that the phenomenon was in some way connected with electric traction only. The observations and investigations by Mr. Cudsworth, Chief Engineer, and Mr. Worsdell, Chief Mechanical Engineer, of the North Eastern Railway of England, dispel this idea. There are various theories with regard to the matter, but it is quite certain that corrugations do not arise as the effect of composition or texture, as corrugated rails removed from places where the influence occurs and put down where

it does not exist are said to become quite smooth again; they are to be found on straight roads as well as curves. Again it is curious to note that while some assert that the process takes place owing to too much elasticity of the road, others attribute it to too much rigidity, so that there is evidently a great deal more to be learnt before a final judgment can be passed.

Noise of Trains.—The question of the noise of train and tram travelling is one that deserves more attention than it receives, as noisiness diminishes very greatly the comfort of the traveller. That a great deal of it is unavoidable there can be no doubt. The latest types of carriages, Pullman, Mann and Corridor, are certainly much quieter to travel in than some of the older and cheaper carriages, and those to the design of which less attention has been paid. Rolling stock provided with six-wheeled bogies run much more smoothly and quickly than that supported on four-wheeled bogies. Generally speaking, our roads are more noisy than those of the old country, perhaps because everything is drier as a rule, and there is more reverberation. Then the passenger in Australia hears more noise because the windows are mostly all open, whereas in the old country, the chilliness and moisture of the climate require that they should be generally closed. In the United States of America, travelling is mostly done in Pullman cars, and to these there are double windows, which are nearly always kept closed to keep out heat and dust in summer and cold in winter, and effectually exclude noise from outside. There is one thing certain, that some types of cars are quite unnecessarily noisy, I refer to our suburban type of American car and most tramway cars. The roofs and floors of these cars act like the back and belly of a fiddle; they seemed designed to give forth sound.

Composition of Steel Rails.—The composition and hardness of steel rails is a subject of itself, and it is impossible

to more than touch on it at the present moment. To find a material which will resist wear or at least render the life of the permanent way a longer one is a matter of the highest importance, and though excessive wear of railway rails is largely due to the excessive stiffness of the locomotives used, there can be no doubt that the adoption of a harder and tougher material for rails is a step in the right direction. Some years ago the desire for high carbon was in the ascendant, and some very excellent results were obtained together with examples of extreme brittleness, owing reputedly to excess of carbon. The latest material is silicon steel, the use of which seems at first a step in the wrong direction, as silicon has always been looked upon as a most objectionable ingredient, except in quantities of not more than about ·1%, but Mr. Sandberg first burns all the silicon out and then puts back the quantity required, and it is stated that when it is thus added it does not bring with it the same objectionable qualities but gives great hardness and toughness to the steel. The price of the steel is higher, amounting from 5/- to 7/6 per ton extra. The present Chief Commissioner, Mr. T. R. Johnson, is a great advocate for its use, and I understand that orders have been issued for considerable quantities, both for renewals and new lines. I hope my successor in the chair, who some years ago interested himself in the subject, will find time to pay some attention to this question, which is one for the chemist and physicist as well as the engineer.

New Inventions.—There have been many inventions and developments of inventions during the past twelve months in various lines of science and engineering, but none I think, so captivating to the imagination as Brennan's Monorail. Before this when we heard of the term "Monorail" we had to think of Lartigue or Behr, or the suspended system exemplified on the Eberfeld Barmen and similar lines. All these require costly structures to carry them—the latter is a

particularly nice system—I travelled in the cars on the occasion of my last visit to the continent of Europe. I saw something of the Lartigue method, and I had the opportunity of meeting the celebrated Mr. Behr, and listening to the description of the system by the author himself. This system, which was advocated for the Liverpool–Manchester high speed route by some of the highest authorities in the scientific world, did not receive the support of the public. But while Mr. Behr's train requires an expensive structure to run upon, the centre of gravity of which for the purposes of stability lies below the line of support, Mr. Brennan is able to content himself with a mere rope on the top of which his machine supports itself in the air, apparently disregarding the principles of gravity, so much so that if you put a weight on one side or try to pull it over it moves over in the opposite direction, and so gets its balance restored. The principle involved is that of the gyroscope or gyrostat as Mr. Brennan calls the pair of apparatus, which are kept revolving at a high velocity on the car. It remains to be seen of what practical use the invention turns out to be, but its simplicity and ease of application would seem to insure for it a great future.

It is sometimes said that one learns more from failures than from successes. Let us hope at any rate that the one or two terrible events, for which the past twelve months will be noted, will result in ultimate benefit. I refer in the first place to the Quebec Bridge disáster, the report on which has recently appeared. The disaster should certainly put a stop to the tendency to allow higher and higher strains on known materials, and it should be a reminder that the strains on compound structures are not always easily determined, and that it devolves on the engineer to see that his joints and connections are thoroughly well designed and the stresses on the members

of the structure brought as it were into line, and the lines of forces controlled by efficient bracing.

The other event to which I refer was the disastrous Braybrook accident. It would not be right to comment on the event, as the matter is *sub judice*, but it is not going too far to say that such an accident ought not to occur at all if the very effective modern system of signals established were properly watched and attended to. There seems to have been a spirit growing which sooner or later must lead to a catastrophe, and there must have been many hair breadth escapes before, at any of which similar disasters might have occurred. It is to be hoped that this spirit of recklessness will now be controlled.

I must not conclude my address to you without referring shortly to the losses in membership by death that have been sustained by the Society during the past twelve months. Among our Honorary Members we have lost Sir Benjamin Baker, Mr. Robert L. J. Ellery, Sir James Hector and Lord Kelvin.

Sir Benjamin Baker, who died from heart failure on 19th May, 1907, at the age of 67 years, was for many years with the late Sir John Fowler closely connected with the engineering work of this State. Sir John Fowler held for many years the position of Consulting and Inspecting Engineer to the Government of New South Wales, and vast quantities of rails and machinery were received here after careful and close scrutiny by his firm and staff as regards specification, workmanship and material. Sir Benjamin Baker is perhaps best known to the world in his association with Sir John Fowler as the designer of the Great Forth Bridge, and more recently in connection with the Assouan Dam. He was at quite an early stage associated with Sir John Fowler on the Metropolitan District Railways, and more recently he took a leading part in the construction of the City and

South London Railway, Central London Railway and other tube railways. He took a very active part in many great engineering enterprises, and was consulted at all points and on many subjects by engineers, public bodies, and governments in different parts of the world. He received various honours from the universities of the old country, was a Fellow of the Royal Society, a past President of the Institution of Civil Engineers, a member of council of the Institution of Mechanical Engineers, and an Honorary Member of the Canadian Society of Civil Engineers, as well as of the American Society of Mechanical Engineers. He also held the dignities of Knight Commander of the orders of St. Michael and St. George and of the Bath.

Lieutenant Colonel R. L. J. Ellery died on January 16th. He was for many years Director of Williamstown and Melbourne Observatories. Colonel Ellery had a long career during which the appliances at the establishments over which he presided were enormously improved, and at his instigation a four feet reflector was mounted, which at the time of its erection was the most powerful instrument of its kind in the southern hemisphere. Colonel Ellery's work was extensive and varied, and he has left a name as one of the leading astronomers of the southern hemisphere. He retired from the office of director in 1895, but was active in the scientific world almost up till the day of his death. He was elected a Fellow of the Royal Society in 1873, and he was also a Fellow of the Royal Astronomical Society, and a prominent member of many colonial societies and of the Australasian Association for the Advancement of Science.

Sir James Hector, F.R.S., was born on March 16th, 1834. He took his degree of M.D. at the Edinburgh University in 1856 and served as assistant to Edward Forbes and Sir James Simpson. He was appointed to the post of surgeon and naturalist to Captain Palliser's expedition to the Rocky

Mountains in British North America. The best known result of this expedition was the discovery of the pass by which the Canadian Pacific Railway now crosses from the prairies of the north-west to the Pacific coast. On his return from America he was appointed geologist to the Government of Otago, and from this on the scene of his work lay in New Zealand. He was an active teacher, a profound investigator, a lucid writer, and many of his works such as his "Outlines of New Zealand Geology," his "Hand-book of New Zealand," the later editions of which were published in 1886, are works of permanent value. Sir James Hector was made a K.C.M.G. in 1887, he was a Fellow of the Geological Society and of the Royal Geographical Society, and was also elected third President of the Australasian Association for the Advancement of Science.

The Right Hon. Lord Kelvin, known for so many years as Sir William Thomson, died at the age of 83. It is difficult, in view of his many honours and the large amount of work he has carried out to give a short statement that would be in any way adequate to represent the career of this great man, who was one of the greatest physicists which the world has produced. For more than sixty years he was prominently before the scientific world, and right up to the time of his death his wonderful activity was always a marvel. I may refer to the account of him which was given in *Nature* on the 26th December of last year.

With regard to ordinary members, the loss has been severe. The names of those who have thus left us are Edward H. Jenkinson, David Ramsay, John C. Rolleston, F. B. W. Woolrych, J. I. Haycroft, Walter A. Smith, and H. A. Lenehan. I should like particularly to refer to some of those gentlemen in consequence of the special interest which they took in the work of our Society.

Mr. James Isaac Haycroft was born at Cork in 1854. He graduated with honours in the Queen's University in Ireland

and became Master in Engineering in 1882. He occupied the position of borough engineer to the Woollahra Municipal Council for eleven years, after which he obtained an appointment in the Public Works Department of this State, and was connected especially with the Tramway Construction Branch. Mr. Haycroft was a diligent attendant at the meetings of the Royal Society and especially at those of the Engineering Section of which for several years he was a member of committee. His services in the Department of Works were highly appreciated, and he died much regretted by those with whom he came into intimate contact.

Mr. Walter A. Smith, M. Inst. C.E., who was one of the best known and most popular officers in the Public Works Department, received his death by falling during a visit of inspection from the staircase leading up to the tower on Pyrmont Bridge. Mr. Smith was 48 years of age, and had been an officer of the Works Department for twenty-five years. For several years he was Metropolitan Engineer in the Roads Branch, but on the inception of the Local Government Act he was placed in charge of operations at Barren Jack Dam. Early in this year, however, he returned to Sydney to take up his old post. Mr. Smith's career was one in which ability and high character were prominent and he leaves an irreproachable record behind him.

Mr. Henry Alfred Lenehan died at the age of 65 years. He was appointed assistant at the Sydney Observatory in 1870, he was Acting Government Astronomer during the illness and retirement of the late Mr. Russell, and was recently appointed Government Astronomer. Mr. Lenehan was a Fellow of the Royal Astronomical Society. He had the interest of our Society always at heart. He became a member in 1874, has been a member of council for the last fourteen years, and was President from 1905-6, since

which time he has been on the roll of Vice-Presidents. In Mr. Lenehan the Society has lost one of its most active members. He was always to the fore when any work was to be done or movement to be supported by personal energy or otherwise.

THE VISCOSITY OF WATER.

By Richard Hosking, B.A. (*Camb.*)

[Communicated by Prof. Pollock, D. Sc.]

[With Plates IV. – IX.]

[*Read before the Royal Society of N. S. Wales, June 3, 1908.*]

In my previous experiments on the determination of viscosity by the efflux method,[1] I have always arranged to have the rate of flow of liquid in the capillary tube very small. The kinetic energy correction in the well known reduction formula was thus always small in comparison with the first term. In the present experiments, however, I have purposely increased this rate of flow in order to test the formula in cases where the kinetic energy correction is much greater. The glischrometer used in these experiments was of the same form as those previously used by me, but the bulbs were larger. It is shown in *Plate 4*, fig. 1. At a, b, c, and d, platinum wires are inserted, which are almost touching inside the tubes. The capillary C is fitted to the limbs by rubber bands. The volume of the bulb R at 0° C. is 10·2801 ccs., and that of L at the same temperature 10·3201 ccs. Four capillaries were carefully selected for separate use in the glischrometer, and their ends were ground with fine emery, in a lathe. Their lengths, measured directly with callipers, were 5·570,

[1] Phil. Mag., March 1900, May 1902, May 1904.

6·494, 5·408, and 6·456 cms. respectively at 0° C., and their radii approximately were ·019, ·019, ·020, ·020 cms. respectively, at 0° C. (The exact determination of the equivalent radius of each capillary was made at the end of all the experiments. It involved the cutting up of the tube, and the careful measurement of the sections). Sufficient freshly distilled water was put in to fill up the glischrometer from *b* to *c*.

The ends *A* and *B* were connected to the reservoir of compressed air or the outside air by means of three-way taps. Measurements of viscosity were taken first with the water flowing out of *R* into *L*, and secondly with the water flowing in the opposite way, under the pressure of air in the reservoir. The average of the two determinations was taken as an absolute value of the viscosity. The pressure was measured by means of (1) a water manometer 200 cms. long, (2) a mercury manometer in cases where the pressure was greater than 200 cms. of water.

To facilitate the reading of the water manometer, a pair of small parallel mirrors was attached to each of the arms. These were inclined so as to make an angle of 45° with the vertical manometer scale. One was fixed near the centre of the arm, and opposite a telescope; the other could be moved along the arm and clamped in front of the water surface. When the mirrors had been set, it was thus possible to read off the positions of the two water surfaces by means of the telescope, at the same instant; for both images were arranged to be side by side in the field. The pressures employed varied between the limits 100 cm. (water) and 42 cms. (mercury).

The time of flow was in most cases very short, the average being about one minute, but in extreme cases it was as low as 22 seconds. Special means had to be employed to register the time intervals correctly. The chronograph

used was kindly supplied by the Sydney Observatory. It consisted of two electro-magnets side by side. The armatures were provided with needles. Paper tape was fed through rollers immediately over the needle points at the rate of about 5 cms. per second. A special spring enabled the needles to travel forward a little on piercing the tape, and prevented the tearing of the tape. One needle was used for recording seconds by direct reference, through electrical contacts, to a standard clock. The other needle punctured the tape when a key was pressed at the transits of the meniscus in the glischrometer at the points *a* and *b* in the one case; or at *c* and *d* in the other. These transits were observed always through telescopes.

The procedure in determining the viscosity was as follows. The bath temperature was arranged to be as close to the desired temperature as possible, and the heating flame was adjusted. The pressure of air in the reservoir was raised or lowered to the proper level. Double readings of pressure, time of flow and temperature were taken. The pressure was next altered, and more readings were taken. In most cases, the determinations were repeated. Another capillary was then placed in position in the glischrometer and the series was repeated.

The Reduction Formula.—In the Journal and Proceedings of the Royal Society of New South Wales are published three most important papers by G. H. Knibbs,[1] dealing with the history, theory, and determination of the viscosity of water by the efflux method. Knibbs has shown that the reduction formula is

$$\eta_t = \frac{\pi R^4}{8\,VL\left(1 + n\,\frac{R}{L}\right)}\,g.\rho.h.T - \frac{m.\delta.V\,(1 + 2\,kt)}{8\pi L\left(1 + n\,\frac{R}{L}\right)\,T} \quad \ldots\ldots(1)$$

[1] This Journal, volumes XXIX., XXX., and XXXI.

In this formula L is the length and R the radius of the capillary, and T the time taken for volume V of the liquid of density δ to flow through the capillary under a pressure $g\rho h$; nR is a small length of tube producing a loss of pressure equivalent to that arising from the friction at the ends, its value must be calculated for each series of experiments; m is the numerical factor in the kinetic energy correction, which has a theoretical value of 1·12, but which has a practical value which must be determined. The factor m has been neglected in so many recent determinations of viscosity that it is worth the while to repeat the information given by Knibbs respecting it. In 1860, Neumann deduced the value $m=1$, and Jacobsen used it in his "Introduction to Hæmodynamics (1860)." Hagenbach deduced the value $m = 1$, in the same year. Reynolds (following Bernoulli) in 1883, used the value $m=\frac{1}{2}$. Couette in 1890, independently obtained the value $m=1$. Boussinesq (1891) obtained a more accurate value $m=1{\cdot}12$. Gartenmeister stated (1890) that Finkener had in an unpublished treatise shown that Couette's value was the correct (?) one. Wilberforce (1891) pointed out the defect in Hagenbach's reasoning, and he used the value $m=1$. Knibbs has shewn that theoretically Neumann's correction as deduced by Boussinesq is correct, and that experimentally its value varies considerably. Knibbs has deduced values of m from Jacobsen's results, and stated that individual results show how, even under circumstances in which uniformity might be expected, it is not realized; and that if the correction be of sensible magnitude, the deduced viscosity is to the extent of this uncertainty, unreliable.

Determination of m and n.—Preliminary experiments were made in order to obtain correct (experimental) values for the constants m and n. The temperatures were kept as close to 50° C. as possible, and under different pressures,

the times of flow were recorded. The pressures were reduced to equivalent pressures at 50° C. Knibbs has shown that the reduction formula, for experiments carried out at a certain temperature, may be expressed in the form

$$C + c/T = \rho\, h\, T \text{ ....(2)}$$

where $C = \eta_t\,(1 + n\,R/L)\,\dfrac{8\,V\,L}{\pi\,g\,R^4}$ ....(3)

and $c = \dfrac{m\,\delta\,V^2}{g\,\pi^2\,R^4}\,(1 + 2\,kt)$ ....(4)

Equation (2) is that of a straight line such that if $1/T$ be taken as abscissæ, and corresponding values of $\rho\,h\,T$ as ordinates, the line passing through the points so determined will intersect the axis of ordinates at a distance C from the origin, and make with the axis of abscissæ an angle whose tangent is c. When c has been obtained m is deduced by means of equation 4.

Equation (3) may be written in the form

$$\frac{C\,\pi\,g\,R^4}{8\,V\,L} = \eta_t\left(1 + n\,\frac{R}{L}\right).$$

The left hand side of the equation will have different values for different capillaries in the glischrometer.

Calling the left side K we have

$$K = \eta_t + n\,\eta_t\,R/L \text{ or } K = \eta_t + l\,R/L \text{ ....(5)}$$

where $l = n\,\eta_t$.

This is the equation of a straight line such that if values of R/L be taken as abscissæ, and corresponding values of K as ordinates, the line passing through such points will intersect the axis of ordinates at a distance η_t from the origin, and make an angle with the axis of abscissæ whose tangent is b. From value of b obtained in this way, n is at once deduced.

Typical Observations with Tube I. in Glischrometer.

Temp. (t° C.)	Manometer Reading (h) cms	Temp. of Manometer. ° C.	Time of Flow (T) secs.	Bulb being emptied.	$\rho h T$ (reduced to 50°) × 10^{-3}	$\frac{1}{T}$
50·05	[1]108·29	22·9	71·38	R	7·713	·01401
50·03	108·27	,,	71·46	L	7·718	·01400
50·00	108·31	,,	71·45	R	7·707	·01400
50·00	108·31	,,	71·33	L	7·697	·01402
50·10	150·28	26·0	54·34	R	8·145	·01840
50·10	150·30	,,	54·37	L	8·150	·01839
50·00	196·20	22·9	43·98	R	8·598	·02274
50·00	196·14	,,	43·74	L	8·546	·02286
50·00	196·10	24·2	44·03	R	8·600	·02272
50·00	196·17	,,	43·70	L	8·540	·02288
50·04	[2]20·30	23·9	33·58	R	9·239	·02978
50·03	20·30	,,	33·52	L	9·220	·02984
50·02	20·30	,,	33·58	R	9·236	·02978
50·01	20·30	,,	33·53	L	9·232	·02985
50·10	25·40	26·0	28·35	R	9·764	·03527
50·10	24·40	,,	29·24	L	9·674	·03420
50·05	30·38	23·9	24·78	R	10·204	·04035
50·06	30·38	,,	24·93	L	10·267	·04011
50·07	30·38	,,	24·72	R	10·184	·04045
50·08	30·38	,,	24·95	L	10·280	·04008
50·00	35·40	22·9	22·32	R	10·701	·04480
50·00	35.40	,,	22·38	L	10·726	·04468
50·00	35·40	,,	22·28	R	10·683	·04488
50·00	35·40	,,	22·38	L	10·726	·04468
50·10	40·40	22·9	20·36	R	11·171	·04912
50·10	40·40	,,	21·40	L	11·737	·04673
50·10	40·40	,,	20·39	R	11·188	·04904
50·10	40 40	,,	21·40	L	11·737	·04673

[1] Water Manometer. [2] Mercury Manometer.

Typical Observations with Tube II. in Glischrometer.

Temp. (t° C.)	Manometer Reading (h) cms.	Temp. of Manometer. °C.	Time of Flow (T) secs.	Bulb being emptied.	$\rho h T$ (reduced to 50°) $\times 10^{-3}$	$\frac{1}{T}$
50·08	[1]108·41	26·7	80·41	R	8·716	·01244
50·08	108·25	,,	80·27	L	8·676	·01246
50·08	108·13	,,	80·81	R	8·729	·01237
50·08	108·15	,,	80·48	L	8·690	·01242
50·05	151·12	26·7	60·40	R	9·113	·01656
50·06	151·02	,,	60·30	L	9·084	·01658
50·07	150·96	,,	60·40	R	9·118	·01656
50·07	150·96	,,	60·18	L	9·065	·01661
50·02	197·10	26·7	48·58	R	9·549	·02058
50·04	197·20	,,	48·15	L	9·470	·02077
50·05	197·04	,,	48·45	R	9·531	·02064
50·05	197·08	,,	48·15	L	9·468	·02077
50·00	[2]20·40	26·7	36·79	R	10·153	·02718
50·00	20·38	,,	36·68	L	10·113	·02726
50·00	20·38	,,	36·93	R	10·180	·02708
50·00	20·38	,,	36·85	L	10·157	·02714
50·10	30·42	26·7	27·00	R	11·145	·03703
50·10	30·42	,,	27·16	L	11·200	·03682
50·02	30·42	,,	27·29	R	11·237	·03664
50·02	30·42	,,	26·97	L	11·116	·03707
50·10	40·39	21·9	22·07	R	12·107	·04552
50·10	40·39	,,	21·97	L	12·053	·04511
50·10	40·89	,,	22·17	R	12·152	·04564
50·10	40·39	,,	21·91	L	12·020	·04585

[1] Water Manometer. [2] Mercury Manometer.

Typical Observations with Tube III. in Glischrometer.

Temp. (t° C.)	Manometer Reading (h) cms.	Temp. of Manometer. ° C.	Time of Flow (T) secs.	Bulb being emptied.	$\rho h T$ (reduced to 50°) × 10^{-3}	$\frac{1}{T}$
50·07	[1]108·28	23·5	54·56	R	5·897	·01833
50·07	108·18	,,	54·60	L	5·897	·01831
50·07	108·15	,,	54·57	R	5·891	·01833
50·07	108·17	,,	54·56	L	5·893	·01833
50·20	151·14	23·4	41·69	R	6·316	·02399
50·24	151·14	,,	41·64	L	6·325	·02401
50·22	151·08	,,	41·72	R	6·321	·02397
50·22	151·08	,,	41·58	L	6·300	·02404
50·10	197·40	23·5	34·00	R	6·705	·02941
50·10	197·30	,,	33·93	L	6·690	·02948
50·10	197·14	,,	33·94	R	6·684	·02947
50·10	197·26	,,	33·95	L	6·691	·02946
50·07	[2]20·30	23·2	26·55	R	7·311	·03767
50·07	20·30	,,	26·47	L	7·290	·03779
50·07	20·30	,,	26·52	R	7·303	·03772
50·07	20·30	,,	26·44	L	7·282	·03783
50·08	30·39	23·9	19·98	R	8·237	·05006
50·08	30·39	,,	19·86	L	8·187	·05036
50·08	30·39	,,	19·98	R	8·237	·05006
50·08	30·39	,,	19·82	L	8·171	·05046
50·10	40·42	24·2	17·51	R	9·606	·05711
50·10	40·42	,,	16·43	L	9·016	·06088
50·10	40·42	,,	17·54	R	9·624	·05701
50·10	40·42	,,	16·22	L	9·900	·06165

[1] Water Manometer. [2] Mercury Manometer.

Typical Observations with Tube IV. in Glischrometer.

Temp. (t° C.)	Manometer Reading (h) cms	Temp. of Manometer. ° C.	Time of Flow (T) secs.	Bulb being emptied.	$\rho h T$ (reduced to 50°) × 10^{-3}	$\frac{1}{T}$
50·10	[1]108·08	26·7	61·26	R	6·614	·01632
50·10	108·10	,,	60·80	L	6·561	·01645
50·10	108·09	,,	61·83	R	6·675	·01617
50·10	108·10	,,	61·21	L	6·607	·01634
50·04	150·97	26·7	46·49	R	6·995	·02151
50·01	151·07	,,	46·30	L	6·967	·02160
50·00	150·96	,,	46·50	R	6·990	·02150
50·00	150·96	,,	46·30	L	7·955	·02160
50·00	197·17	26·0	37·44	R	7·348	·02671
50·00	197·07	,,	37·35	L	7·326	·02671
50·00	197·04	,,	37·54	R	7·359	·02664
50·00	196·98	,,	37·37	L	7·326	·02677
50·10	[2]20·92	25·7	28·25	R	8·023	·03539
50·10	20·96	,,	28·00	L	7·998	·03571
50·10	20·92	,,	28·32	R	8·042	·03531
50·10	20·92	,,	28·10	L	7·980	·03559
50·10	30·98	25·7	21·30	R	8·954	·04698
50·10	30·99	,,	22·80	L	9·594	·04386
50·10	31·00	,,	21·40	R	9·010	·04671
50·10	31·00	,,	22·58	L	9·498	·04429
50·00	40·47	25·7	20·78	R	11·378	·04812
50·00	40·47	,,	21·33	L	11·682	·04688
50·00	40·47	,,	20·43	R	11·185	·04895
50·00	40·47	,,	21·05	L	11·530	·04750

[1] Water Manometer. [2] Mercury Manometer.

The numbers in columns 6 and 7 were used to obtain the curves given in Figures 2, 3, 4 and 5. It will be noticed that for a considerable distance the lines are straight, indicating constant values for c in equation 2, and therefore for m for the particular capillary. This constancy is remarkable when we consider the enormous speed with which the water is forced through the tubes in many cases. The individual observations show also that there is no variation in any particular case, and that the value of m in the general formula can be relied upon, when determined in this way. There is therefore no necessity to keep the kinetic energy correction small in comparison with the first term in determining viscosities by the efflux method, provided of course, that the time of flow and pressure can be measured with sufficient accuracy. This will be shown later, where values have been worked out. In certain curves it will also be noticed that at a particular point, there is an abrupt change in the direction of the line, indicating either a largely increased value for m, or a change in the nature of the flow. This is most marked in both the curves for Tube IV. and in one of the curves for Tube III.

The following values for C and c in equation (2) were obtained from the curves, and the corresponding values of m were deduced by equation (4).

	Tube I.		Tube II.		Tube III.		Tube IV.	
	R to L	L to R	R to L	L to R	R to L	L to R	R to L	L to R
C	6350	6330	7400	7440	4570	4570	5400	5390
$10^{-4} \times c$	9·60	9·81	10·00	9·90	7·78	7·78	7·24	7·60
m	1·130	1·164	1·164	1·162	1·128	1·136	1·166	1·216

The values for m are all greater than the theoretical value. There are also two values for each capillary according as the liquid flows in at one end or the other. This fact is most marked in the case of Capillary IV.

The above values for C were used in calculating K in equation 5, for the four tubes. R/L was also calculated.

These values are collected in the following table.

	Tube I.	Tube II.	Tube III.	Tube IV.
K (mean)	·005504	·005463	·005480	·005478
R/L	·003407	·002908	·003774	·003172

It is evident that there is no linear relation between K and R/L. When the above values are plotted in the way already mentioned, it will be noticed that they lie along a straight line parallel to the axis of abscissæ; that, therefore, k in equation 5 has zero value, *i.e.*, the value for n is zero. See Figure 6.

A set of readings was taken at 25° C. and also at 0° C., and values for K_{25} and K_0 were found. The results are tabulated below, and the corresponding graphs appear in Figure 6. They bear out the conclusions arrived at in connection with the results at 50° C.

	Tube I.	Tube II.	Tube III.	Tube IV.
$K_{(25·0)}$	·00896	·00893	·00892	·00890
$K_{(0·05)}$	·01791	·01790	·01790	·01791
R/L	.003407	·002908	·003774	·003172

In the general reduction formula, the most difficult constant to measure accurately is R, the mean radius of efflux. Capillaries are not generally right circular cylinders, nor even elliptical cylinders; and as the degree of precision with which R must be calculated is always four times as great as that required in the deduced viscosity, the examination and measurements of the capillaries must be carried on with extreme care.

Tubes I. II. III. and IV. were in the first place selected from a large number on account of their uniformity of bore

—tested with a small mercury column—and their circular end sections.

The first method of measuring *R* was by contained volumes of mercury. The values obtained (at 0° C.) for the mean radii were ·018968, ·018926, ·020416 and ·020482 cms. respectively.

At the conclusion of all the experiments, sections about ½ cm. in thickness were cut from the tubes at regular intervals; they were ground, polished and mounted in a brass plate. Three independent sets of readings of their dimensions were obtained by me, firstly by direct comparison with a micrometer eye-piece in a microscope; secondly by means of a microscope fitted to the dividing engine belonging to the Physics Laboratory, Melbourne University; and thirdly by means of a micrometer microscope at the Sydney University. The following average values were obtained for the radii of the sections reduced to 0° C.

Capillary I. (Circular)	First Method.	Second Method.	Third Method.	Mean Values.
Section 1	·01905 cm.	·01879 cm.	·01880	·018838
„ 2	·01929 „	·01919 „	·01899	·019106
„ 3	·01932 „	·01933 „	·01877	·019048
„ 4	·01926 „	·01880 „	·01881	·018882

[Mean radius (by mercury) = ·018968 cm.]; Mean = ·018968 cm.

Capillary II. (Circular)	First Method.	Second Method.	Third Method.	Mean Values.
Section 1	·01899 cm.	·01889	·01880	·018862
„ 2	·01896 „	·01861	·01880	·018763
„ 3	·01912 „	·01910	·01891	·019009
„ 4	·01906 „	·01909	·01890	·018990

[Mean radius by mercury = ·018926 cm.] Mean = ·018906 cm.

Capillary III. (Elliptical)	First Method.	Second Method.	Third Method.	Mean Values.
	·02023	·02066	·02069	·020603
Section 1	·02016	·01969	·02020	·020023
	·02083	·02064	02066	·020682
„ 2	·02016	·02009	·01993	·020022
	·02124	·02119	·02069	·020948
„ 3	·02043	·01983	·01996	·020000
	·02097	·02032	·02075	·020643
„ 4	·02043	·02010	·01998	·020095
			(*a*)	·020719
Mean radius by mercury = ·020416.			Mean (*b*)	·020035

Capillary IV. (Elliptical)	First Method.	Second Method.	Third Method.	Mean Values.
	·02138	·02125	·02088	·021087
Section 1	·02023	·02070	·01976	·020152
	·02130	·0211[illegible]	·02086	·021040
„ 2	·02043	·02007	·01984	·020015
	·02144	·02143	·02068	·021057
„ 3	·02023	·01954	·01976	·019765
	·02183	·02125	·02079	·021042
„ 4	·02023	·01997	·01994	·019723
			(*a*)	·021056
Mean radius by mercury = ·020482.			Mean (*b*)	·019914

In determining the mean value for each section, the values obtained by the three methods were weighted in the following manner, Method 1, weight, 1; Method 2, weight, 2; Method 3, weight, 3; thus for Capillary 1, Section 1, by adding together ·01905 cm., twice ·01879 cm., and three times ·01880 cm., and dividing the sum by 6, we obtain the value ·018838 cms. The mean obtained in this way is, I consider, the best value the individual results will produce, taking in account the experimental difficulties in measuring such small bores in the three cases.

The mean values by measurement were then combined with the values obtained by mercury column and in this way the final values were obtained.

Capillary I., circular cylinder, radius ·018968 cm. at 0° C.
,, II., ,, ,, ,, ·018916 ,,
,, III., elliptical cylinder, semi-axes (*a*) ·020762 ,,
(*b*) ·020076 ,,
,, IV., ,, ,, ,, (*a*) ·021061 ,,
(*b*) ·019919 ,,
,, III., mean radius of efflux R $\left(\text{where } R^4 = \dfrac{2\,a^3 b^3}{a^2 + b^2}\right)$
= ·020413 cm.
,, IV., mean radius of efflux R = ·020474 cm.

An accuracy of 1 in 1000 was aimed at throughout the experiments. The values for the constants in the reduction formula having been obtained, the viscosity was determined from the various observations which had been made from time to time, including those already mentioned.

A special set of experiments at 0° C. was made at a fixed pressure in order to obtain accurate values of the viscosity at 0° C. The thermometer registered 0·05° C. throughout the series. With tube I in the glischrometer, under a pressure of 197 cm. of water, the average time of flow was 109·7 secs. The first term of the reduction formula was found to be ·018690, and the second term ·000769. The value for the viscosity at 0·05° was ·01792; which reduced to 0° C., becomes ·01795. A second determination gave the same values practically. The observations and reductions are given on page 48, also a similar set at 25° C. p. 49.

Most of the experiments, however, were carried out at 50° C. with the water flowing under different pressures. In the following tables (p. 50) are collected the various results. The pressures are given in centimetres of mercury, the times of flow in seconds, the values of viscosity (double observations) in absolute measure, and the kinetic energy correction—second term—also in absolute measure. The pressures and times are approximate, and the viscosity values are reduced to the even temperature 50° C.

Temperature 0° C.

Tube in Glischro-meter.	Temp. (t)	Pressure (h)	Time T	Direction of Flow.	First Term.	Second Term.	η_t			η reduced to 0° C.
I.	0·05	197·00	109·99	R to L	·018690	·000769	·01792	·01792	·01791	·01794
	0·05	197·00	109·55	L to R	·018690	·000769	·01792			
	0.05	197·00	109·84	R	·018660	·000770	·01789	·01791		
	0·05	197·00	109·55	L	·018690	·000769	·01792			
II.	0·05	196·90	127·74	R	·018410	·00576	·01783	·01784	·01786	·01789
	0·05	197·00	127·30	L	·018425	·00576	·01785			
	0·05	196·90	127·87	R	·018430	·00577	·01785	·01787		
	0·05	196·90	127·63	L	·018465	·00574	·01789			
III.	0·05	196·95	80·60	R	·018960	·001066	·01789	·01791	·01792	·01795
	0·05	196·95	80·42	L	·018990	·001065	·01793			
	0·05	196·95	80·72	R	·018990	·001066	·01792	·01792		
	0·05	196·95	80·36	L	·018980	·001065	·01792			
IV.	0·05	197·20	93·69	R	·018670	·00809	·01786	·01791	·01790	·91793
	0·05	197·10	93·88	L	·018770	·00805	·01796			
	0·05	197·10	93·81	R	·018683	·00808	·01787	·01790		
	0·05	197·10	93·65	L	·018723	·00806	·01792			

These results give mean value for viscosity of water at 0° C. = ·01793.

Temperature 25° C.

Tube in Glischro-meter.	Temp. (t)	Pressure (h)	Time (T)	Direction of Flow.	First Term.	Second Term.	η_t			η reduced to 25° C.
I.	25·38	196·97	60·35	R	·010245	·001401	·00884	·00885	·00886	·00894
	25·38	196·93	60·17	L	·010268	·001400	·00887			
	25·38	196·93	60·36	R	·010242	·001400	·00884	·00886		
	25·38	196·95	60·25	L	·010282	·001400	·00888			
	25·00	197·00	60·92	R	·010347	·001385	·00896	·00897	·00897	·00897
	25·00	197·05	60·71	L	·010356	·001385	·00897			
	25·00	197·10	60·98	R	·010366	·001384	·00898	·00898		
	25 00	197·10	60·74	L	·010364	·001384	·00898			
II.	25·24	196·78	68·84	R	·009906	·001067	·0C884	·00884	·00884	·00889
	25·24	196·69	68·65	L	·009912	·001066	·00885			
	25·24	196·85	68.79	R	·009902	·001068	·00883	·00884		
	25·24	196·69	68·72	L	·009922	·001066	·00886			
	24·98	197·04	69·19	R	·009998	·001058	·00893	·00894	·00894	·00894
	24·98	197·00	69·08	L	·009995	·001055	·00894			
	24·98	197·10	69·25	R	·010005	·001057	·00895	·00894		
	24·98	197·00	69·08	L	·009995	·001055	·00894			
III.	24·96	197·10	45·85	R	·010792	·001871	·00892	·00894	·00894	·00894
	24·96	197·00	45·84	L	·010831	·001864	·00897			
	24·96	197·00	45·82	R	·010778	·001872	·00891	·00894		
	24·96	197·00	45·84	L	·010831	·001864	·00897			
IV.	25·08	196·15	52·04	R	·010315	·001456	·00886	·00887	·00887	·00889
	25·08	195·95	52·01	L	·010340	·001451	·00888			
	25·08	196·05	52·03	R	·010309	·001456	·00885	·00887		
	25·08	196·05	52·02	L	·010345	·001451	·00889			

Mean value for viscosity of water at 25° C. = ·00893.

Results at 50° C. with Tube I. in Glischrometer.

Pressure (h)	Time of Flow (T)	Viscosity values $\eta \times 10^5$	Viscosity (mean) $\eta \times 10^5$	Second Term. $\times 10^5$
7 cm.	71 sec.	552 551 554 554	553	118
11 „	54 „	552 554 553	553	156
15 „	44 „	552 552 551 550	551	193
20 „	33 „	550 550	550	250
25	28·8	551	551	292
30	24·9	550	550	338
31	24·4	547	547	348
33	23·5	549	549	357
35	22·4	552 554 556	554	376
40	20·9	590 592	591*	400

Results at 50° C. with Tube II. in Glischrometer.

Pressure (h) (Approx.)	Time of Flow T (Approx.)	Second Term $\times 10^5$	Viscosity $\times 10^5$	Mean Viscosity $\times 10^5$
7·3 cm.	80·5 sec.	91	549 550	550
11 „	60·3	121	549 549 549 549	549
15 „	48·3	151	549 548	548
20 „	36·8	199	549 548	549
30 „	27	269	553 553	553
40 „	23	316	557 561	559*
42 „	21·5	340	565	565*
			Mean	·00500

Results at 50° C. with Tube III in Glischrometer.

Pressure (h) (Approx.)	Time of Flow (T) (Approx.)	Second Term $\times 10^5$	Viscosity (double readings) $\eta \times 10^5$	Viscosity (mean) $\eta \times 10^5$
7·3 cm.	54·6	156	552, 551, 550, 549	550·5
11 „	41·6	205	553, 551	552·5
15 „	33·9	252	552, 551	551·5
20 „	26·5	323	554, 554	554
30 „	19·9	430	557, 555, 558, 556, 559	557*
35 „	17·9	478	558, 562, 565	562*
40 „	17·0	500	615, 607, 617, 613, 604, 609, 611	612*

Mean ·00552

Results at 50° C. with Tube IV. in Glischrometer.

Pressure (h) (Approx.)	Time of Flow (T) (Approx.)	Second Term $\times 10^5$	Viscosity (double readings) $\eta \times 10^5$	Viscosity (mean) $\eta \times 10^5$
7·3	61·5	123	546, 552	549
11	46·3	162	547, 547	547
15	37·5	201	544, 545, 543, 547	545
20	28·1	268	546, 546, 546, 546	546
24	25·3	297	...	554
25	24·4	308	546, 546	546
26	23·8	316	...	551
27	23·2	325	550, 548	549
28	22·7	332	...	556*
29	22·6	333	...	588*
30	22·3	339	...	593*
31	21·9	343	...	598*
32	21·9	344	...	634*
34	21·5	350	...	668*
36	21·2	355	...	709*
38	21·0	359	...	751*
40	21·0	359	822, 806	814*
44	20·2	373	835, 832	837*

Mean ·00548

With Tube I. in the glischrometer, the formula gives constant values up to a pressure of 35·4 cms. of mercury, when the time of flow is about 22 seconds. It will be noticed that at this point the kinetic energy correction is more than 60 per cent. of the viscosity, and the average velocity in the tube is 400 cms. per sec.

In the case of Tube II. the formula breaks down suddenly at a pressure between 35·7 cm. and 36·9 cm., the time of flow being about 24 secs., and the correction at pressure 35·7 cm. more than 55 per cent. of the viscosity. The velocity in this case is 370 cm. per sec.

For Tube III. the figures are, pressure between 20·4 cm. and 30·4 cm., time of flow less than 26 secs., second term 60 per cent. of the viscosity; and for Tube IV. when the pressure is 27 cm. and the second term is nearly 60 per cent. of the viscosity, the deduced value is satisfactory, but an increase of pressure of 1 cm. brings about some decided change. The highest velocities reached in both cases, before the change, was about 340 cms. per sec. The curves

Viscosity values ($\times$ 10^5) at 50° C. collected.

Pressure.	Tube I.	Tube II.	Tube III.	Tube IV.	Average.
7·3 cm.	553	550	551	549	551
11·0 „	553	549	552	547	550
14·7 „	551	548	552	545	549
20 „	550	549	554	546	550
24 „	...	...	...	554	554
25 „	551	...	...	546	549
26 „	...	...	...	551	551
27 „	550	...	...	549	550
29 „	551	...	...	(588)	551
30 „	550	553	(557)	(593)	551
31 „	547	...	...	(598)	547
33 „	549	...	...	...	549
34 „	551	...	...	(668)	551
35 „	554	...	(562)	...	554
36 „	...	...	(574)	(709)	
37 „	(558)	...	(571)	...	
38 „	...	...	(578)	(751)	
39 „	(573)	...	(599)	...	
40 „	(591)	(559)	(612)	(814)	
42 „	...	(565)	...	...	
43 „	...	...	...	(837)	
Av. =	·00551	·00550	·00552	·00548	

Mean Value = ·00550

in Figure 5 (*Plate 8*) indicate that when the change takes place, there is a large increase in the value of *m*, if the formula still holds; but the individual results do not agree sufficiently well to enable one to draw definite conclusions from them. The values for the viscosity of water at 50° C., obtained with the various capillary tubes in the glischrometer are collected in the foregoing table. The mean value is ·00550.

Results.—

(1) The constants in the reduction formula were all determined with the greatest possible degree of accuracy, including *R*, *n* and *m*.

(2) For each capillary in the glischrometer—four were used separately—two values for *m* were found, one for each of the ends. These values were in every case greater than the theoretical value 1·12.

(3) For the series of capillary tubes used, experiments at temperatures 0° C., 25° C., and 50° C. gave in each case zero values for *n*.

(4) Absolute values for the viscosity of water at 0° C., 25° C., and 50° C. were obtained, namely ·01793, ·00893, and ·00550, which are probably correct to 0·1 per cent.

(5) The values obtained for *m* were constant over a big range of pressure; and at a very high pressure there was an indication of an abrupt change in the value of *m*, or in the nature of the flow. The velocities at this pressure were much below the critical velocities for the various tubes, but were all above the lower limit of critical velocity.

(6) Consistent values for the viscosity of water at 50° C. were obtained in cases where the kinetic energy correction was as high as 60 per cent. of the viscosity.

I have much pleasure in acknowledging my indebtedness to Professor J. J. Thomson, Cavendish Laboratory, Cam-

bridge; Professor Lyle, Melbourne University; Professor Pollock, Sydney University; and Mr. G. H. Knibbs, F.R.A.S., Federal Statistician, formerly Director of Technical Education, N.S.W., and Lecturer in Surveying, University of Sydney, for valuable assistance during the progress of this research, which was commenced at the Cavendish Laboratory, Cambridge, and completed at the Sydney University.

Note on the Viscosity of Solutions.—The viscosity of certain lithium chloride solutions was determined with the glischrometer described in the previous paper. The only novel feature of the measurements was the automatic recording of the time of flow. The inner platinum wires at *b* and *c* (Fig. 1, *Plate 4*) were connected by insulated wires, also the inner wires at *a* and *d*. Wires were fastened to the outer wires at *a*, *b*, *c* and *d*, and were connected to four plugs on a double reversing key. The two remaining plugs were joined by wires through a battery, and one of the electro-magnets already described. With the key in one position, there was electrical communication between the battery and electro-magnet and the outer c on the one side, and the outer *b* on the other side. The circuit was complete only when the solution filled the spaces at both c and *b*. With the key reversed, the battery was connected to the outer *d* and the outer *a* and the circuit was complete when the solution filled the spaces at *a* and *d*. By regulating the amount of solution in the glischrometer, the signals could be made as short as necessary, at the beginning and end of the flow from R to L, or in the opposite direction, and the time of flow could be read off accurately on the tape.

The following set of readings will be sufficient to illustrate the accuracy with which determinations of the viscosity of solutions can be made with this arrangement:

Lithium Chloride Solution, Temperature 20·75° C.

Pressure (h)	Time (T)	Correction $\times 10^3$	η	η (mean)
198·8 cm.	57·2 sec	150	·01201	·01200
198·2 „	56·4 „	151	·01198	
179·3 „	62·8 „	136	·01204	·01200
179·1 „	62·8 „	138	·01197	
151·0 „	73·1 „	118	·01200	·01200
151·2 „	73·0 „	118	·01200	
127·1 „	85·6 „	101	·01197	·01198
127·0 „	85·1 „	101	·01198	
100·5 „	106·6 „	81	·01200	·01201
100·0 „	106·8 „	81	·01203	

Average ·01200

NOTE ON A CUPRIFEROUS PORPHYRITE AND QUARTZ VEINS IN THE NELLIGEN DISTRICT.

By H. I. JENSEN, D. Sc.

[*Read before the Royal Society of N. S. Wales, June 3, 1908.*]

ON a recent trip to the South Coast Districts I was interested to find between Nelligen and Braidwood, near Sugarloaf Mountain, an extensive outcrop of a dark basaltic looking porphyrite which contained fragments of native copper and small masses of carbonates and silicates of copper. Local residents informed me that lumps of native copper up to 70 ℔s. in weight had been obtained in this rock, but all endeavours to find 'the lode' had been fruitless. Mr. Meares, by whose aid I was directed to the spot, and I picked out numerous small pieces of copper and copper ores which appeared to be sprinkled about in certain portions of the lava. In other places these small metalliferous inclusions were wanting.

On closer examination I found that wherever the copper contents were at all noticeable the lava also contained numerous inclusions of crystallised limestone, schist, slate, quartz and rhyolite. Where the basaltic rock was free from these inclusions the copper ores were also absent.

On my return to Sydney I assayed a sample of the basalt free from inclusions to see if copper was an essential constituent of it. I powdered carefully about 10 ℔s. of the basalt and took 10 grams of the powder to test. Not the faintest trace of copper was indicated.

It appears from these considerations that the copper here is not an original constituent of the igneous magma, as it is in the cupriferous andesites and tuffs of the Illawarra district. It is undoubtedly derived from a metalliferous lode through which the basalt has burst, though the small masses of dendritic native copper and mossy malachite, obtained in the weathered portions of the mass, are formed by the secondary alteration of the original inclusions of sulphide and oxide ores.

The basaltic mass which I examined in a valley near Sugarloaf Mountain is over half a mile wide and extends in a north and south direction for about ten miles, and patches rich in copper inclusions occur here and there, I am told, along its whole length. It is therefore probable that this lava has found its way to the surface along a fissure vein containing rich metallic ores. The copper ores obtained in the basalt contain gold. From an economic point of view the occurrence is valueless, the basalt being nowhere rich enough in metal to pay for the extraction. It may however be possible to pick up the ore-body to the north or south of the basaltic intrusion.

The rock here termed basalt is a volcanic rock, in places quite vesicular and amygdaloidal. Its petrological description is appended.* Basalt is an appropriate field name.

This rock is certainly later than the Silurian schists and probably later than the Devonian, and may even be as late as Tertiary, but its exact relations to the Devonian I have not yet worked out. The surrounding rocks are Devonian shales, quartzites and tuffs. They contain well preserved fossils, *Rhynconella pleurodon*, *Spirifer disjuncta* and *Chonetes*. The mineralisation of the area appears to have taken place in the late Devonian period.

The Quartz Veins of the Nelligen district share in common with most of the auriferous reefs of the Shoalhaven district the peculiar property of cutting out at a depth of 50 - 60 feet. This disagreeable feature has caused the failure of so many mining enterprises on the South Coast.

On my trip through the Nelligen district I noticed in many cliff faces and road cuttings many small lenticular quartz veins. They commence as a fine streak, gradually thicken and thin out again to a streak. Such veins occur of all sizes in the Silurian, and are often rich in gold.

An examination of these veins led me to the view that they were formed during the orogenic movements which folded, contorted and metamorphosed the Silurian strata. In my opinion the heat and pressure due to the orogenic disturbances not only crushed, crumbled and recrystallised the Silurian sediments, but their original moisture contents became vaporised, and performed a pneumatolytic action whereby they caused the silica, in excess of what was necessary for the formation of metamorphic minerals, to tend to separate out in streaks or schlieren in the semi-plastic mass. At the same time gold was leached by these vapours out of the sediments and concentrated in the quartz veins.

It is generally supposed that all these quartz reefs, which cut out in depth and have no relation to any fissure vein,

were offshoots from an igneous mass which once covered the sedimentary rocks but is now removed by denudation. Such an hypothesis fails to account for the small veins which are so abundant in the Nelligen district, whereas the hypothesis that their quartz and gold are derived from the original sediments by metamorphism accounts for both the small veins and large reefs which behave in the manner described. The metamorphic rocks of the Nelligen district are of considerable interest including zoisite schist, mica schist, biotitic schist, epidotic schists and many other varieties of schist which I intend to give an account of later.

I hope shortly to visit the district again and to be able to give to this Society a general account of the many points of interest in the physiography, general geology, economic geology and petrography of the country between Nowra and Nelligen and the Pigeon House Range.

* Petrological Note.—The cupriferous basalt is a porphyritic, rather decomposed, olivine-basalt. The base is fine grained and microcrystalline. The phenocrysts consist of felspar (plagioclase). The constituents of the base are plagioclase, augite (decomposing to uralite and chlorite), olivine and magnetite. Secondary chlorite is plentiful. This rock was therefore a somewhat acid basalt before decomposition set in. It contains no olivine phenocrysts.

Name. Porphyritic andesitic basalt.

RECORDS OF AUSTRALIAN BOTANISTS—(*a*) GENERAL, (*b*) NEW SOUTH WALES.

By J. H. Maiden,
Government Botanist and Director of the Botanic Gardens, Sydney.

[With Plates X. - XIV.]

[*Read before the Royal Society of N. S. Wales, July 1, 1908.*]

I have used the term "Australian botanist" in a somewhat wide sense, having included collectors of note whether they described their finds or not, notable horticulturists, and botanists who have described Australian plants whether they visited this land or not. I have included no living man, so far as I am aware. Some notes on South Australian botanists will be found in (5), and I am taking steps to publish my notes on the botanists of other Australian States in their respective States. It will be seen how imperfect is the record of some who have worked amongst us and who have not been removed by the hand of death very long. Records of departed botanists form a branch of Australian history of practical value to working botanists. They afford a guide to their published works and indicate where their observations were made.

The list of species named after the various botanists and collectors are valuable (as I have often found) for tracing important botanical details, particulars of journeys, biographical notes and other useful information. My assistant, Miss A. M. Jenner, has obtained these by searching the seven volumes of the Flora Australiensis, from beginning to end.

In the 'Sydney Morning Herald' of 7th July, 1906, was a leading article advocating a National Portrait Gallery,

and I wrote at length on the proposal, my letter being published in the issue of the 14th. This refers more specially to oil-paintings and meritorious works of art, but I would make a plea for the collection of portraits of any kind, no matter how crude, of Australian men of science. Are collections of portraits of medical men, engineers, chemists, zoologists, geologists, etc., in existence? We know that only very imperfect collections have been made. Our own Society has a number of photographs of its own members, and lithographs and engravings of others, the Botanic Gardens Museum is caring for those of botanists, and the Mitchell library for all kinds of portraits. But specific institutions or societies should make it their business to gather together the portraits of the men most interesting to them, and the sooner that organised effort takes place the better, since every day the links with the past become fewer. It only remains to be said that I shall be grateful for corrections or for suggestions for additions to the names of botanists.

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Mennell, Philip.—"The dictionary of Australian biography . . . from the inauguration of responsible government down to the present time (1855 – 1892)." London, 1892 (**6**).

Maiden, J. H.—"Forest Flora of New South Wales." Government Printer, Sydney (**7**).

Kew Catalogue of Portraits of Botanists, 1906 (**8**).

See also—

(*a*) *Sachs, Julius von*—"History of Botany," (1530 – 1860). Authorised translation by Garnsey and Balfour, Oxford, Clarendon Press, 1890 (**9**).

(*b*) "Kew Collectors." *Pharm. Journ.*, 27/3/97, p. 270.

(*a*) General. [By this I mean botanists who collected in two or more Australian States or who did not confine their descriptive work to the plants of one State. I am aware I have not been quite consistent. For instance, I have placed Allan Cunningham in the New South Wales list, as he was Superintendent of the Botanic Gardens here; nevertheless, he was an "Australian" botanist. I have excluded French botanists, as the expeditions of the French to Australia, particularly during the first half century of settlement, are so important that I propose to devote a special paper to them.]

Backhouse, James (1794 – 1869). Born 8th July, 1794; died at York, England, 20th January, 1869. Nurseryman. Botanised in Teesdale, Yorkshire, etc., 1803-65. Missionary Friend in Norway and the Southern Hemisphere. Correspondent of J. E. Smith and W. J. Hooker. Pritzel 11; (the only entry is "A monograph of the British Hieracia," York 1856, 8 vo. 92 pp.) *Journ. Bot.* vii (1869), 51; (a valuable and interesting account of his life and botanical work from the pen of J. G. (Baker), himself also a member of the Society of Friends; *Journ. Hort.*, xli (1869), 32 (a brief note); *Gardeners' Chronicle*, 1869, 136 (a moderately brief

note); *Royal Society's Catalogue*, 1, 147 ; vi, 573; vii, 65. The above is based on (1). An excellent though brief account of his work will be found at (3). See also (6).

Backhouse was an admirable botanist and collected in every Australian colony, also in Norfolk Island. I have given an account of his South Australian work in (5) where is a list of species which commemorate him. He wrote the following, which contain many valuable botanical observations :—"Extracts from the letters (and journal) of J. B. . . in Van Dieman's Land and New South Wales (Australia, Mauritius, South Africa), accompanied by G. W. Walker." London, 1838-41, 8 vo. "A narrative of a visit to the Australian Colonies." London, 1843, 8 vo. "A narrative of a visit to Mauritius and South Africa." London 1844, 8vo. At Kew there is a MS. volume labelled "Backhouse, James, Botany of New South Wales" (2 vols. fol.)

Banks, Joseph (1743 – 1820). Born in London 13th February, 1743, died near the same city 19th June, 1820. He was the only son of William Banks of Revesby, Lincolnshire, who left him a large fortune. Educated at Christchurch, Oxford, D.C.L. 1771, baronet 1781, K.B. 1795, Privy Councillor 1797. President of the Royal Society from 1778 until his death. With Cook on his voyage of circumnavigation (1768–1771) during which New South Wales was discovered. Banks maintained a scientific and art staff on Cook's ship, the "Endeavour," Solander being the principal member of it. He made large botanical collections in "New South Wales" (Botany Bay and Endeavour River) which formed the basis of a fine illustrated work (engraved at his expense) recently issued by the Trustees of the British Museum. He was the personal friend of King George III. and had the oversight of the Royal Garden at Kew. By virtue of his position as President of the Royal Society he was the arbiter of science in Britain for many years. He

sent botanical collectors to various parts of the world (including Australia), and received their seeds and collections of plants for Kew, and their dried plants for his own herbarium, which, with his library, was the most celebrated botanical institution of its time. His botanist-librarians were successively Solander, Dryander, and Robert Brown (who survived him). He was the patron of the Bauers and other botanical artists. His herbarium is in the British Museum. He ever identified himself with Australian interests, and all that I know of his botanical activities will be found in my "Life of Sir Joseph Banks, the Father of Australia," now in the press.

Bennett, John Joseph (1801 – 1876). Born at Tottenham, 8th January, 1801. M.R.C.S., F.R.S., Fellow and Secretary from 1840 – 1860, of the Linnean Society. Appointed in 1827 to the Botanical Department of the British Museum, where he was keeper from 1857 to 1870. Author of *Plantæ Javanicæ rariores*, 1838-52. Died at Maresfield, Sussex, 29th February, 1876. The genus *Bennettia* and the fossil *Bennettites* are named in his honour. At Kew there is a plaster cast from a bust modelled in 1871, by H. Weekes, R.A. (Clean shaven face turned slightly to the left, neck bare) (8). See also *Proc. Linn. Soc.* (1875-80) 4; *Journ. Bot.* 1876, 97 – 104, which is an admirable account of him, with a portrait. He was assistant to Robert Brown and legatee of his herbarium. He described a few Australian plants. Had charge of the old Australian collections at the British Museum and authorised the distribution of the duplicates to various herbaria which took place soon after his death in 1876.

Bentham, George (1800 – 84). Born at Stoke, Plymouth, England, 22nd September, 1800, died in London, 10th September, 1884. As to Bentham's share in the "Flora Australiensis," a work which has laid Australian botanists

under an eternal obligation to him, he says[1] the work "is entirely and exclusively mine, with the assistance indeed, but not the co-operation of Baron von Mueller." For biographical references to this eminent man see *Nature*, xxx, 539-43; *Proc. Royal Society*, XXXVIII, i–v; Asa Gray's "Bentham" in *Proc. Amer. Acad. of Arts and Sci.*, xx, 527 (1884), reprinted in Sargent's "Scientific papers of Asa Gray" (1889); Dyer's Eulogium in *Proc. Linn. Soc.* (1887-8) p. 71; Britten and Boulger, p. 14. But especially see the "Life of Bentham" by B. Daydon Jackson in the "English Men of Science" Series (1906); this contains a valuable bibliography of his works. Benthamiana are enumerated in the *Cat. of Kew Library*, (Bulletin, Additional Series, iii, 1899) pp. 42, 43. [See *Plate 10* copied from *Journ. Bot.* vol. xxii.]

The following Australian species commemorate him:—

Colobanthus Benthamianus, Fenzl. = *C. subulatus*, Hook. f.; *Olax Benthamiana*, Miq.; *Acacia Benthami*, Meissn, = ?; *Daviesia Benthamii*, Meissn. = *D. incrassata*, Sm.; *Pultenæa Benthamii*, F.v.M.; *Spadostyles Benthamii*, Endl. = *Pultenæa humilis*, Benth.; *Weinmannia Benthami*, F.v.M.; *Scævola Benthamia*, De Vr. = *S. striata*, R. Br.; *Microtis Benthamiana*, Reichb. = ? *Thelymitra Benthamiana*, Reichb. = ?

Brogden, James, (————). Eighty-four New Holland plants by this collector were on sale in London. (*Hooker's Journ. Bot.* IX, 190 [1857]).

Brown, Robert (1773–1858). Botanicorum facile princeps (Humboldt). The founder of Australian systematic botany. Born at Montrose, Scotland, 21st December, 1773, died in London, 10th June, 1858. Educated at Marischal College, Aberdeen. Joined the army as a surgeon, 1795 and corresponded with Sir Joseph Banks on botanical matters. The latter appointed him naturalist to Flinders'

[1] *Journ. Linn. Soc.*, xx, 304 (1884).

voyage of discovery to Australia in the "Investigator." In Australia 1802-5. Speaking of Brown's researches on Australian plants, Hooker says:

"Hence, when we regard the interest and novelty of the field of research, the rare combination of qualities in the botanist, and the advantges and facilities which he enjoyed, we can easily understand why the botanical results should have been so incomparably greater, not merely than those of any previous voyage, but than those of all similar voyages put together."

Author of "Prodromus Floræ Novæ Hollandiæ," styled "Opus aureum" in Germany. See Hooker's Eulogy of Brown in *Proc. Linn. Soc.* 1887-8, pp. 54 – 67. Botanist-librarian to Sir Joseph Banks 1810-20, then legatee of Sir Joseph's noble herbarium and library, with reversion to the British Museum. Brown became keeper of Botany to that institution in 1827. For further particulars of this eminent man, whose memory all Australians should revere, see my forthcoming "Life of Sir Joseph Banks."

Dryander, Jonas (1748 – 1810). Born at Gothenburg, Sweden, 5th March, 1748, died in London, 19th October, 1810. A pupil of Linnaeus. He arrived in London 10th July. 1777, and after Solander's death in 1782 became Sir Joseph Banks' botanist-librarian. He was librarian of the Royal Society and Vice-President of the Linnean Society. In his capacity as curator of the Banksian botanical collections he gave much attention to Australian plants, describing a number in *Aiton's Hortus Kewensis*, of the first portion of the 2nd edition of which he was practically the author, although it is customary to refer to the new plants described in that work as Aiton's. The only purely Australian botanical work published by Dryander is "Chloris Novæ Hollandiæ, or Catalogue of the Plants of New Holland and Van Diemen's Land hitherto published, as far as they have come to the knowledge of J. Dryander." (*Ann. Bot.* of

König and Sims, ii, 504-32, 1806). Robert Brown acknowledges his indebtedness to Dryander. Further details concerning the latter will be found in my forthcoming "Life of Banks." He is commemorated in the Proteaceous genus *Dryandra* and in *Grevillea Dryandra*, R. Br.

Endlicher, Stephen Ladislaus (1804–1849). Hungarian botanist and philologist; was born at Pressburg. Professor of Botany in the University, 1840, and Director of the Botanic Gardens and Botanic Museums, Vienna. Author of *Prodromus Floræ Norfolkicæ*, 1833; *Iconographia Generum Plantarum*, 1838; also *Genera Plantarum*, 1836-40; *Flora Brasiliensis*, 1840; *Enchiridion Botanicum*, 1841; and other works. Died at Vienna. There is in Kew a lithograph by Strixner from a drawing by B. J. Rauh. (Standing figure to knees, in spectacles, wearing a long sash and resting his right hand on his sword, facing spectator.) (8). He has placed Australians under an obligation by his work on Norfolk Island plants (Floræ Norfolkicæ) and by his "Generum Plantarum," which contains many descriptions of Australian genera. See also Asa Gray's review of this work in *Amer. Journ. of Sci. and Arts*, XXXIX, 176 (Reprinted in Sargent's "Scientific papers of Asa Gray.") He is commemorated by the following Australian plants:—

Acacia Endlicheri, Meissn. = *A. strigosa*, Link, var. *Endlicheri; Bossiœa Endlicheri.* Meissn. = *B. eriocarpa*, Benth.; *Apalochlamys Endlicheri*, DC. = *Cassinia spectabilis*, R.Br.; *Astartea Endlicheriana*, Schau. = *A. fascicularis*, DC.; *Melaleuca Endlicheriana*, Schau. = *M. seriata*, Lindl.; *Senecio Endlicherii*, DC. = ?; *Verticordia Endlicheriana*, Schau. = *V. Preissii*, Schau.; *Polypompholyx Endlicheri*, Lehm. = *P. multifida*, F.v.M.; *Grevillea Endlicheriana*, Meiss.; *Frenela Endlicheri*, Parlat.; *Alania Endlicheri*, Kunth.; *Pteris Endlicheriana*, Ag. = *P. comans*, Forst.; *Xerotes Endlicheri*, F.v.M.

Forster, Johann Reinhold (1729–1798). D.C.L., M.D. German naturalist and traveller. Born at Dirschau, and

descended from a Yorkshire family which migrated to Prussia. Visited Russia, and came to Warrington in 1766 as a professor of natural history and teacher of languages. Accompanied Captain Cook on his second voyage, as naturalist, 1772-5, and published on his return "Observations made during a Voyage round the World"; "Characteres generum plantarum quas in itinere ad insulas maris Australis, colligerunt [auctores] annis 1772-75." Londini, 1776, 4to; "Beschreibungen der Gottungen von Pflanzen . . . . Aus dem Lateinischen übersetzt . . . . durch J. S. Kerner." Stuttgart, 1779, sm. 8vo. (The two latter in collaboration with his son). From 1780 to his death he filled the chair of natural history and was Director of the Botanic Garden at Halle. Author also of "Floræ Americæ septentrionalis . . . . an enumeration . . . . with their English names, etc." London, 1771, 8vo. The genus *Forstera* was dedicated to him by Linnæus the younger. At Kew there is a line engraving of him by J. F. Boux after a painting by Ant. Graff. Also a bust (within an oval surrounded by plants) in a short wig, face three-quarters to the right. (From (**8**) with a few additions by J. H. M.)

Forster, Johann Georg Adam (1754 – 1794). M.D., F.R.S. German traveller and naturalist. Born at Nassenhuben, the son of the preceding. Accompanied his father on his voyage with Captain Cook, and afterwards assisted him with his publications, translating his "Voyage round the World" into German. Professor of natural history at Cassel, 1778-84, and at Wilna, and librarian at Mayence to the Elector, 1788. He lost all his property when the Prussians took Mayence, and resolved to go to India, but died at Paris. He was the author of "Geschichte und Beschreibung des Brodbaums," 1784; "De plantis esculentis insularum Oceani Australis commentatio botanica," Berolini, 1786; "Florulæ insularum australium Prodromus,"

Gottingæ, 1786, and other works.[1] There is at Kew a photograph from a drawing taken of him at Otaheite (Tahiti), also a bust, head bent in profile to the left, sailing boat and island in the background (8).

The two Forsters made many botanical discoveries in the Pacific Islands, Fuegia, and New Zealand, but only one of Cook's ships, the "Adventure," commanded by Captain Furneaux, visited any part of Australia, arriving at Adventure Bay, Tasmania, in February, 1773. The Forsters are commemorated by the following Australian plants:—

Brathys Forsteri, Spach. = *Hypericum gramineum*, Forst.; *Euchiton Fosteri*, Cass. = *Gnaphalium japonicum*, Thunb.; *Microseris Forsteri*, Hook. f.; *Wollastonia Forsteriana*, DC. = *Wedelia biflora*, DC.; *Thelymitra Forsteri*, Sw. = *T. longifolia*, Forst.; *Agrostis Forsteri*, R. et S. = *Deyeuxia Forsteri*, Kunth.; *Carex Forsteri*, Wahlenb. = ? *Dichelachne Forsteriana*, Trin. = *D. crinita*, Hook. f.; *Grisebachia Forsteriana*, Wendl. et Dr. = ?; *Howiea Forsteriana*, Becc. = *Kentia Forsteriana*, Muell. = *Pandanus Forsteri*, Moore et Muell.; *Psilotum Forsteri*, Endl. = *Tmesipteris Forsteri*, Endl. = *T. tannensis*, Bernh.

Gray, Asa (1810 – 1887). "The United States Exploring Expedition, under Commodore Wilkes, visited Tasmania and Sydney in 1839, and large collections were made near Port Jackson, etc. These have been in part published by Professor Asa Gray, of Harvard University, Cambridge, in his excellent "Botany of the United States Exploring Expedition, of which one quarto volume of letterpress and one folio volume of plates alone have hitherto appeared." (3). See also "Brackenridge," p. 93. Asa Gray never visited Australia.

Harvey, William Henry (1811 – 1866). M.D., F.R.S., F.L.S. Born at Summerville, near Limerick, February,

[1] "De plantis magellanicis et atlanticis commentationes." (*Comm. Soc. Gotting.* ix.) [Gottingæ, 1787] 4to. "Herbarium australe, etc." Gottingæ, 1797, 12 mo.; are from his pen.

1811. Went to school at Ballitore, Co. Kildare, the master of which was an accomplished botanist. Sailed in 1835 for Cape Town and studied the botany of South Africa. Returned to England in 1842, and became the leading authority on algæ. Hon. M.D. of Dublin and Curator of the Herbarium of Trinity College, 1844 ; and succeeded, in 1856, to the Chair of Botany at the University. In 1849 he visited the United States, and between 1853-6 India, Australia and the South Sea Islands. Author of "Genera of S. African Plants," 1838 ; "Manual of British Algæ," 1841 ; "Phycologia Britannica," 1846-51 ; and numerous other works. Died at Torquay. The genus *Harveya* was dedicated to him. At Kew there is a coloured crayon drawing of him by Sir Daniel Macnee, P.R.S.A., also a bust, seated, clean shaven, face three-quarters to the left. Dimensions 17½ ins. by 13¾ ins. Hooker collection. Also a lithograph, 1850, by T. H. Maguire. Half length, seated, holding a book, face three-quarters to the right. Autograph (facsimile) (**8**).

"In 1854 he visited Australia for the purpose of investigating the Algology of its shores ; he landed at King George's Sound, went overland to Swan River and Cape Riche, then to Melbourne, Tasmania, and Sydney, forming magnificent collections of Algæ, many of which have been published in the "Phycologia Australica," in this work, and elsewhere." (**3**).

In addition to the works already enumerated, see "Nereis australis ; or Algæ of the Southern Ocean, etc." London, 1847, 8 vo. "Some account of the marine botany of the Colony of Western Australia," (*Trans. R. Irish Acad.* xxii.) Dublin, 1855, 4 to. "Phycologica australica : or a History of the Australian Seaweeds, etc." London, 1858-63, 5 vols. 8 vo. See also his papers on the Algæ of Tasmania, *Tas. Journ.*, Vol. II, pp. 377, 421, 1846; Vol. III, pp. 55, 153, 209, 1849. See also an obituary notice in Seemann's *Journ.*

Bot. 1866, 236, also "Memoir of W. H. Harvey, M.D., F.R.S.," (London, 1869), with a portrait. Chapters xiii and xiv are devoted to his botanical travels in Australia, where plants other than sea-weeds also engaged his attention. He is commemorated by the following Australian plants :—

Sarcopetalum Harveyanum, F.v.M.; *Acacia Harveyi*, Benth.; *Seseli Harveyanus*, F.v.M.; *Verticordia Harveyi*, Benth.; *Caulerpa Harveyi*, F.v.M., a sea-weed figured in "Phycologia australica."

Heward, Robert (1791–1877). Died at Wokingham, Berkshire, England, 24th October, 1877. F.L.S. 1836. In Jamaica, 1823-6, "Ferns of Jamaica," *Mag. Nat. Hist.*, 1838. Herbarium at Kew. Pritzel 143. Jackson 370. *Journ. Bot.*, 1877, 380. Royal Society's Catalogue, iii, 342. Lasègue, 266, etc. *Gardener's Chronicle* 1877, ii, 571. The above from (1). He is chiefly known to Australian botanists as the friend, legatee and biographer of Allan Cunningham (see *Lond. Journ. Bot.*, i, 107 and 263; also first series iv, 231–320, the whole published in one vol. by Heward). Doubtless owing to his relations with Cunningham he ever retained an interest in Australian plants.

He is commemorated in *Hewardia*, J. Sm. = *Adiantum Hewardia* Hook.; *Dryandra Hewardiana*, Meissn.; *Grevillea Hewardiana*, Meissn. = *G. concinna*, Br. var. *racemosa; Pimelea Hewardiana*, Meissn. = *P. elachantha*, F.v.M.

Kalckbrenner, Carl (1806–1886). He was an eminent authority on fungi, and described many Australian species, some of which are published in Mueller's *Fragmenta*. Others were published in *Proc. Linn. Soc., N.S.W.* (of which Society he was a corresponding member), viz., "Definitions of some new Australian fungi," vii., 104; "Fungi aliquot Australiæ orientalis," vii., 563; "New species of *Agaricus* discovered in West Australia," vii., 638; "Description of two new fungi," viii., 175. He died in 1886 near Zips, Hungary, pastor of the Church at Wallendorf. A brief note

on his life, and a portrait (tab. 22), will be found in Acta Horti Bergiana, Band 3, No. 2 (Wittrock).

Kippist, Richard (1812–1882). Born at Stoke Newington, London, 11th June, 1812; died at Chelsea, London, 14th January, 1882. Entered the service of the Linnean Society in 1830, and in 1842 was chosen Librarian, which post he filled till 1881. He did not publish much, but he always took an interest in Australian plants and assisted Bentham, Mueller, and other workers at such plants with his advice. Biographical notices of him will be found in *Proc. Linn. Soc.*, 1880-2, p. 64, and "Nature," 19th January, 1882. See also (1). His works include:—"On Jansonia, a new genus of Leguminosæ from Western Australia." *Trans. Linn. Soc.*, xx., 383. "On Acradenia, a new genus of Diosmæ," *ib.* xxi., 207, and he is commemorated in the Australian genus *Kippistia*, F.v.M. = *Minuria*, also in *Dryandra Kippistiana*, Meissn.; *Hakea Kippistiana*, Meissn.

Lambert, Aylmer Bourke (1761–1842). Born at Bath, 2nd February, 1761; died at Kew, 10th January, 1842. For biographical details see (1). He was a wealthy and cultured patron of botany, who early busied himself in collecting Australian herbarium specimens, and raising Australian plants. His herbarium was second only in importance to that of Sir Joseph Banks, but at his death it was broken up, part going to the British Museum and part to the Herbier Delessert. He is commemorated in the Australian *Lambertia*, Sm.; *Scævola Lambertiana*, De Vr. = *S. Kœnigii*, Vahl.; *Hakea Lamberti*, Sweet = ?

Lhotsky, Johann (1800–?) Natus d. 27. m. Junii 1800 in Lemberg (Galizia, Austria), Pragae, Vindobonae, Berolini Parisiis studiorum causa versatus gradum Dr. med. adeptus, Vindobonæ vixit et m. Majo 1830 ad Brasiliam abiit, initio ad Bahia, dein m. Majo 1831 navi in prov. Rio de Janeiro ad plantas et alias res naturales colligendas. In Rio her-

barium ab ill. archiatro Patricio da Silva Manso in prov. Matto grosso collectum acquisivit atque in Germaniam misit, ubi pluribns museis europaeis venditum est. E Brasilia 1832 in Australiam profectus per plures annos in New South Wales, alpibus australianis et Tasmania itinera fecit. De ejus morte nil cognitum est.—Scripsit praeter alia: A journey from Sydney to the Australian Alps, undertaken in the months of January, February, and March, 1834 . . . with some general information respecting the Colony of New South Wales, Sydney, 1835, 8 vo. 110 p. Some remarks on a short vocabulary of the Natives of Van Diemen's Land 1839. Some data towards the botanical geography of New Holland 1843.

Lit. Flora Ratisb. vol. XII (1829) 2, p. 634 – 637, XIII (1830) 1, Beil. p. 37 – 40, XIV (1831) 2, p. 647 – 656, XV (1832) 2, Intelligenzbl. p. 25 – 40, XVII (1834) 1, p. 239. Lasègue, Mus. Deless. p. 281-2. J. H. Maiden, Departm. of Agric. Sydney, Miscell. Publ. No. 331 (1899) Flora of Mount Kosciusko, p. 6, 8. V. Maiwald, Geschichte der Botanik in Böhmen (1904) p. 118. Pritz. Thes. II ed. p. 184; Cat. Sc. Pap. IV p. 2, VI p. 713, XII p. 445.

Itinera.—I. 1830-31 civit. Bahia (ins. Itaparica, Incarnação, Bahia, Ilheos etc.) II. 1831-2 civit. Rio de Janeiro (Corcovado, Tijuca, Morro do Papagayo, Praja grande, Serra dos Orgãos, Magé, Capocina, Troxal etc.) et Minas Geraes. III. 1832 – ? iter Australiense. Societas botanica Ratisbonensis plantas Lhotskyanas Brasilienses variis herbariis europaeis (Wien, Berlin, St. Petersburg, de Candolle, Leipiz etc.) vendidit. (The above is from the pen of Herr I. Urban, Botanic Garden, Berlin, in Martius' *Flora brasil.* Vol. I, part i, p. 42.)

Hooker (3) says his collections were dispersed; he probably sold them. He sold zoological specimens, *e.g.* Gray, *Ann. Mag. Nat. Hist.* ii, 307 (1839) describes a "New

Holland Gerboa rat" (*Hapalotis albipes*, Licht.) sold by him to the British Museum. See an appreciation of Ferdinand Bauer from Lhotsky's pen in Hooker's *Lond. Journ. Bot.* ii, 106 (1843). He was for a time in the service of the Tasmanian Government (? as Medical Officer). The date of his death is unknown. He is commemorated in the Myrtaceous genus *Lhotzkya*, Schauer, and in *Leptorrhynchus Lhotzkyanus*, Walp.=*L. squmatus*, Less.

Lindley, John (1799-1865). Ph. D., F.R.S., F.L.S. Botanist and horticulturist. Born at Catton, near Norwich, where his father was a nurseryman, and educated at Norwich Grammar School. Assistant Librarian to Sir J. Banks, when he published *Rosarum Monographia*, 1820, *Collectanea Botanica* and *Digitalium Monographia* in 1821, assistant secretary of the Royal Horticultural Society, 1822, first professor of botany at the University of London, 1829, and lecturer on botany to the Apothecaries' Company 1836. It was on his recommendation that Kew Gardens were acquired for the nation. He published many works. Member of the Institute of France. Died at Turnham Green, London (**8**). See also (**1**). There is a reproduction of the portrait of Lindley by Eddis, in the Royal Horticultural Society's room at fig. 44, *Journ. R. H. S.*. xxix (Dec. 1904), also of the Lindley medal.

"Dr. Lindley's able sketch of the vegetation of the Swan River Colony, published in 1839, as an appendix to the "Botanical Register," is founded chiefly on Drummond's collections; and it contains a good account of many of the features of the climate of the Colony, many extremely valuable botanical notes on the plants, and figures of eighteen. Dr. Lindley records his obligations to Captain Mangles, R.N., and R. Mangles, Esq., and notices a paper on Western Australia by Dr. Milligan, published in the "Madras Journal" for 1837." (**3**).

Lindley also named the specimens collected on Mitchell's Third Expedition. He was for many years deeply inter-

ested in Australian plants of which he described a large number. He is commemorated in the following Australian plants:—

Dodonæa Lindleyana, F.v.M. = *D. triangularis*, Lindl.; *Hibiscus Lindleyi*, Wall. = ? *Acacia Lindleyi*, Meissn.; *Byblis Lindleyana*, Planch. = *B. gigantea*, Lindl.; *Hardenbergia Lindleyi*, Meissn. = *H. Comptoniana*, Benth.; *Eucalyptus Lindleyana*, DC. = *E. amygdalina*, Labill ; *Eupatorium Lindleyanum*, F.v.M. = *E. cannabinum*, Linn.; *Verticordia Lindleyi*, Schau. = *V. Drummondii*, Schau., var. *Lindleyi; Dampiera Lindleyi*, De Vr. = *D. alata*, Lindl.; *Stylidium Lindleyanum*, Sond. = *S. calcaratum*, R.Br.; *Styphelia Lindleyi*, F.v.M. = *Conostephium minus*, Lindl.; *Atriplex Lindleyi*, Moq. = *A. halimoides*, Lindl.; *Banksia Lindleyana*, Meissn.; *Dryandra Lindleyana*, Meissn. = ?; *Grevillea Lindleyana*, Meiss. = *G. Wilsoni*, Cunn.; *Ptilotus Lindleyi*, F.v.M. = *Trichinium obovatum*, Gaudich.; *Eriochilus Lindleyi*, Endl. = ?; *Pimelea Lindleyana*, *Meiss.* = *P. spathulata*, Labill. (partly); *P. linifolia*, Sm. (partly); *Tribonanthes Lindleyana*, Endl. = *T. longipetala*, Lindl.; *Arthropodium Lindleyi*, Kunth. = *A. paniculatum*, R.Br.; *Sporobolus Lindleyi*, Benth.; *Thysanotus Lindleyanus*, Endl. = *T. dichotomus*, R. Br.; *Vilfa Lindleyi*, Steud. = *Sporobolus Lindleyi*, Benth.

Miquel, Friedrich Anton Wilhelm (————). A Dutch botanist who specalised (*inter alia*) on various families of Australian plants. See a list of some of his work in Pritzel, 195. The following are of special interest to Australian botanists:—"Revisio critica Casuarinarum," (*Verh. Akad. Amst.* xiii). Amstelodami, 1848, 4 to. "Over de Cycadeën in Nieuw Holland," (*Versl. K. Akad. Wet. Amst.* xv, 1863), 8 vo. "De Piperaceis Novæ Hollandiæ," (*Versl. Akad. Amst.* II, ii) Amsterdam, 1866, 8 vo. He is commemorated in the following Australian plants:—

Loranthus Miqueli, Lehm. = *L. pendulus*, Sieb.; *Thryptomene Miqueliana*, F.v.M.; *Grevillea Miqueliana*, F.v.M.; *Encephalartos Miquelii*, F.v.M. = *Macrozamia Miquelii*, F.v.M.

Mitchell, Thomas Livingstone (1792–1855). Born at Craigend, Stirlingshire, Scotland, and died at Darling Point, Sydney, 5th February, 1855. Served throughout the Peninsula War. Surveyor General of New South Wales, 1827. Hooker (**3**) says :—

"Major Mitchell's extensive journeys come next under review, and owing to his great fondness for natural history, and excellent system of observation, his writings and his collections have both proved eminently useful in advancing our knowledge of Australian botany."

It would not be proper to omit Mitchell's name from a catalogue like the present, which includes many promoters of botany. Hooker proceeds to give an admirable resumé of his journeys, with especial reference to matters of botanical interest. Mitchell's works are well known to Australians, and need not be cited here. For biographical details see "Men of the Time in Australia" (Victorian series, 2nd edition, 1882), also (**6**). Pritzel, 195, says that Lindley described 77 new species of plants in various parts of Mitchell's work "Three Expeditions," and that these descriptions were collected together in *Annales des sc. nat.*, Vol. xv. (Jan. 1841). See also Heward, in Hooker's *Lond. Journ. Bot.*, July 1847, pp. 363-72. Major, afterwards Sir Thomas Mitchell, is commemorated in the following Australian species :—

Abutilon Mitchelli, Benth. ; *Busbeckia Mitchelli*, F.v.M. = *Capparis Mitchelli*, Lindl.; *Acacia Mitchelli*, Benth.; *Crotalaria Mitchelli*, Benth. ; *Crotalaria Mitchelli*, F.v.M. = *C. Novæ-Hollandiæ*, DC., *Paryphanthe Mitchelliana*, *Schau.* = *Thryptomene Mitchelliana*, F.v.M.; *Podolepis Mitchelli*, Sond. = *P. longipedata*, A. Cunn.; *Rutidochlamys Mitchelli*, Sond. = *Podolepsis rutidochlamys*, F.v.M. ; *Goodenia Mitchellii*, Benth. ; *Jasminum Mitchellii*, Lindl. = *J. lineare*, R. Br.; *Leucopogon Mitchellii*, Benth.; *Amarantus Mitchellii*, *Benth.*; *Conospermum Mitchellii*, Meissn.; *Eremophila Mitchelli*, Benth.; *Grevellea Mitchellii*, Hook.

= *G. chrysodendron*, R. Br.; *Hakea Mitchellii*, Meissn. = ?; *Persoonia Mitchellii*, Meissn.; *Plantago Mitchelli*, Dcne = ?; *Euphorbia Mitchelliana*, Boiss.; *Phyllanthus Mitchelli*, Benth.; *Primelea Mitchelli*, Meissn. = *P. collina*, R. Br.; *Pterostylis Mitchelli*, Sond. = *Bertya Mitchelli*, Muell. Arg.; *Iseilema Mitchelli*, Anders. = *Anthistiria membranacea*, Lindl.; *Neurachne Mitchelliana*, Nees; *Panicum Mitchelli*, Benth.; *Triodia Mitchelli*, Benth.

Mitten, William (1819 – 1906). Born at Hurstpierpoint, Sussex, 30th November, 1819; died at the same place, 27th July, 1906. An eminent bryologist. He described the Hepaticæ for Hooker's *Flora Tasmaniæ*, and was an authority on Australian hepatics and mosses for many years. Some Australian mosses were enumerated by him in *Trans. R. S. Vict.*, xix., 49. See also "Record of new localities of Polynesian Mosses, with descriptions of some hitherto undefined species." (*Proc. Linn. Soc., N.S.W.*, vii., 98.)

Mueller, Ferdinand (1825 – 1896). Born Rostock, Germany, 30th June, 1825; died at Melbourne 10th October, 1896. Arrived in Adelaide, 1847, and went to Melbourne in 1852 to fill the newly-created post of Government Botanist of Victoria. He began his Victorian botanical explorations in 1853, and in 1856 explored north-western and northern Australia under the leadership of A. C. Gregory, returning with a rich harvest of new plants. In 1857 the Directorship of the Botanic Gardens at Melbourne was conjoined to his office of Government Botanist, and separated from it in 1873. He died in harness, as Government Botanist of Victoria. His official life was synchronous with a renewed development of botanical science in Australia. He assisted Bentham in the preparation of the *Flora Australiensis*. He wrote the "Eucalyptographia," "Iconography of Australian species of Acacia," the "Fragmenta phytographiæ Australiæ," the "Census

of Australian Plants," and many works too numerous to mention at this place. He was elected a Fellow of the Royal Society in 1861 ; the King of Wurtemburg created him a Baron in 1871 ; in 1879 he was created a K.C.M.G. Biographical details may be obtained in the following :— Hooker (**3**) ; Henniker Heaton, "Dictionary of Dates ;" Mennell (**6**) ; "Men of the Time in Australia," Victorian series, 2nd edition, 1882. The following appreciations were written after his death :—Woolls, William, "Sydney Mail," 17th October, 1896 ; Spencer, W. Baldwin, "Victorian Naturalist," xiii., October, 1896 ; Deane, Henry, *Proc. Linn. Soc., N.S.W.*, xxi., 823 (1896) ; Maiden, J. H., *Proc. Roy. Soc., N.S.W.*, xxxi., 38-43 (1897); also, *Trans. Aust. Assoc. Adv. Science*, Adelaide Meeting, 1907 ; Norton, James, *Proc. Linn. Soc., N.S.W.*, xxv., 778 (1900). A bibliography of his works (some of his smaller writings are scattered throughout the world in publications difficult of access), to include, perhaps, reprints of some of his rarer contributions to science, would form a durable and valuable memorial of Mueller, a suggestion originally made by me in *Proc. Roy. Soc., N.S.W.*, xxxi., 41. On 26th November, 1901, there was unveiled a Memorial to him in the St. Kilda General Cemetery, Melbourne, by his Excellency the Earl of Hopetoun, Governor-General, and I made the following address on the occasion :—

"I attend this function by instruction of the Chief Secretary as Government Botanist of New South Wales, and as President of the Linnean Society of that State as a delegate from the Society, by request of the Council. The last resting place of the greatest Australian botanist of recent times is classic ground. To many of our citizens this beautiful monument will be a remembrance of Mueller, who did so much to diffuse a knowledge of its vegetation, but the botanist requires no such adventitious aid, for as long as there are plants in Australia, the name of Mueller will be remembered in connection with them. He is the

last of a trio of distinguished men who have studied Australian plants in Australia itself. I do not refer to the immortal Bentham in this connection, but the names of Robert Brown and Allan Cunningham are inseparably bound up with the elucidation of the flora of this continent. As Lord Rosebery said of Mr. Gladstone, who had not long passed away, 'we are too close to the mountain to grasp its true proportions,' so I would say of our late friend, that we cannot yet fully realise his achievements. Personally I place him second only to Robert Brown, the 'Facile princeps botanicorum' of Humboldt. He is the last of the botanists of the whole continent of Australia; those of us who carry on his work are provincial botanists, confining our researches more or less to one State. We find the botanical work of one State sufficiently engrossing, and thus in botanical matters we are reversing the act of federation, which politically unites all our peoples. But our provincial arrangements are those of convenience only. We are all happily working to a common end. Apart from his intellectual greatness the industry of Mueller was prodigious. The clock was never used by him as an indicator to cease his labours; he seemed to aim at perpetual motion, and now this silent monument points to rest. He was a public servant who did not work for his pay; a portion of this satisfied his modest personal requirements; the rest was spent by him in the furtherance of his studies. He well advertised Australia in the best sense, and while I think his memory will long be green in his adopted country, he is affectionately remembered in other parts of the world, as I can testify. Personally I owe much to my late master, and I have often gratefully acknowledged my indebtedness to him. Much of my life is spent in gardens or in traversing the bush for the purpose of botanical exploration. Though alone in my wanderings, the memory of my late friend is often with me; different plants remind me of Mueller's work in various ways. To me the beautiful lines of Tennyson's "In Memoriam" have a deep and special significance, as I think of the great man in whose honour we are met on this beautiful November day:—

I climb the hill : from end to end
  Of all the landscape underneath,
  I find no place that does not breathe
Some gracious memory of my friend;

Nor runlet trickling from the rock;
  Nor pastoral rivulet that swerves
  To left and right thro' meadowy curves,
That feed the mothers of the flock;

But each has pleased a kindred eye,
  And each reflects a kindlier day;
  And, leaving these, to pass away,
I think once more he seems to die."

Smith, James Edward (1759 – 1828). Born at Norwich, 2nd December, 1759; died at Norwich, 17th March, 1828; buried Lowestoft. M.D. Leyden, 1786; F.R.S., 1785. Founded Linn. Soc., 1788. P.L.S., 1788 – 1828. Purchased Linnæus' Collections, 1784. Knighted 1814. "English Bot.' 1790 – 1814. "Flora Brit.' 1794—1804. Herbarium at Linn. Soc. Pritz. 299; Jacks. 607; "Memoir and Correspondence," by Lady Smith, with portrait by H. B. Love, engr. W. Say, after bust by Chantrey; R.S.C. v, 725; Nich. Illustr. vi, 830, with portrait; Nich. Anecd. viii; Cott. Gard. v, 185: Mag. Nat. Hist. i (1829), 90; Gent. Mag. 1828, i, 297; Allibone, Bust by Chantrey at Linn. Soc. Portrait in Thornton. Copy at Kew. Engr. by R. Pastorini. *Smithia* Aiton. The above from (1). He described a large number of Australian plants, beginning with "A specimen of the botany of New Holland" (1794). Of his papers on Australian plants in *Trans. Linn. Soc.*, I may refer to "Account of two new genera of plants from New South Wales" (*Goodenia* and *Platylobium*), ii, 346. "Botanical Characters of some plants of the natural order Myrtaceæ," iii, 255. "The characters of twenty new genera of plants" iv, 213. "Description of Sowerbœa juncea," v, 159. "Botanical characters of four New Holland plants of the natural order of Myrti," vi, 299. "Characters of three

new species of Boronia," viii, 282. "A botanical sketch of the genus Conchium," ix, 117. "Specific characters of the decandrous papilionaceous plants of New Holland," ix, 244. "Characters of Platylobium, Bossiæa, and of a new genus named Poiretia," ix, 301. "An account of a new genus of New Holland plants named Brunonia," x, 365. He is commemorated by *Smithia* Aiton, and by the following Australian species :—

Eriostemon Smithianus, Hill. = *E. difformis*, A. Cunn. var. (?) *Smithianus; Zieria Smithii*, Andr.; *Eugenia Smithii*, Poir.; *Myrtus Smithii*, Spreng. = *Eugenia Smithii*, Poir.; *Conospermum Smithii*, Pers. = *C. longifolium*, Sm.; *Macdonaldia Smithiana*, Gunn. = *Thelymitra Smithiana*, Hook., f. = *T. flexuosa*, Endl.; *Eriocaulon Smithii*, Br.

Solander, Daniel Carl (1733 – 1782). Born at Pitea, Sweden, 12th February, 1733, died in London, 16th May, 1782. He was a pupil of Linnæus, and came to England in 1759. Was offered the post of Professor of Botany at St. Petersburg in 1762, but declined. Appointed assistant in the British Museum in 1765, and shortly afterwards entered the employment of Sir Joseph Banks, with whom and with Cook he went on the voyage of the "Endeavour," 1768-1771, during which cruise New South Wales was discovered. He was made D.C.L., Oxon., 1771. On the return of the "Endeavour" he lived in Banks' house as botanist-librarian until his death. Like his master (Linnæus) he was a naturalist in the wide sense of the word, a botanist, and a zoologist, although, like Linnæus, he acquired the greater reputation as a botanist. Many of his descriptions of Australian plants will be found in Britten's Botany of the voyage of the "Endeavour," published by the Trustees of the British Museum. His published writings, however, fall short in amount of what might have been expected from so talented a botanist. See (1). For further bio-

graphical details, and, indeed, a "life" of him, see my forthcoming "Life of Banks." His name is commemorated by the Solanaceous genus *Solandra*, Salisbury, and by the following Australian species:—

Spondias Solandri, Benth; *Tribulopsis Solandri*, R. Br. = *Tribulus Solandri*, F.v.M.; *Acacia Solandri*, Benth.; *Banksia Solandri*, Br.; *Orthoceras Solandri*, Lindl. = *O. strictum*, R. Br.; *Agrostis Solandri*, F.v.M. = *Deyeuxia Forsteri*, Kunth.

Woods, Julian Edmund Tenison. (1832–1889). Born in London, 15th November, 1832; died in Sydney, 7th October, 1889. F.L.S., 1863. Went to Tasmania, 1855. Ordained priest, 1857. To Singapore, 1883. President *Linn. Soc., N.S.W.*, 1880-81. Botanical papers in *Proc. Linn. Soc., N.S.W.*, Jackson 622; R.S.C. vi., 436; viii., 270; Geological Magazine, 1890, 288; Ann. Bot., iii., 494 (bibliography); *Proc. Linn. Soc., N.S.W.*, 2nd ser., iv., 1301, with bibliography. The above from (**1**). See also (**6**) and *Proc. Roy. Soc. N.S.W.*, xxiv, 2. His first botanical work in Australia was done in South Australia (*e.g.*, he supplied plants from the "Tattiara country," or Ninety Mile Desert, for the Flora Australiensis), and I have hence given an account of his work in (**5**).

(*b*) New South Wales.

Anderson, James[1] (1797–1842). Born at Boguham, near Stirling, Scotland. Botanical collector on Captain P. P. King's voyage in H.M.S. "Adventure" (1825-1830) to South America, including a survey of the Straits of Magellan, &c. On the homeward voyage he was left at Sydney, became a botanical collector on his own account, and in April, 1835 (on the death of Richard Cunningham), he was appointed Acting Superintendent, Botanic Gardens, Sydney.

[1] Not John, as was stated in (**1**) and (**3**), through confusion with John Anderson, gardener to the Earl of Essex, and author of a paper on *Tetragonia*.

He was superseded by Allan Cunningham (whose faithful friend he was) on 12th February, 1837. He was Superintendent from February, 1838, until his death on 22nd April, 1842. Buried in Devonshire-street Cemetery; remains removed to La Perouse, 1901. His New South Wales plants are in various herbaria. The genus *Andersonia*, R.Br. (Epacridaceæ) does not primarily commemorate James Anderson (as is stated by some authors), but William Anderson, Surgeon and Botanist of Cook's 3rd voyage. See also (**1**), (**3**), (**4**).

Atkinson, Caroline Louisa Waring (1834–1872). Born at Oldbury, 8 miles from Berrima, 25th February, 1834. A daughter of Mr. J. J. O. Atkinson. Married in 1870 Mr. James Snowden Calvert (who accompanied Leichhardt on his first expedition). She spent nearly all her life at "Fernhurst," Kurrajong Heights, and she collected largely for Rev. Dr. Woolls and Mueller. Many of her plants are recorded in the "Flora Australiensis," and in Mueller's "Fragmenta." She possessed considerable literary gifts, and besides writing Australian tales, illustrated by herself, she wrote country sketches for a number of important papers, containing notes on the botany, etc., of the Hawkesbury district. She died 28th April, 1872, leaving a daughter. She was interested in zoology, and was an expert taxidermist. She was an excellent botanical artist, delighting in depicting the native flora. She was known to her intimate friends by the name of "Dianella." She is commemorated by the Loranthaceous genus *Atkinsonia*, also *Erechthites Atkinsoniæ*, F.v.M. and *Epacris Calvertiana*. A horticulturally distinct fern called *Doodia Atkinsonii* (a form of *D. caudata*) was named after her. See (**6**), p. 77. I am indebted to Mr. H. Selkirk for some of the above particulars. [For portrait see *Plate 14.*]

Backhouse, James. See p. 62.

Beckler, Herman. Native of Germany; I do not know the date of his birth and death. He was Medical Officer and Botanist to the Burke and Wills expedition. The instructions to the "Botanical Observer" will be found at p. lxxii., *Trans. R. S. Vict.*, 1860. He collected near the Darling, in N.S.W., and subsequently in the Clarence district, Upper Bellinger, &c. For a list of the species named after him see (7), part 26, under "*Dysoxylon Beckle-rianum.*"

Bennett, George (1804 – 1893). Born at Plymouth, England, 31st January, 1804, visited Ceylon, 1819. M.R.C.S. 1828, F.R.C.S. and M.D. (Glasgow) in 1859. Author of "Wanderings in New South Wales . . . during 1832-4" (1834) and "Gatherings of a Naturalist in Australasia" (1860), which works show him to be a good botanical observer. He was in practice in Sydney for many years. He took great interest in the welfare of the Sydney Botanic Gardens, and greatly interested himself in the cultivation of citrus fruits. He died in Sydney, 29th September, 1893. See (6), also Prof. David's obituary notice in his Presidential Address[1]; also (7) under *Flindersia Bennettiana*, F.v.M. *Eupomatia Bennettii* was also named after him. He is also commemorated in the beautiful Port Jackson seaweed *Claudia Bennettiana*, Harv., figured in "Phycologia Australica," the second volume of which was dedicated to him by Harvey. He was Clarke Medallist of this Society (1890). Portrait in F. M. Bladen's "Historical Notes on the Public Library of N.S.W., 1906."

Bennett, Kenrick Harold (——–1891). Mr. Bennett was engaged in pastoral pursuits, and was a nephew of the better known Hon. W. A. Brodribb, M.L.C. He was an educated bush naturalist, whose tastes lay chiefly in making observations on the habits of birds. See *Proc. Linn. Soc.*,

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[1] *Proc. Linn. Soc., N.S.W.*, xviii., 542 (1893).

N.S.W., xvi., 707 (1891). He also made many observations on our native plants, and published notes "on *Myoporum platycarum*, a resin-producing tree of the interior of New South Wales" (*op. cit.*, vii., 349); "Exhibition of specimens of Spinifex," viii., 180; "Notes on the method of obtaining water from Eucalyptus roots, as practised by the natives of the country between the Lachlan and Darling Rivers," viii., 213; "Remarks on the decay of certain species of Eucalypti," x., 453. He made botanical collections for me in 1886 and 1887, and I can testify as to the accuracy of his observations on plants. For the last few years of his life he lived at Ivanhoe, viâ Hay, and when he died, 30th June, 1891, I should say he was from 50 – 55 years of age.

Bidwill, John Carne (1815 – 1853). Born Exeter, England, and died at Tinana, Wide Bay, Queensland, 16th March, 1853. First Director of the Botanic Gardens, Sydney, and Government Botanist (all other officers in charge having been called Superintendent), 1st September, 1847. He was appointed by the Governor, but owing to some crossing of letters, the Secretary of State appointed Mr. Charles Moore to the position, and accordingly Mr. Bidwill vacated it on Mr. Moore's arrival in January, 1848. Hooker (3) speaks of him as "possessed of a remarkable love of botany and knowledge of Australian plants. . . Mr. Bidwill accompanied me in my excursions around Port Jackson, and impressed me deeply, both then and afterwards in England, with the extent of his knowledge and his fertile talents." His herbarium went to Kew. He travelled and botanised much in New Zealand. After he left the Botanic Gardens, he was appointed Commissioner of Crown Lands at Wide Bay, near Maryborough (now Queensland) and made many botanical observations. He published the first account of the Bunya Bunya Pine

(*Araucaria Bidwilli*). There is some interesting correspondence on this subject in the "Sydney Morning Herald" of 9th, 18th, 20th and 22nd June, 1906. See my biographical notes of him (4), and the following are all supplementary: Quotations in (1) are Pritzel 27; *Journ. Bot.*, 1853, 252; Royal Society's Catalogue, i., 360; Smith's Kew, p. 67; *Ann. and Mag.*, viii., 438 (1842); *Gent. Mag.*, 1853; *Dict. Nat. Biog.*, v. 18. I was indebted to Mr. David Mitchell for the loan of a copy of the following rare work:—"Rambles in New Zealand, by John Carne Bidwill (late of Exeter), Sidney, New South Wales. W. S. Orr and Co., London, 1841, 8 vo., pp. 93, with a map of the author's route." Price, 2/6. The writer states that he arrived in Sydney in September, 1838. Intending to settle in N.S.W. he had (according to the regulations in force in those days), to wait a long time for land to be surveyed which he had selected. In the meantime he visited New Zealand, arriving in the Bay of Islands on 5th February, 1839. The narrative contains copious references to botanical matters. At p. 88 he says:

"These rambles were abruptly (early in April. J.H.M.) put an end to by the increasing business of the mercantile firm at Sydney, with which I am connected, and my time and attention became occupied in other pursuits. But soon after my return to Sydney it was determined that I should go again to New Zealand on commercial business, and having resided for some time at Port Nicholson (Wellington. J.H.M.) and its neighbourhood, I am, at this time (August 1840) enabled to add many further particulars respecting the country from my own continued personal observation."

He conducted an extensive correspondence with Captain P. P. King, R.N., Sir (then Mr.) William Macarthur, of Camden Park, and others. The late Hon. P. G. King, M.L.C., lent me a large number of Bidwill's letters to his father, Captain King. They contain scarcely anything

else but references to plants (his movements are also interesting for biographical purposes), and to botanical and horticultural, chiefly hybridising, work. He was a born horticulturist, as well as botanist. It has been already shown how high an opinion Hooker held of him, and these extracts (hitherto unpublished), are valuable as throwing light upon one of the most eminent of my predecessors, concerning whom few details have been published, and one who would have been one of the foremost of Australian botanists had his life been spared.[1]

January, 16, 1841.—"Was at Moreton Bay when your letter arrived. Shall sail for England on 1st February, certain, so they say. Did you not promise me a letter to Sir W. Hooker . . . I did not find many new things at Moreton Bay. A beautiful blue Nymphæa was the most unexpected—it is common on the Clarence, but is very rare on the Brisbane. (See p. 92.) A new fruit from Wide Bay, 150 miles north of Moreton Bay. It is a *Capparis*, with a fruit as large as a large peach, and said to be very good. I will leave word with Robertson (Sydney Botanic Gardens) to give you one. A small fig, quite as good as the garden fig, and an abundant bearer. Fruit round, size of a cherry. Robertson will have plants. On the top of the Great Glass House, or Beawah, I found a *Dendrobium* about twice as large as *D. Kingianum* from the Buckun (the Gloucester Buckets, J.H.M.), but otherwise exactly like it; flower not seen. I fell in with a person who had been exploring down the Condamine, and who says he thinks that the Condamine is the same as the Boyne. He is a very intelligent person; you may know him, Mr. Stuart Russell. The Bunya Bunya (in his writing it looks like Bunza Tanza, J.H.M.) is a very curious looking tree, the bark smooth and black, the branches very numerous at the whorls, but only remaining very near the top of the tree, instead of there being only about 5 or 6 branches at one whorl, as in *A. excelsa;* there

[1] Justice has never been done to Bidwill's undoubtedly great attainments. A portrait of him does not appear to exist.

are 12 or 15, which never divide or make lateral shoots, and in the largest trees the branches are not so thick as my wrist. The fruits are very like those of *imbricata*, and the branches on which they are borne could not be distinguished from branches of that tree. The fruit is as large as a hat, and the kernel (in the largest ones) larger than the kernel of a Brazil nut, or as large as three large almonds; it is, when young, sweet and agreeable, but as it gets old it acquires a disagreeable taste, resembling old peas and raw beans. I have not seen a ripe one yet. I do not imagine they contain any oil, as there is no nutty flavour in the taste of them. I dare say that when they are old they may be very nourishing, but do not expect that the whites will think them very good food. A large tree bears about 16 cones of different sizes, from that of a child's head to that of a man's. The trunk hardly tapers to the branches, and appears likely to make beautiful spars, from the exceeding small size of the branches. The largest tree I saw was about 120 feet high, and 4½ feet in diameter, but it is not so high or large a tree as the common Moreton Bay Pine, of which I saw one tree only, 150 years old, which was 175ft. high and 2ft. diameter. It would not have given so long a spar as a Bunya of same diameter, but I fancy that it would produce the same amount of timber in one fourth of the time that the Bunya would. . . . I want some plants and seeds of *Caesalpinia sepiaris* (Deccan thorn), to make fences with."

On 1st April, 1844, he offered Captain King a collection of seeds, part of which he had received from Kew.

October 19, 1844.—"I send the number of the 'London Journal of Botany,' containing the account of the 'Bunya Bunya.'"

December 31, 1844.—"Mr. Macarthur has a great many hybrid *Crinums* just coming into flower—one opened on Friday, between *scabrum* and *pedunculatum*—a splendid flower, much larger than either parent, white with a pink stripe quite as dark, but narrower than in *scabrum*. Petals 5 inches by 1 inch. Flowers 8 inches across. Certainly the finest *Crinum* I have ever seen. You will

before this have received the seed of *Eugenia Mitchelli.* Mr. Macleay is delighted with it, and says it is a capital fruit."

January 28, 1845.—"W. Macarthur writes me that some of his later roots of hybrid *Crinums* are even superior to the first. A plant of *Musa Cavendishii* has arrived at the Gov. Garden (Sydney) from Kew."

February 15, 1845.—"The sketch obviously represents the Liverpool Plains *Crinum*, which is a peculiar one. I sail on Wednesday next in the 'Coquette,' for Tahiti."

February 8, 1846 ?—"On going on board the 'Brightman' just now I found your parcel with the newspaper in my cabin. They (the *Passifloras*) would not fruit with me at Tahiti. I was much delighted at looking over the Flora Antarctica at Dr. Bennett's (Dr. George Bennett. J.H.M.), not the less so as I see that in it I have credit done me for my early discoveries in New Zealand. I often had occasion to feel annoyed at seeing my plants, which I procured from Tongariro, named as discovered by Dieffenbach, &c, who discovered them 4 years after I did,[1] but then I sent all my plants (except an imperfect set) to Lindley, who never published one of them, and it was only from the evidence contained in the very imperfect herbarium which I gave to Sir William Hooker, when I was in England, that I was enabled to prove that *Lindleyana* (*sic.*) of Dieffenbach's or Somelans (*sic.*) plants were discovered by them for the first time, as it is they have never found several of my plants. Lindley has served a like trick with the rare Tahitian Orchids which I sent him in spirit (at my own expense) on my return thence."

May 12, 1846.—"There is nothing particular in flower at Camden (Mr. William Macarthur's); several of Leichhardt's things have flowered, but all poor and miserable—a *Tephrosia*, a thing related to *Goodia*, an *Hibiscus*, more miserable than I thought an *Hibiscus* could be, and a poor ? *Mena* (a bluish *Crota-*

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[1] **For a brief account of Bidwill's and Dr. Ernest Dieffenbach's botanical explorations, see Cheeseman's "Manual of the New Zealand Flora," xxi.**

laria); there is, however, a very handsome scarlet-flowered prostrate *Hibiscus*, quite new and peculiar from the Pine River."

August 13, 1847.—"I returned here about a week since, from Wellington and Molong."

September 27, 1847.—"There is a new *Dendrobium* at the Gardens (he was now in charge of the Sydney Botanic Gardens) from the Friendly Islands I believe, rather handsome in the style of *speciosum*, but greenish. Plant very pretty, and rather curious to us here, being neither after the manner of *speciosum*, &c., or of another family such as *linguaeforme*, *canaliculatum*, &c., but with a thin stem and alternate oval thinnish leaves. I began at the Gardens (Sydney Botanic) yesterday, but have not yet received my official instructions. Mr. (Deas) Thomson has so much to do that he has been obliged to put off making them out from time to time. I am inclined to think that your *Pittosporum* is only the female plant of *P. undulatum*. They are sometimes hermaphrodite, sometimes male and sometimes female by abortion of the stamens; if you examine further I think you will find this to be the case."

December 26, 1847.—"I received your note last evening, and thank you for the seeds, part of which I will give to W. Mc.A. (Macarthur) as you desire. I was at Camden on Tuesday and Wednesday, in order to see the new *Gladioluses*, and choose those which were best worth nursing to send to England; several of them were superb; there were also a good many handsome hybrid *Crinums*. I have a much handsomer variety of *Gladiolus oppositiflorus* than the Camden one which I gave you, and will send you some seed of it if you like; it is not, however, a good seed bearer, in fact very bad. I have not one *good* pod out of all the flowers which I impregnated, and it has set seed if nothing else; on the contrary a very inferior variety has set seed at every flower, and the pods are all fat and large. I shall have a root for you of a rather handsome one, which I raised from seed of Mr. Herbert's *oppositiflorus*, by *oppositiflorus cardinalis*. It is not so handsome as my fine *oppositiflorus*, but I think must be better than *ramosus*. I was amazingly disgusted to-day with a new species which I have

been taking a great deal of care of, '*Ludwigi*;' it has a very large root, 7 leaves, which are broader than those of *oppositiflorus*, and slightly hairy; the scape is somewhat imperfect, being apparently unable to disentangle itself from the leaves which ensheath it, so that I cannot say what the thing may look like when the upper flowers open, scape with more than 28 (! !) flowers, spathes transparent (!) almost membraneous, rounded rather more than I have represented (figures not reproduced), flowers apparently with all the lobes equal, as in *Ixia* (!) not more than an inch diameter, colourless or semi-transparent, greenish-white; if *cuspidatus* is a beast, this is the most wretched of beasts. I never saw so miserable a thing; at the same time it is very curious. I am sorry that I have no *psittacinus* to try to cross it with at present, because its great number of flowers and its shape might possibly be useful elements to introduce into a completed cross, although in itself it is so miserable; although I impregnated all the flowers on four roots of *Natalensis*, with the pollen of *oppositiflorus*, I doubt if I have one seed that will grow, although all the capsules were swollen to their full size; in most of them all the seeds were mere scales, but on three or four of them were one or two seeds, which seemed about half the size of a good *pure* one. This is very extraordinary, as the common cross, which is so easily produced, gives *gandavensis*, which itself is an abundant seed bearer when impregnated by its own pollen, or that of either of its parents. I had a very curious bulb in flower here, but some vagabond broke it off to-day. I have an idea that it is *Amaryllis Banksiana*, but it looks very like a *Nerine*, but has 60 or 70 flowers; the strange part of it is that it flowers when in full leaf, like a *Crinum*, and I had impregnated it with *C. scabrum*, in order to see if it was possible to form a cross between the genera. It was not so handsome as *A. Josephiniæ*, but still rather pretty when in full flower. I send you some seed of *Hibiscus Sidneyi* by *H. Richardsoni*; *H. Sidneyi* is from *heterophyllus*, by *splendens*. I have called the farther cross *Pyrmonti*, because Pyrmont is *out* of Sydney, a very bad pun I know, but I gave the name because I thought that, having some sort of meaning, I should be less likely to forget it

than if it had none at all. It will probably be a large yellow flower. I went to Government House last Thursday to see young Fitz-Roy, and the Governor sent for me. He said that he was very sorry to hear the report of my supercession (at the Botanic Gardens)—spoke very kindly. I asked him if in accordance with his rules for making appointments, I should be eligible, as I had never been on his list. He said, 'Yes—what did I want?' I said that if there was any chance of a new Commissionership being formed to the northward I should like it very well. He said that I should certainly have it if such a thing occurred but that he did not know when a vacancy might happen." (So far his experiments were undertaken at the Botanic Gardens.)

December 27, 1847.—"I do think that I shall like the Commissionership better than my present situation. I am aware that there will be disagreeables connected with it, but I shall at al events there have a fixed rule of conduct laid down for me, whereas here all the blame which may arise will be laid upon my shoulders, when in reality I might have nothing whatever to do with the matter, . . . I understand that Mr. Keck at the jail was at the Gardens yesterday, and spoke to Kidd very highly of Mr. Moore,[1] who apparently is a friend of his."

Maryborough, April 20, 1849.—"There is no danger of my being removed from my district as you fear. It will improve, I have more than £500 per annum for doing what is only a pleasure to me. I would however willingly do more for my pay."

In a list of plants introduced into the Colony during the year 1849-50, *Amaryllis Ameliæ*, a hybrid raised by Mr. J. C. Bidwill, is enumerated ('Second Ann. Rep. of the Australasian Botanic and Horticultural Society' [1850]). The Gigantic Water Lily of Australia (*Nymphæa gigantea*) was described by Hooker (*Bot. Mag.* t. 4647) from material

[1] Mr. Moore informed me that he arrived in Sydney, 14th January, 1848, so this conversation apparently took place before Mr. Moore's arrival.

sent by Bidwill from Wide Bay in 1851. The genus *Bidwillia*, Herbert, commemorates him, also the following species:—

Brachychiton Bidwilli, Hook. = *Sterculia Bidwilli*, Hook.; *Cupania Bidwilli*, Benth.; *Hyptiandra Bidwilli*, Hook. f.; *Saccopetalum Bidwilli*, Benth.; *Acacia Bidwilli*, Benth.; *Tephrosia Bidwilli*, Benth.; *Helichrysum Bidwillii*, Benth.; *Loranthus Bidwillii*, Benth.; *Myrtus Bidwillii*, Benth.; *Jasminum Bidwillii*, Vis. = *J. lineare*, R.Br.; *Cryptocarya Bidwillii*, Meissn. = ?; *Araucaria Bidwilli*, Hook.

Brackenridge, J. D. (————). He was a member of the "Scientific Corps" of Commodore Charles Wilkes' United States' Exploring Expedition (1838 – 1842), which visited New South Wales in 1839. He collected mostly in the Sydney and Hunter River districts, and the specimens collected by the expedition were described in Asa Gray's work on the botany of the Expedition (New York, 1857).

"The ferns and allied orders were worked up by Mr. Brackenridge. With the exception of a few presentation copies of Mr. Brackenridge's portion of this work which happened to have been sent off to Europe, the whole stock was burnt in the fire which destroyed the storehouse, so that it has now become extremely rare." (Seemann, *Fl. Vitiensis*, vii).

Brackenridge was attached to the U.S. Ship "Vincennes" as "Assistant Botanist," apparently serving the whole of the cruise. William Rich "joined the "Peacock" at Callao and the Vincennes at San Francisco," as "Botanist," and Brackenridge was probably subordinate to him. They worked together. Mr. Brackenridge is sometimes also called "Horticulturist." The genus *Brackenridgea*, Gray, (Ochnaceæ) figured, from Fiji (there is also an Australian species) commemorates him. See (2).

Burton, David (——– 1792). Governor Phillip[1] says he was brought up as a gardener, and was sent out in the

[1] *Hist. Rec.*, i. (2) 599.

"Gorgon," (22nd September, 1791) as a "Superintendent." He was styled "the public gardener" at Parramatta, and it is stated that he was sent out by Banks, but I have seen no Banksian memorandum about him.

"The following parcels of land were in cultivation at Parramatta in November 1791, . . . The above grounds were measured by David Burton, the public gardener, who observes that the soil in most places is remarkably good, and only wants cultivation to be fit for any use, for the ground that has been longest in cultivation bears the best crops." (Hunter, p. 562).

A report by Burton on some land near Parramatta, will be found at Hist. Rec. i, (2) 599. He was killed, 13th April, 1792, by a gun-shot wound when duck-shooting on the banks of the Nepean. He was evidently much esteemed.

"This young man, on account of the talents he possessed as a botanist, and the services which he was capable of rendering in the surveying line, could be but ill spared in this settlement." (Collins, Ist. Ed. 205; 2nd Ed. 164).

He is credited in Aiton's Hortus Kewensis with having introduced *Podolobium trilobatum* to cultivation. Britten and Boulger, p. 28, quote Salisbury, *Parad. Lond.* f. 73 as giving a reference to Burton. The *Burtonia* of Salisbury is *Hibbertia*. The *Burtonia* of Robert Brown is a leguminous genus.

Caley, George (177– –1829). Born in Yorkshire, England between 1775 and 1780. Educated at the Manchester Grammar School. He wrote to Sir Joseph Banks, asking to be employed as botanical collector abroad. He arrived in New South Wales in 1800 in Banks' pay. Governor King marked out a "botanic garden" for him at Parramatta, under Colonel Paterson's directions. He explored New South Wales, naming Mount Banks after his patron, and made other geographical discoveries, while he obtained large botanical collections. He also botanised in Tasmania.

He left Sydney for England in 1810 and rejoined the Middleton (near Manchester) Botanic Society. Later on he became Curator of the Botanic Garden, St. Vincent, West Indies (1816 – 1822). He returned to England, May 1823, then settled in London, dying at Bayswater, 23rd May, 1829. He collected birds and other fauna. As regards his botanical work, both Banks and Brown never hesitated to speak of the value of it and of the ability of Caley. Robert Brown speaks of him as "Botanicus peritus et accuratus." I have pointed out (Agric. Gazette N.S.W., October 1903, p. 988) that he discovered hybridization in the genus Eucalyptus. He is commemorated in the genus *Caleya*, also in *Dodonæa Caleyana*, G. Don = *D. boroniæfolia*, G. Don; *Viola Caleyana*, G. Don; *Acacia Caleyi*, A. Cunn. = *A. podalyriæfolia*, A. Cunn.; *Anadenia Caleyi*, R. Br. = *Grevillea ramosissima*, Meissn.; *Banksia Caleyi*, R.Br.; *Grevillea Caleyi*, R. Br.; *Persoonia Caleyi*, F.v.M. = *P. chamæpeuce*, Lhotsky; *Prostanthera Caleyi*, Benth. = ?.

Recently I have dedicated a New England Ironbark, *Eucalyptus Caleyi*, to his memory, to remind botanists of his discovery of hybridisation in the genus, in which he showed an Ironbark to take a part.

Carron, William (1823 – 1876). Born in Norfolk, England, 18th December, 1823, died at Grafton, N.S.W., 25th February, 1876. His daughter informs me that he arrived in Sydney in 1843 in charge of plants for one of the Macleays (Alexander or William Sharp). On 29th April, 1848, Edmund B. Kennedy, Assistant Surveyor, left Sydney in the barque "Tam o' Shanter" to explore the country lying between Rockingham Bay and Cape York. Carron was botanist of the Expedition, and on its return (he and Jacky Jacky were the only survivors), he published a pamphlet "Narrative of Kennedy's Expedition," which is abstracted in H. Stuart Russell's "Genesis of Queensland." There is

an addendum to MacGillivray's "Voyage of the Rattlesnake," entitled "E. B. Kennedy's Expedition for the exploration of the Cape York Peninsula" (1852) by Carron. Mueller in *Trans. Phil. Soc. Vict.* ii, 159, may also be referred to. See also Woolls' "Lectures on the Vegetable Kingdom, p. 46; Royal Society's Catalogue vii, 339; also (1).

"A beautiful marble tablet has just been received from England for erection in St. James' Church, commemorative of the fate of Assistant Surveyor Kennedy and his party. Kennedy was killed by the aborigines in the vicinity of the Escape River, December 13, 1848. The persons of the expedition who perished by disease were: Thomas Wall (Naturalist); C. Niblet, James Luft, E. Taylor, W. Costigan, E. Carpenter, J. Mitchell, J. Douglass and Dennis Dunn. The survivors were William Carron (Botanist), William Goddard, and Jackey Jackey (Aboriginal)." ('Sydney Herald' of 2nd March, 1852).

After some work at collecting he was permanently employed as "Collector," Botanic Gardens, Sydney, from 1st November, 1866 to 31st December, 1875. Mr. Carron reported to the Secretary for Lands, 28th December, 1871 (ordered by Legislative Assembly to be printed, 28th July, 1872) on certain Timber Reserves newly formed in the Clarence River district. The reserves were Glen Ugie, Coldstream, Chambigne Creek and Pine Ridge. On 25th April, 1872, Mr. Charles Moore, Director, Botanic Gardens, forwarded a more voluminous report by Mr. Carron, Botanical Collector, on additional Timber Reserves in the Clarence, Richmond and Tweed districts (ordered by the Legislative Assembly to be printed 10th December, 1872). It would appear that the setting apart of these reserves was in connection with the foundation of a Forest Department in the Colony, since it had been found that timber (especially cedar) had been so extravagantly cut, that further control was necessary. Mr. Carron uses the follow-

ing names which are useful to trace synonymy (a) *Flindersia Greavesii*, "Bulboro" or "Teak," (b) *Eugenia Jambolana*, "Durobbi." In the "Gardeners' Chronicle" of 27th Jan., 1872, Dr. George Bennett wrote that Carron had gone to Lord Howe Island in H.M.S. "Rosario." Mrs. Pryce (Mr. Carron's daughter) mentions to me that her father arranged the flowers (named after Cunningham), for the litho-portrait in the "Sydney Mail" (Portrait Series No. 7) of Allan Cunningham which is so well known. She also states that her father selected the New South Wales timbers prepared at the Botanic Gardens for the Philadelphia Exhibition. He left the Botanic Gardens to take up the post of Forester on the Clarence River, but died shortly after taking up his duties. [For portrait, see *Plate 12.*]

. . . "well known for his extensive and accurate acquaintance with the flora of Australia, as also for his readiness to impart to others his valuable stores of information." (Prof. W. J. Stephens, President, *Proc. Linn. Soc. N.S.W.*, iii., 442).

Mueller named the genus *Carronia* (*Bauhinia*) after him. He is also commemorated by the following :—

Bauhinia Carronii, F.v.M.; *Fagus Carronii*, C. Moore = *F. Moorei*, Benth.; *Phaius Carroni*, F.v.M. = *P. grandifolius*, Lour.

Carron also collected the following plants in the ill-fated Kennedy Expedition :—

Nepenthes Kennedyi, F.v.M.; *Goniopteris Kennedyi*, F.v.M. = *Meniscium Kennedyi*, F.v.M.; *Polypodium Kennedyi*, F.v.M.; *P. urophyllum*, Wall.

"Amongst the survivors (of Kennedy's Expedition) was Mr. Carron, the botanist, whose narrative is full of excellent observations on the vegetation of the swampy and almost impracticable country traversed. It includes the notice of a *Nepenthes*, which with the rest of the collection, was lost." See (**3**).

Clowes, G. (————). "Mr. G. Clowes, a gentleman who visited New South Wales for his health, and trans-

mitted to Kew very copious and fine specimens of New South Wales plants." (3). We have a few of his specimens in the National Herbarium, Sydney. I know nothing further about him.

Collie, Robert (1839–1892). Born on the banks of the Dee, Aberdeenshire, Scotland. Was ordained into the Presbyterian Ministry in 1866. He arrived in New South Wales in 1876, and was in charge of the church at Newtown, Sydney, until his death, which occurred on 18th April, 1892. He took a great interest in N. S. Wales botany and wrote a paper on "The influence of bush fires on the distribution of species." (These *Proceedings*, xxi., 103, 1887). He bequeathed his herbarium and botanical library, together with a terra-cotta plaque of himself, to the Linnean Society of New South Wales. He was a Fellow of the Linnean Society of London for some years. See a list of specimens of plants collected by him at King George's Sound and named by Woolls, *Proc. Linn. Soc. N.S.W.*, xiv, 317 and xv, 295; see also xvii, 668 (1892); also these *Proceedings* xxvi, 14 (1892). [For portrait see *Plate 11.*]

Considen, Denis (————). He was assistant-surgeon to the Colony, under White, at its inception. He was one of the few British officers who investigated the natural history of the place. He writes to Banks, under date, Port Jackson, 18th November, 1788,[1] sending various zoological specimens. He also sends herbarium specimens, Grass-tree gum, and speaking of the "large Peppermint tree," (Eucalyptus) says, "if there is any credit in applying these and many other simples to the benefit of the poor wretches here, I certainly claim it, being the first who discovered and recommended them." In commemoration of this pioneer work with Eucalyptus I have dedicated

[1] *Hist. Rec.*, i, (2) 220.

Eucalyptus Considenana[1] to his memory. Secretary of State Dundas wrote,[2] 14th July, 1792, granting leave of absence to Considen to return to England should the state of his health continue to require it. I know nothing further concerning this worthy.

Cunningham, Allan (1791 – 1839). I have given so full an account of Allan Cunningham, King's Botanist and Superintendent of the Botanic Gardens, Sydney, at (4) that I have but little to add at this place. The marble tablet to his memory in St. Andrew's Scots' Church is by Clewett of Sydney. "Cunningham on the vegetation of the N.W. Shores of Terra Australis, 1826," in "Botanical Miscellanies, 1825 – 1844," I have not seen. There is much information concerning Cunningham's journeys in Stuart Russell's "Genesis of Queensland." In (8) there is a note on a "Crayon drawing by Sir Daniel Macnee, P.R.S.A. To the waist, seated, with arms folded, clean-shaven face three-quarters to the right looking slightly upwards. Dimensions 17½ ins. by 13½ ins. Hooker Collection." There is a water-colour portrait of him in the Linnean Society's collection by J. E. H. Robinson. The coniferous genus *Cunninghamia* commemorates him, also a very large number of species.

Cunningham, Richard (1793 – 1835). Born at Wimbledon, London, 12th February, 1793; murdered by natives near the modern Dandaloo, N.S.W., April 1835. Brother of Allan. Employed on "Hortus Kewensis" circ. 1808. Colonial Botanist and Superintendent of Botanic Gardens, Sydney 1833-35. Pritzel 73; *Comp. Bot. Mag.* (ii. 1826) 210, with litho. portrait from one by McNee, belonging to Sir W. J. Hooker; Royal Society's Catalogue ii, 105; *Gardeners' Chronicle*, 1881, ii, 440; *Lond. Gardeners' Mag.* 1836; *Mag. Zool. Bot.* i, (1837), 210; *Dict. Nat. Biog.* xiii.

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[1] *Proc. Linn. Soc. N.S.W.* 1904, p. 475. [2] *Hist. Rec.*, i, (2) 632.

317. The above is from (1). I have given a pretty full account of him at (4). The memorial tablet of him in St. Andrew's Scots Church, Sydney, was from the Chantrey Studio, London.[1] In the catalogue of the Kew library there is a MSS. folio volume of Bond and Duncanson's drawings in the Kew Collection by Richard Cunningham.

Daintrey, Edwin (1814 – 1887). Born at Petworth, Sussex, England, 2nd September, 1814. Died at Randwick, near Sydney, 3rd October, 1887. Buried at Long Bay Cemetery, Randwick. He studied medicine (was in his fourth year) but his health obliged him to give it up. He then entered a solicitor's office and was admitted solicitor in England. Coming to New South Wales in the early forties he settled in Sydney, where he practised his profession. He was at one time honorary Secretary of the Australian Library in Bent Street, and was of cultivated literary tastes. He was Associate to Sir James Dowling for some years. He and the late Walter Bradley were great friends and took a keen interest in the Sydney Zoological Gardens. He was a founder of the Linn. Soc., N.S. Wales, and Professor Stephens, President of the Society, in making his obituary notice, speaks of him as an excellent botanist. His name is commemorated in *Acacia Daintreana*, F.v.M. = *A. excelsa*, Benth.; and *Pterostylis Daintreana*, F.v.M. (R. Daintree, Government Geologist of Queensland, also collected for Mueller. See *Fragm.* The names are sometimes confused). Portrait in F. M. Bladen's "Historical Notes on the Public Library of N.S.W., 1906."

Fawcett, Hugh Charles (1812 – 1890). Born 16th May, 1812, where, is not known to me. He died 15th March, 1890, probably at Stroud, N.S.W. He occupied the position of Police Magistrate at Tabulam (Casino) from 31st October 1862, to 7th August, 1870. On the latter date he left the

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[1] "New South Wales Magazine," August, 1843.

Public Service, but re-entered it on 1st July, 1883, as Police Magistrate and Clerk of Petty Sessions at Bullahdelah, holding also the position of Mining Warden. On the 1st December, 1885, his head quarters were transferred from Bullahdelah to Stroud. He held the position of Police Magistrate at the last named town (visiting Bullahdelah, Bungwall, Forster, and Tea Gardens) with, in addition from 1st July, 1887, the offices of Clerk of Petty Sessions and Crown Lands Agent, till the date of his death. The above particulars have been obligingly forwarded to me by Mr. J. L. Williams, Under Secretary of the Department of the Attorney General and of Justice. He collected botanical specimens for Baron von Mueller, particularly when in the Richmond River district. Part of his herbarium is in the National Herbarium, Sydney, presented by Mrs. Coleman (1905) widow of Mr. Coleman, M.P. for Lismore. The following plants commemorate him:—

Cylicodaphne Fawcettiana, F.v.M. = *Tetranthera reticulata*, Meissn. = *T. Fawcettiana*, F.v.M.; *Rhipogonum Fawcettianum*, F.v.M.

Field, Barron (1786—1846). Born London, 23rd October 1786; died Torquay, England, 11th April, 1846. F.L.S., 1825. Judge of the Supreme Court of N.S. Wales, 1816-24. Sent plants to Hooker. Jackson 400, *Proc. Linn. Soc.*, i, 298; *Exotic Flora*, t. 222. *Dict. Nat. Biog.* xviii, 399. The above particulars are taken from (1). The most signal service he performed for Australian botanisst consists in the publication of his "Geographical Memoirs on New South Wales etc." (London, 1825). He thus saved some valuable papers read before the Philosophical Society of Australia, more than one of which is of value to the botanist. He is commemorated in the genera *Fieldia*, Gaud. = *Vanda*, and *Fieldia*, A. Cunn. Colla wished to commemorate his memory in *Cassia Barrenfieldii*, afterwards corrected to *Cassia Fieldii*, Colla = *C. australis*, Sims.

Fitzgerald, Robert Desmond (1830 – 1892). Born at Tralee, Ireland, 30th November, 1830, died at Hunter's Hill, Sydney, 12th August, 1892; buried in Balmain Cemetery. He arrived in Sydney in 1856 and shortly afterwards entered the Surveyor-General's office, retiring from the rank of Deputy Surveyor-General in November, 1887. He was a remarkably skilful draughtsman and employed his gift not only in depicting parts of plants, but living plants as they grew wild and their surroundings in nature. For many years he devoted himself entirely to the study of Orchids and his monument consists of his noble work "Australian Orchids," the drawings being almost invariably from fresh specimens and the work of his own hand, while the lithographs are the work of his old friend and coadjutor Mr. A. J. Stopps. Mr. Fitzgerald visited every Australian State and Lord Howe Island in search of material for his beloved work. Not only was he an accomplished artist, but a sound botanist, an excellent combination of gifts. He left no herbarium. See "Sydney Mail," 3rd September, 1892, also (1), *Vict. Nat.* ix, 75, and Deane in *Proc. Linn. Soc. N.S.W.*, xxi, 827 (1896). He is commemorated in the following species:—*Sarcochilus Fitzgeraldi*, F.v.M.; *Dracophyllum Fitzgeraldi*, F.v.M.; *Eugenia Fitzgeraldi*, F.v.M. and Bail. [For portrait see *Plate 12.*]

Fleming, James (———). The "Cumberland," armed colonial schooner, left Sydney, 23rd November, 1802, under the command of Lieutenant Robbins for Port Phillip and Tasmania. Following is a record: "The voyage of His Majesty's Colonial Schooner "Cumberland" from Sydney to King Island and Port Phillip in 1802-3. A journal of the explorations of Charles Grimes, Acting Surveyor-General of New South Wales. Kept by James Fleming." Note by Governor King:—

"The writer of this journal (James Fleming) was sent to examine the soil, timber, etc. of King Island and Port Phillip; he

is very intelligent, and a man in whom I could place great confidence in his knowledge of the objects that fell to his share." (P.J.K. = Phillip Gidley King.)

The above journal was found by Mr. J. J. Shillinglaw in the archives of the Colonial Secretary's Office, Sydney, and published in that gentleman's "Historical Records of Port Phillip." (Govt. Printer, Melbourne, 1879). The botanical references are slight, Fleming however (p. 22), ("looked over seeds and specimens") evidently made collections. Rev. Samuel Marsden writes to Banks from Sydney, 27th April, 1803,[1] introducing

"John (the name is James, J.H.M.) Fleming (spelt Flemming in the above Journal), is sent to England by the 'Glatton,' by His Excellency the Governor with the charge of the plants and seeds from this couutry. He is a man of experience and real knowledge in agriculture, a good gardener and botanist. From Fleming's local knowledge of the Colony and the state of improvements we are in, I have requested him to make such a collection as will benefit the settlement of fruits, seeds, etc., etc."

King refers to him as "a very good man, a gardener, . . . a sensible man."[2] W. A. Chapman writing to Mrs. King, London, 16th October, 1804,[3] says "James Fleming has got an appointment to a botanical garden in the West Indies and is gone out." This perhaps refers to St. Vincent, but I have not been able to trace his subsequent career. Evidently he worked in Sydney, and was well known to Governor King, but I have been unable to trace anything about his career in Sydney.

Fraser, Charles (—— – 1831). Born in Scotland (?) died in Sydney, 31st December, 1831. The first officially appointed Superintendent of the Sydney Botanic Gardens. Originally a private soldier in the 46th Regiment. Accom-

[1] *Hist. Rec.* v, 99. [2] *Ib.*, v, 136. [3] *Ib.*, p. 479.

panied Oxley's Expedition in 1817. Visited New Zealand, Moreton Bay, Tasmania, Western Australia. I have given many particulars concerning him at (4). He wrote some excellent reports of his botanical journeys, and I should be very glad if these could be published in a memorial pamphlet some day. He is commemorated by the following species which help to trace his journeyings:—

Abutilon Fraseri, Hook.; *Boronia Fraseri*, Hook.; *Campylanthera Fraseri*, Hook. = *Spiranthera Fraseri*, Hook. = *Pronaya elegans*, Hueg.; *Cochlospermum Fraseri*, Planch.; *Commersonia Fraseri*, J. Gay; *Hartighsea Fraserana*, A. Juss. = *Dysoxylon Fraseranum*, Benth.; *Sida Fraseri*, Hook. = *Abutilon Fraseri*, Hook.; *Acacia Fraseri*, Hook. = *A. podalyriæfolia*, A Cunn.; *Sophora Fraseri*, Benth.; *Swainsona Fraseri*, Benth.; *Calythrix Fraseri*, A. Cunn.; *Melaleuca Fraseri*, Hook. = *M. striata*, Labill.; *Andersonia Fraseri*, Sond. = *A. sprengelioides*, R.Br.; *Leucopogon Fraseri*, A. Cunn. = *L. multiflorus*, R.Br.; *Limnanthemum Fraserianum*, Griseb. = *L. indicum*, Thw.; *Marsdenia Fraseri*, Benth.; *Dryandra Fraseri*, Br.; *Hakea Fraseri*, Br.; *Lomatia Fraseri*, Br. = *L. ilicifolia*, R.Br.; *Persoonia Fraseri*, Br. = *P. saccata*, R. Br.; *Persoonia Fraseri*, Meissn. = *P. angustiflora*, Benth.; *Trichinium Fraseri*, Cunn.; *Casuarina Fraseriana*, Miq.; *Encephalartos Fraseri*, Miq. = *Macrozamia Fraseri*, Miq.; *Urostigma Fraseri*, Miq. = *Ficus Fraseri*, F.v.M. = *Ficus Cunninghamii*, Miq.; *Bulbine Fraseri*, Kunth. = *B. bulbosa*, Haw.; *Hierochloa Fraseri*, Hook., f. = *H. redolens*, R.Br. var. ? *Fraseri*; *Lindsæa Fraseri*, Hook.; *Schizoloma, Fraseri*, J. Sm = *Lindsæa Fraseri*, Hook.; *Todea Fraseri*, Hook. et Grev.

Fullagar (——). He collected Lord Howe Island plants for Mueller. See Lind. The justaposition of the two names may be simply those of independent collectors, *e.g.* Moore and Fullagar (*Fragm.* ix, 69, 72, 76). He alone collected *Tylophora enervis*, and *Marsdenia tubulosa*, *Fragm.* ix, 71; *Ipomœa bona-nox*, 74. He is commemorated by *Lomaria Fullagari*, F.v.M.

Good, Peter (—— - 1803). There is no record of the entry of this young Scotch gardener into Kew. He appears to have been in the employment of Earl Wemyss, 1796. In 1793 he was selected from the Kew staff to proceed to Calcutta to bring home a collection of plants prepared by Christopher Smith. He returned to Kew, where he filled the position of foreman until 1st March, 1801, when he was appointed Botanical Collector under Robert Brown, the botanist attached to Flinders' voyage (H.M.S. Investigator) of survey of the coast of Australia; at a salary of £100. Brown wrote to Banks, Port Jackson, 30th May, 1802[1]:—

"In Mr. P. Good I have a most valuable assistant, a more active man in his department could hardly, I believe, have been met with."

Banks to Brown, 8th April, 1803,[2] speaks of—

"Your able and quiet assistant, Peter Good. His diligence and docility have been before tried."

Brown wrote to Banks, Sydney, 6th August, 1803[3]:—

"Poor Peter Good, who while he enjoyed health was most indefatigable, and whose exertions in his department were without doubt the cause of his untimely fate, died a few days after our arrival here of dysentry, contracted soon after our departure from Timor." **The date of his death was 11th June, 1803.** "On Monday last, Mr. Good, botanist, belonging to H.M.S. "Investigator," and who died on the preceding day on board that ship, was brought on shore for interment. A number of officers attended in procession to the place of burial, where, after the funeral ceremonies were performed, a party of marines fired three vollies over the grave."[4]

There is a letter,[5] from Brown to Banks, giving particulars of the disposal of Good's private effects. See also Salisbury, *Parad. Lond.*, t. 41; *Gardeners' Chronicle*, 29th October,

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[1] *Hist. Rec.* iv, 177. [2] *Ib.* v, 89. [3] *Ib.* v, 181.
[4] *Sydney Gazette,* Sunday, 19th June, 1803. [5] *Hist. Rec.* v, 204.

1881, p. 568; Britten and Boulger (1); *Kew Bulletin*, 1891, 301; *Journal Kew Guild*, v, 28 (1897). The genus *Goodia*, Salisb. was dedicated to his memory, and also a *Banksia* and a *Grevillea* by Brown. In Hortus Kewensis many plants are attributed to Good; they were collected under the supervision of Brown. The seeds were forwarded to Kew, where many new plants were raised from them, conspicuous amongst them being numerous species of Proteaceæ, Myrtaceæ, and shrubby Leguminosæ. These ultimately made Kew famous for New Holland plants, Dr. Lindley calling special attention to these plants in his "Report on Kew," drawn up in 1838.

Gordon (—). Governor King, writing[1] to Under-Secretary King, 10th March, 1801, says:—

"By the 'Anne' I received a letter from you respecting a young man sent out here as a botanist, named Gordon. It appears that he is employed by a Mr. Woodford, who has neglected to send me any directions respecting supplying this man with £8 per month, which he informs him in his letter and his agreement that he has done. The man is victualled from the store, and I have given him assistance."

I know nothing further concerning him.

Harvey, W. H. See page 69.

Haviland, Edwin (1823 – 1908). Born at Gloucester, England, 20th July, 1823, died at Petersham, Sydney, 22nd May, 1908. Buried at Woniora Cemetery, Sutherland, the following day. All his papers were published in the Proceedings of the Linnean Society of New South Wales between the years 1882 and 1888. They consist of "Occasional notes on the inflorescence and habits of plants indigenous in the immediate neighbourhood of Sydney,"

[1] *Hist. Records* iv, 332, where Mr. Britton has a footnote "George Caley mentions this man in one of his letters to Sir Joseph Banks."

(nine papers). "The flowering seasons of Australian plants," (eight papers). "Some remarks on the fertilization of the genus Goodeniaceæ." "On a microscopic fungus parasitic on the genus Cucurbitaceæ." He was a Fellow of the Linnean Society of London, and for some years a member of the Council of the Linnean Society of New South Wales. His work lay in the direction of the morphology and physiology of plants; taxonomy had no attractions for him. A busy commercial man up to the time of his retirement, a few years ago, he could not travel far, and hence he specialised on the plants of Sydney. For a brief notice of his work see p. 3, part i of my "Illustrations of New South Wales plants" (1907). [For portrait see *Plate 11.*]

Kidd, James (1801–1867). Born in Scotland, 1st August, 1801, and died in the Botanic Gardens, Sydney, 15th February, 1867. Photograph (*Plate 12*) taken 1863. He was first appointed Overseer, Botanic Gardens, 20th July, 1833. In 1844 he was Superintendent till the appointment of Mr. J. C. Bidwill as Director on 1st September, 1847. He then reverted to his position as Overseer, which he held until his death. He travelled over the Blue Mountains and other districts for seeds and living plants for the garden. He made some of the first olive oil in New South Wales, and was awarded the Silver Medal of the New South Wales Horticultural Society in 1842. The Botanic Gardens owes much to his faithful work.

King, Philip Parker (1793–1856). Born at Norfolk Island, 13th December. 1793; died at "Grantham," North Sydney, 25 February, 1856. Captain, R.N. Rear-Admiral 1855. F.L.S. 1824; F.R.S. 1824. "Narrative of the Survey of Australia," 1818-22 (with Allan Cunningham), 1827. "Narrative of the voyages of H.M.S. 'Adventure' and 'Beagle,' 1826-36." "Icones Plantarum," t. 1082.

Plants at British Museum, Kew and Edinburgh. Pritzel 164; Royal Society's Catalogue iii, 655; *Proc. Linn. Soc.*, 1856-7, xxviii; Gentleman's Magazine, 1856, i, 426; *Dict. Nat. Biog.* xxxi, 149. The above is from (1). He was buried at St. Mary's, South Creek, N.S.W. With Mr. Bidwill and Mr. William Macarthur he did much work in the hydridization of bulbous plants. I possess his annotated copy of De Candolle's Prodromus; this shows in some measure how he studied Australian plants. He is commemorated in the genus *Kingia*, R.Br., and also in the species *Dodonæa Kingii*, G. Don = *D. viscosa*, L. ? var. *angustifolia*; *Acmena Kingii*, G. Don=? *Eugenia Smithii*, Poir.; *Dendrobium Kingianum*, Bidw.

Leichhardt, Friedrich Wilhelm Ludwig (1813 – 1848). Born at Trebalsch, near Beeskow, Prussia, 23rd October, 1813; lost in Australia, 1848. Letters in *Journ. Bot.*, 1845-8. Papers in *Tasmanian Journ. Nat. Science*, iii, (1847); *Fl. Tasmaniæ*, cxxi; Woolls; *Dict. Nat. Biog.* xxxii, 426. The above is from (1). I have no intention of giving at this place a lengthy account of Leichhardt. He was, apart from being an explorer, a botanist. He collected largely, and his works contain frequent botanical references. He planned a herbarium for Sydney; see his letter to Mr. Durando of Paris.[1] Lieut. B. Lynd, Military Barrack Master, late 63rd Regiment, and Secretary of the Committee of the Botanic Garden and Museum (now the Australian Museum) at Sydney, he says has "been like father and brother to me."[2] Mr. Lynd, who was Leichhardt's friend and executor, presented Leichhardt's herbarium to the Sydney Museum, and at Baron von Mueller's request, it was forwarded to Melbourne for investigation, some years later. Very few of the plants were, however returned, and these were handed by the Trustees of the Australian Museum to

[1] *Lond. Journ. Bot.*, v, 658, (1846). [2] *Op. cit.*, 659.

my predecessor (Mr. Moore), a few years ago. I incorporated them in the National Herbarium of New South Wales founded by me, and thus they form part of a herbarium for Sydney which Leichhardt had only seen in a vision. I have a letter from James Kidd, Superintendent, Botanic Gardens, dated 6th April, 1846, in which he reports that Leichhardt had presented 200 kinds of seeds, collected by him in his recent expedition. Leichhardt gave botanical lectures in Sydney (Hooker's *Lond. Journ. Bot.* iv, 280) and I have spoken to gentlemen who attended his lectures. Leichhardt published "Journal of an Overland Expedition in Australia, from Moreton Bay to Port Essington, a distance of over 3000 miles, during the years 1844-45," (London, 1847). See also "Australasian Bibliography," Public Library, Sydney, p. 228 (1888). A useful but brief account of his work will be found at (3). Some of Leichhardt's reports are printed in Dr. Lang's "Cooksland." See also Henry Stuart Russell's "Genesis of Queensland," page 373 etc., and Favenc's "History of Australian Exploration." See also "An historical review of the Explorations of Australia," (Mueller in *Trans. Phil. Soc. Vict.*, ii, p. 156). See also *Journ. Bot.* xxvii, 273. John F. Mann published a pamphlet entitled "Eight months with Leichhardt in the pears 1846-47," (Sydney, 1888). The following Australian plants commemorate him and usefully indicate his journeys; the genus *Leichhardtia*, R.Br., also the following species:—

Commersonia Leichhardtii, Benth.; *Euphoria Leichardtii*, Benth.; *Harpullia Leichardtii*, Muell.; *Unona Leichhardtii*, Muell. = *Melodorum Leichhardtii*, Benth.; *Acacia Leichhardtii*, Benth.; *Bauhinia Leichhardtii*, F.v.M. = *B. Cunninghamii*, Benth.; *Chorizema Leichhardtii*, F.v.M. = *Isotropis filicaulis*, Benth.; *Macropteranthes Leichhardtii*, Muell.; *Psoralea Leichhardtii*, Muell. = *Indigofera glandulosa*, Willd.; *Sarcocephalus Leichhardtii*, F.v.M.; *Anthocercis Leichhardtii*, F.v.M.; *Datura Leichhardtii*, F.v.M.; *Lyonsia Leichhardtii*, F.v.M. = *Parsonsia Leichhardtii*, F.v.M.;

Marsdenia Leichhardtiana, F.v.M ; *Prostanthera Leichhardtii*, Benth.; *Vitex Leichhardtii*, F.v.M. = *Gmelina Leichhardtii*, F.v.M.; *Amanoa Leichhardtii*, Baill. = ?; *Briedelia Leichhardtii*, Baill. = ?; *Ficus Leichhardtii*, Miq. =?; *Urostigma Leichhardtii*, Miq. = ? ; *Alsophila Leichhardtiana*, F.v.M.; *Livistona Leichhardtii*, F.v.M. = *L. humilis*, R.Br.

Lewin, John William (? 1770 – 1819). His tombstone in La Perouse Cemetery (transferred from Devonshire Street) states that he died 27th August, 1819, aged 49 years. An artist who depicted many New South Wales plants. He landed in Sydney in 1798 (H.M.S. Buffalo), I have stated all I knew of him at that time in *Proc. Linn. Soc. N.S.W.*, xxvii, 746 (1902). He was coroner at the time of his death. The late Hon. P. G. King, M.L.C., gave me the following memorandum dated 27th October, 1901, referring to Lewin's drawings of native plants then in his possession. The drawings were lent by Mr. King for study. At his death they became the property of his grand-daughter, Miss Goldfinch, who kindly presented seven of them to the Botanic Gardens, where they are framed.

"Remarks on the history of this collection of drawings of Australian plants.—There appear to have been two sets of drawings by J. W. Lewin in 1805, 1808. There is a pencil note on the drawing of *Macrozamia* signed J. W. Lewin, 30th August, 1805. 'This is for the Governor's collection. Mrs. King's is already done.' Mr. Lewin very seldom signed the papers. In Mrs. King's collection there is a drawing of the *Mimosa* signed by him, also of *Kennedya* No. 262. There are two figures of the *Zamia* and someone has pencilled on one of them 'same as 178 and 179' but the 179 is erased. Nearly all the drawings have been numbered, but I have no trace of the catalogue to which the numbers referred. The names have been pencilled in by Allan Cunningham perhaps about the year 1840 (he died in 1839) when he was at Vineyard where Mr. Governor King resided with H. H. McArthur and his family. Allan Cunningham's initials, A.C, occur occasionally see

No. —. Probably he had the catalogue as he gives the authorities —R. Brown, Sprengel, De Candolle, etc. The two sets are mixed up—very few of the numbered sheets exist."

Alexander Macleay was one of a small syndicate which subsidised Lewin to collect and send home specimens. (Jardine's *Naturalists' Library*, xiii, 46, 1842). In the "Records of the Australian Museum," vol. v, p. 121 (1906) there is an excellent account of him as an ornithologist from the pen of Mr. A. J. North.

Lhotsky, J. See p, 72.

Lind (————). He collected (? with Fullagar, see *Fragm.*, ix, 70, 74, 76) plants in Lord Howe Island for Mueller before 1875. Some of his plants are enumerated in *Fragm.*, ix. 78.

Lynd, Lieut. B. (————). Secretary to the Botanic Garden Committee circa 1846 (succeeding Revd. G. E. Turner), and friend of Leichhardt. See page 108.

Macarthur, William (1800–1882). Born at Parramatta, 16th December, 1800, died at Camden Park, N.S.W., 29th October, 1882. Son of the celebrated Captain John Macarthur. He was a competent botanist, horticulturist and agriculturist, and his operations helped to make Camden Park celebrated. He entertained eminent scientific men who visited the Colony and bore the reputation of a cultured gentleman. No. (**1**) states that he sent plants to Backhouse which are now in Herb. Kew and Brit. Mus.; also quotes Pritzel 199 and Hooker (**3**). There is a portrait of him in the Australian Club, Sydney. See also F. M. Bladen's "Historical Notes on the Public Library of New South Wales," 1906. As a young man he studied viticulture and wine making in France, and he made the Camden Park vineyards renowned. His wines gained prizes in open competition at the Paris Exhibition of 1855. He published a work on the vine under the *nom de plume* of

"Maro." He was one of the Commissioners of the Colony to that Exhibition and was knighted and received the Legion of Honour for his services. He was an accomplished French scholar. His horticultural work is referred to in Sydney *Hort. Mag.*, vii, 112. His work on hybridising *Crinums* is referred to by Bidwill, *supra* p. 88, and these two workers and Captain P. P. King, R.N., did valuable work in hybridising bulbous plants, and the result of Mr. Macarthur's horticultural work may be seen at Camden Park even at the present day. He sent his gardener Mr. P. Reedy, to New Guinea with Mr. (afterwards Sir) William Macleay's Expedition, the "Chevert" for new plants, and the preface of Mueller's "Descriptive notes on Papua Plants." Part i, shows that the material for it was placed at his disposal by Sir William Macarthur. I have a copy of this Part with the corrections in Sir William's handwriting. He made collections of N. S. Wales timbers for the Paris Exhibitions of 1855 and London 1862, and supported these specimens with herbarium material which is now at Kew. His catalogue is most valuable in that it contains most of the authentic aboriginal names which have been preserved of the trees etc. of the counties of Cumberland and Camden, N. S. Wales. He is commemorated in the genus *Macarthuria*, Endl., also in the species: *Alsophila Macarthurii*, Hook. = *A. Leichhardtiana*, F.v.M.; *Hemitelia Macarthurii*, F.v.M. = *Cyathea Macarthurii*, F.v.M. I am indebted to Lieut. Col. J. Macarthur Onslow, his grandnephew, for some of the above particulars.

McLean, John (———). Acting or Assistant Superintendent of the Sydney Botanic Gardens at intervals from 1st April 1829 to 1836, but I have very few particulars concerning him. For such as I have, see (**4**).

Macleay, Alexander (1767–1848). Born in Ross-shire, the son of the Deputy-Lieutenant of Caithness, 24th June,

1767. Fellow 1794, and Secretary, 1798–1825, of the Linnean Society. Fellow of the Royal Society 1809. Colonial Secretary of New South Wales 1825-37, and first Speaker of the Legislative Council 1843-46, and First President of the Australian Museum at Sydney, founded in 1836. His name was given by Robert Brown to the genus *Macleaya* (*Bocconia*), belonging to the poppy family. Died at Sydney 18th June, 1848. There is a silhouette drawn on paper and a bust, profile to the right, in the Hooker Collection. There is also a line engraving by Charles Fox, after a painting by Sir Thomas Lawrence, P.R.A., belonging to the Linnean Society; to the waist, seated, clean shaven face, three-quarters to the right (8). There is a copy of this in the rooms of the Linnean Society of New South Wales. A distinguished entomologist and "a practical botanist." (R. Brown, *Proc. Linn. Soc.* ii, 45). See also (1). The Sydney Botanic Garden was under his official care in the early days and owes much to him. An admirable account of him from the pen of Mr. J. J. Fletcher will be found in the Macleay Memorial volume (Sydney 1893), in honour of his nephew, Sir William Macleay. He is commemorated in *Anopterus Macleayanus*, F.v.M.; *Catakidozamia Macleayi*, Hill=?; *Macrozamia Macleayi*, Hort.=?; *Leichhardtia Macleayana*, Sheph. = *Octoclinis Macleayana*, F.v.M.; *Frenela Macleayana*, Parlat.= *Callitris Macleayana*, F.v.M.

Macleay, William Sharp (1792–1865). Son of the preceding. Born in London, 21st July, 1792; died in Sydney, 26th January, 1865; buried at Camperdown, Sydney. See Rev. R. L. King's Pres. Address in *Trans. Ent. Soc. N.S. Wales*, i, p. 43. Also introduction to *Macleay Mem. Vol.*, by J. J. Fletcher, both of which give a full account of him and of his contributions to science. See also (1). He was the author of "Remarks on the identity of certain general laws which have lately been observed to regulate the natural distribution of insects and fungi." (*Trans. Linn.*

Soc., 1825). Like his father his tastes lay chiefly in the domain of entomology, but he had a considerable knowledge of Australian plants and had the reputation of being a good botanist. There are memorial tablets to both Macleays in St. James' Church, Sydney.

McWilliam, Dr. (———). Some of his specimens (Port Jackson) in the National Herbarium, Sydney, are over fifty years old, but I have been unable to trace full particulars concerning the collector. Kippist in *Trans. Linn. Soc.*, xxi, 209, refers to a plant introduced to Kew in 1845 'in a case sent by Dr. McWilliam in 1845 from Norfolk Island.' This may give a clue to the doctor. Dr. McWilliam is also credited in Harvey's *Nereis Australis*, (1847) with seaweeds from Norfolk Island.

Moore, Charles (1820—1905). Born 10th May, 1820, at Dundee, Scotland. On the recommendation of Prof. Henslow, he was appointed Director of the Botanic Gardens, Sydney, by the Secretary of State, and arrived in Sydney 14th January, 1848. From that date until 5th May, 1896, a period of over 48 years, he occupied the post with advantage to the country and credit to himself. He died 30th April, 1905, and was buried 2nd May in Rookwood Cemetery. He was a member of this Society for forty-nine years, occupied the offices of President, Vice-President and Councillor, and contributed several papers to its Journal. I contributed notices of Mr. Moore to the "Sydney Morning Herald" and Daily Telegragh" of 2nd May, 1905; there is a notice in the "Gardeners' Chronicle" of 13th May, 1905, by F. W. Burbidge, and one in the "Journal of the Kew Guild" for 1905 by his nephew, F. W. Moore, Director of the Botanic Garden, Glasnevin, Dublin. The following were published by him :—"Lord Howe's Island; sketch of of the vegetation, etc." Sydney 1869, fol. "A census of the plants of New South Wales," Sydney, 1884, 8vo.

"Handbook of the flora of New South Wales," assisted by E. Betche, Sydney, 1893, 8vo. "Catalogue of plants in the Government Botanic Gardens, Sydney," Sydney, 1895, 8vo. "Woods of New South Wales, Sydney International Exhibition, 1870." He also wrote a Journal of a "Cruise in H.M.S. "Havanah," (Commodore Erskine) to the South Sea Islands, extending from 14th July to November, 1850." Visited New Zealand, New Hebrides, and New Caledonia. The journal, which is in MS. is in the possession of his family in Sydney. A portrait of Mr. Moore was hung in the Museum of the Botanic Gardens in March 1906. It was the gift of some personal friends, including Mr. W. J. Trickett, M.L.C., and Mr. Haege. He is commemorated by the following species:—

Cocculus Moorei, F. Muell. = *Pericampylus incanus*, Miers; *Streptothamnus Moorei*, F.v.M.; *Villaresia Moorei*, F.v.M.; *Eucryphia Moorei*, F.v.M.; *Rubus Moorei*, F.v.M.; *Aralia Moorei*, F.v.M.=*Heptapleurum venulosum*, Seem.; *Eugenia Moorei*, F.v.M ; *Randia Moorei*, F.v.M.; *Lactaria Moorei*, F.v.M. = *Ochrosia Moorei*, F.v.M.; *Piptocalyx Moorei*, Oliv.; *Pisonia Mooriana*, F.v.M. = *P. Brunoniana*, Endl ; *Stenocarpus Moorei*, F.v.M. = *S. salignus* R.Br. var. *Moorei; Actephila Mooreana*, Baill.; *Dendrobium Moorei*, F.v.M.; *Fagus Moorei*, F.v.M.; *Frenela Moorei*, Parlat.= *F. robusta*, A. Cunn. var. *microcarpa; Alsophila Moorei*, J. Sm.=?; *Chloris Moorei*, F.v.M. = *C. acicularis*, Lindl.; *Cyathea Moorei*, Hook. et Bak. = *C. Macarthurii*, F.v.M.; *Drymophila Moorei*, Baker; *Hemitelia Moorei* Baker; *Hymenophyllum Moorei*, Baker = ?; *Kentia Mooreana*, F.v.M. = *Clinostigma Mooreanum*, F.v.M. *Rhipogonum Mooreanum*, F v.M. = *R. album*, R. Br.; *Schœnus Moorei*, Benth.; *Todea Moorei*, Bak.; also *Sporochnus Moorei*, Harv., fig. in Harvey's "Phycologia Australica."

Norton, James (1824 – 1906). He was born in Sydney, 5th December, 1824, and died there 18th July, 1906. He wrote but little, yet took the liveliest interest in the flora of New South Wales, cultivating many species, conserving

others, and was an ardent horticulturist. He was Chairman of Trustees of the Public Library, Member of the Legislative Council, one of the founders of the Linnean Society of New South Wales, and for many years its honorary treasurer. A sympathetic account of his work will be found in *Proc. Linn. Soc., N.S.W.*, xxxii, 6 (1907) by the then President of the Society, Mr. Thomas Steel. He is commemorated in *Adenochilus Nortoni*, Fitz., a rare Blue Mountain Orchid.

Paterson, William (1755–1810). Born Montrose ?; died on voyage from Australia, 21st June, 1810. Colonel, F.R.S., 1798, F.L.S., 1797. In South Africa 1777-9. "Narrative of Journeys," 1789. Lieut.-Governor of New South Wales, 1800 – 1810. Collected in South Africa and Australia. Plants in Herb. Mus. Brit., Brown, *Prodr.* 303; Hooker's *Flora of Tasmania*, cxxiv; Lasègue, 278, 446; *Cottage Gardener*, viii, 329, etc.; ix, 3 (1). He collected plants and seeds for Sir Joseph Banks, see *Hist. Rec.* iv, 229, 417; vi, 768. He co-operated with Péron. He collected Eucalyptus manna and reported on it. He was for a considerable time Lieut.-Governor at Port Dalrymple (Launceston, Tasmania), where he collected and made botanical observations. The Paterson River, N.S.W. was named after him by Governor King. See quotations from his journal of explorations in the Hunter River district in *Hist. Rec.* iv, 450. For many particulars concerning him see vol. ii of this work. He is commemorated in the genus *Patersonia*, R.Br., also in the species:—

Hibiscus Patersoni, DC., *Hibiscus Patersonius*, Andr., *Lagunæa Patersonia*, Bot. Mag., all synonyms of *Lagunaria Patersoni*, Ait.; *Caladenia Patersoni*, Br.; *Centrolepis Patersoni*, R. et S. = *C. strigosa*, R. et S. var. *Patersoni; Desvauxia Patersoni*, Br. = *Centrolepis strigosa*, R. et S. var *Patersoni; Lomaria Patersoni*, Spreng.; *Stegonia Patersoni*, Br. = *Lomaria Patersoni*, Spreng.; *Thysanotus Patersoni*, Br. See my forthcoming "Life of Sir Joseph Banks."

Richardson, John (———). Mitchell in the expedition on which he explored Australia Felix (Victoria) was accompanied by John Richardson,[1] who was officially designated "Collector of Plants" and whose "occasional employment" was shepherd. Richardson River or Creek was named by Mitchell after the botanical collector who had an involuntary bath in the stream. Mitchell's words are[2]—

"The latter, who was my botanical collector, Richardson, took his soaking on a cold frosty morning so philosophically, talking to his comrades as he made his way to the bank, partly swimming, partly floating on two huge portfolios, that I gave his name to the creek, the better to reconcile him to his wet jacket."

He of course, largely collected in New South Wales, and the plants were named by Lindley. Sweet desired to commemorate him with the following plants:—*Hibiscus Richardsoni*, Sweet=*H. trionum*, Linn.; *Alyxia Richardsonii*, Sweet = *A. ruscifolia*, R.Br.

Robertson, William (———). Acting Superintendent, Botanic Gardens, Sydney, from April 1842 until his death in July, 1844. See (4). Bidwill refers to him.

Rudder, Augustus (1828—1904). He was born at Birmingham, England, 10th November, 1828, and died at Orange Grove, Cabramatta, near Sydney, 11th December, 1904. He was for many years an officer of the Forest Department, New South Wales, being appointed Forester, 20th August, 1884. He retired 16th August, 1896. He early interested himself in timbers, barks, and other vegetable products as dyes, and assisted his father in preparing a large series of specimens (may of which I have seen) for the London International Exhibition of 1862. My acquaintance with Mr. Rudder began while he was forester in the Gloucester-Manning district, with head-quarters at Booral.

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[1] "Three Expeditions," ii, 2. [2] *Op. cit.*, 172.

I long held the opinion that his knowledge of the trees and timbers of his district was profound. He formed a herbarium of all the trees of his extensive district and made collections of the timbers, most of which were, he informed me, unfortunately lost. Many of his herbarium specimens were presented to me after he left the Public Service, and are now in the National Herbarium, Sydney. Many of his reports on forestry questions are valuable documents, and are in the archives of the Forest Department. At my instigation he contributed some articles to the *Agricultural Gazette of New South Wales*, and he was a contributor to the press on forestry questions. I named the North Coastal Red Box of New South Wales *Eucalyptus Rudderi* in honour of this excellent observer. (*Proc. Linn. Soc. N.S.W.* xxix, 779). [For portrait see *Plate 11.*]

Shepherd, Thomas (1779 ? – 1835). Born in Scotland on the estate of the Earl of Crawford, where his father was head gardener. Died in Sydney, 30th August, 1835, aged 56 years. Proprietor of the Darling Nursery, Sydney. He was a practical gardener who lectured on horticulture and landscape gardening and encouraged the cultivation of New South Wales plants. He delivered lectures on the horticulture of Australia, at the Mechanics' Institution, Sydney, which are reported at length in the "Sydney Herald" in the year 1834. They were separately published as "Lectures on the Horticulture of New South Wales, delivered at the Mechanics' School of Arts, Sydney," 8vo. pp. iv, 80. Sydney, 1835. (The preface contains some brief particulars of his family). "Lectures on Landscape Gardening in Australia," 8vo. pp. viii, 95, Sydney, 1836. (The Botanic Gardens copy has two pages of notes in the holograph of the author). There is a marble tablet to his memory near the pulpit, in St. Andrew's Scots Church, Sydney, the work of W. Patten, Sydney.

Shepherd, Thomas William (1824–1884). Son of the preceding. Born at Hackney, near London, 11th March, 1824, died at Ashfield, near Sydney, 27th August, 1884. Proprietor of the Darling Nursery. Agricultural Editor of the "Town and Country Journal," Sydney. There are some excellent articles from his pen in the "Sydney Magazine of Science and Art":—"On the hybridisation of plants." "On native plants, and the pastoral, agricultural and horticultural resources of Australia," (six papers in Vol. i, 1858). He collected many New South Wales plants, largely in the Illawarra, some of which were sent to Woolls and Mueller. The following orchid commemorates him:—*Dendrobium Shepherdi*, F.v.M. = *Bolbophyllum Shepherdi*, F.v.M.

Shepherd, Patrick Lindesay Crawford (1831–1903). He wrote papers on horticultural subjects first published in the "Sydney Magazine of Science and Art" (1858-9). Subsequently he wrote on Draining and Manuring, and was a frequent contributor to the newspapers on such subjects. Mr. Shepherd was a native of Sydney, and the youngest son of Thomas Shepherd. He was connected with the firm of P. L. C. Shepherd and Son, Seed Merchants Sydney. In 1874, he was elected representative in the Legislative Assembly of the Nepean Electorate, but never sought re-election; this was during the time of the Martin admistration, and on 30th December, 1887, he was summoned to the Legislative Council, and held his seat up to the time of his death, which took place on 31st July, 1903, at his residence "Birnam," Shaftesbury Road, Burwood. Mr. Shepherd took a great interest in the defences of New South Wales, and in 1864 joined the Volunteer Artillery, in which he remained for twelve years. During the last eight years, he held the rank of Major. He was also a Vice-President of the Horticultural Society of New South Wales. He was buried at Rookwood, Sydney.

Sieber, Franz Wilhelm (———). Native of Prague, Bohemia. He collected in New South Wales for seven months during the year 1823, and took considerable and excellent collections to Europe, which he sold in numbered sets bearing the labels "Flor. Nov. Holl." and "Pls. Exot." Descriptions of many plants bearing his name as author are published in De Candolle's Prodromus and other works, but whether the descriptions were actually the work of Sieber, does not transpire. Before he came to Australia he published a work "Avis de plantes. . ." (Ankündigung von Herbarien). (Prague, 1821) 8vo. which I have not been able to consult. He is commemorated in the following species:—

Cryptandra Sieberi, Fenzl. = *C. amara*, Sm.; *Lasiopetalum Sieberi*, Steetz. = *L. ferrugineum*, Sm. var. *cordatum; Viola Sieberiana*, Spreng. = *V. hederacea*, Labill.; *Acacia Sieberiana*, Scheele = *A. discolor*, Willd.; *Acacia Sieberiana*, Tausch. = *A. crassiuscula*, Wendl.; *Quintinia Sieberi*, A. DC.; *Spadostyles Sieberi*, Benth. = *Pultenæa euchila*, DC.; *Brachycome Sieberi*, DC.; *Eucalyptus Sieberiana*, F.v.M.; *Callistemon Sieberi*, DC. = *C. salignus*, DC. var. *Sieberi*, F.v.M.; *Melaleuca Sieberi*, Schau. = ?; *Schidiomyrtns Sieberi*, Schau. = *Bæckea crenulata*, DC.; *Verticordia Sieberi*, Dies. = *V. Fontanesii*, DC.; *Leucopogon Sieberi*, DC. = *L. juniperinus*, R.Br.; *Lysinema Sieberi*, Benth. = *L. pungens*, R.Br.; *Mitrasacme Sieberi*, A. DC. = *M. polymorpha*, R.Br.; *Wahlenbergia Sieberi*, A. DC. = *W. gracilis*, A. DC.; *Endiandra Sieberi*, Nees; *Hemigenia Sieberi*, Benth. = *H. purpurea*, R.Br.; *Prostanthera Sieberi*, Benth.; *Carumbium Sieberi*, Muell. Arg. = *C. populifolium*, Reinw. *Calorophus Sieberianus*, Steud. = *Restio fastigiatus*, R.Br.; *Caustis Sieberi*, Kunth. = *Gahnia Sieberi*, Bœckel; *Cheilanthes Sieberi*, Kunze = *C. tenuifolia*, Swartz.; *Cladium Sieberi*, F.v.M. = *Gahnia Sieberi*, Bœckel; *Cyperus Sieberi*, Kunth. = *C. fulvus*, R. Br.; *Cyperus Sieberi*, Nees = ?; *Cyperus Sieberianus*, Spreng. = *C. surinamensis*, Rottb.; *Dichelachne Sieberiana*, Trin. = *D. sciurea*, Hook. f.; *Dichopogon Sieberianus*, Kunth.; *Echinopogon Sieberi*,

Steud. = *E. ovatus*, Beauv.; *Gahnia Sieberi*, Bœckel; *Gahnia Sieberiana*, Kunth. = *G. psittacorum*, Labill.; *Heleocharis Sieberi*, Kunth. = *H. variegata*, Kunth.; *Hypoporum Sieberi*, Nees = *Scleria lithosperma*, Willd.; *Lepidosperma Sieberi*, Kunth. = *L. concavum*, R. Br.; *Lepidosperma Sieberi*, Nees = *L. resinosum*, F.v.M.; *Melachne Sieberi*, Schrad. = *Gahnia Sieberi*, Bœckel; *Paspalum Sieberianum*, Steud. = ?; *Pleea Sieberi*, Reichb. = *Anguillaria dioica*, R.B.; *Poa Sieberiana*, Spreng. = *P. cæspitosa*, Forst. var. *australis*.

Stackhouse, T. (—— - 1886). Commander R.N. With William Macleay he founded the Linnean Society of N.S.W. Macleay, who always depreciated his own efforts said, "The Society was formed, chiefly through the exertions of Captain Stackhouse, R.N."[1] Professor W. J. Stephens, President of the Linnean Society of New South Wales, said of him—

"He died at Rocky Mouth, Clarence River, where he had been residing for eight months under the kind care of Dr. Hood, and he must be regarded as the originator of this Society, of which he was the first Honorary Secretary. His special pursuit was botany, though all branches of science, even of the most speculative, interested him to a very unusual degree. After his removal from Sydney he resided for some years at Yamba, in the Clarence River district, where he employed himself with great success in the investigation and discovery of rare or new species; and where, unfortunately, he contracted by exposure to severe weather the illness to which he ultimately succumbed."[2]

Stephenson, William (—— - 1863?). M.R.C.S., L., 4th March, 1814. Surgeon and collector of objects of natural history in Mitchell's Expedition into the interior of Tropical Australia. (See Mitchell's "Tropical Australia"). He afterwards settled on the Manning River in practice as a Surgeon. He came to the Manning from the Richmond

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[1] "Sydney Morning Herald," 2nd November, 1885.

[2] *Proc. Linn. Soc., N.S.W.*, xi, 1211 (1886).

River, and at first lived at Cundle, afterwards removing to Taree, where he died about 1863. Taree friends say he was originally an Army doctor, and while on service he received a wound which lamed him and ever afterwards caused him to ride side-saddle. He had been in India and China. He used to ride a black pony, which took him all through Mitchell's Expedition. He had a peculiar habit of whistling "in season and out of season." He contributed some vegetable products (with notes) to the Paris Exhibition of 1855. See the Catalogue of the New South Wales exhibits p. 71. The following species commemorates him:—*Siebera Stephensonii*, Benth., (*Trachymene Stephensonii*, Turcz.) I am indebted to the Revd. W. C. Hawkins and to Mr. G. S. Hill, for some of the above particulars.

Strange, Frederick (1826? – 1854). Born at Aylsham, Norfolk, England, and murdered by aborigines at Percy Island, Queensland, 15th October, 1854. He was a collector of objects of Australian natural history, which he sold in England and elsewhere. He devoted himself entirely to this work and met his death at an early age in this occupation. He specially devoted himself to birds, shells and plants. He left a few scientific notes. They have been bound up in a pamphlet entitled, "Literary Notices of the late Frederick Strange, Naturalist," which has been lent to me by his son, Mr. F. R. Strange of Mosman, Sydney. They are:—"Port Cooper (New Zealand). A narrative of a trip sixty-four miles to the west of Port Cooper," by F. Strange, Naturalist. The trip lasted from Sunday, 4th March, 1849, to Saturday, 10th. His observations were geographical, and included references to natural history, and were published in the Supplement of "Sydney Morning Herald," 26th January, 1850). "Family Columbidæ or Pigeons," from "Notes on the brush birds of Australia," by F. Strange, Naturalist. ("Moreton Bay Courier," 4th July, 1851). "Ptilorus

paradiseus or Rifle Bird," from the same. "Natural History," Mr. F. Strange. ("London Morning Advertiser," 24th June, 1852). This journal announced that Mr. Strange has just arrived in England per the Vimeira in 94 days, with a most valuable collection of specimens of natural history—

"They are the accumulation of the last three years' research; the tract of country explored has ranged in one direction from Mount Warning, on the south to Bribie's Island on the north of the colony, likewise over a considerable portion of New Zealand, Mr. Strange has been a resident in Sydney, South Australia. Moreton Bay, etc., for a number of years, but previous to the final adoption of his home in the new world, he embarked in the third vessel which left the shores of England, in order to the formation *(sic)* of a new settlement in South Australia, where he remained twelve months prosecuting his labours in natural history, botany and in acquiring information relating to the resources of the colony. At this time he became acquainted with Mr. J. Gould, the celebrated ornithologist, who was engaged collecting materials for his admirable work on the 'Birds of Australia.' In the latter end of this year, 1839, he was engaged upon an expedition with Captain Sturt and Commander Pullen (who is now, or was recently, engaged for the search for Sir John Franklin) to explore the country north of the north-east angle of the Murray, during which the entire party nearly perished, being compelled to bleed their horses to quench their thirst, on account of the entire want of water. A very advantageous location being offered him in New South Wales, he left South Australia in 1841, and examined all the country from Cape Howe to Wide Bay, about 900 miles off the coast, and upon his return he took a nine months' cruise in her Majesty's Ship 'Acheron,' during which he visited Wellington, Auckland and the Canterbury Settlement. It may be remarked that he was the first white man who made the attempt to cross the Middle Island to the western coast of New Zealand. In his collection he has brought with him the

only living specimen in Europe of the Gigantic Water Lily *(Nymphœa gigantea)*, so elegantly described in last May number of Sir William Jackson Hooker's botanical work." (See *Bot. Mag.* t. 4647. "Several cultivators" in England had seed early in 1852).

Similar information was contributed to the "Kilmarnock Journal" of 24th June, 1852, and the "Norwich Mercury" of 26th June, 1852, and constitutes most of the information we possess concerning Mr. Strange. In the "Sydney Morning Herald" of 21st November, 1854, is an account of the murder of Mr. Strange, Mr. Spurling (son of Captain Spurling) and two others by the natives of (the second) Percy Island, Queensland. See also the issue of 2nd December. See also the "Empire" of 21st and 23rd November, 1854, and the "Moreton Bay Free Press" of the same date, the last account being much the fullest. Mr. W. Hill, afterwards Colonial Botanist, Brisbane, was of the party which was conveyed to Percy Island in the Ketch "Vision," of which Mr. Strange was the owner. The massacre took place on the 15th October. Collections of dried plants made by him from Sydney, Broken Bay, New Zealand, New Caledonia, etc., were on sale in London. (Hooker's *Journ. Bot.*, ix. 189, 1857). An interesting note entitled, "Frederick Strange, the Conchologist," by Mr. Charles Hedley, will be found in the *Colonial Museum Bulletin*, No. 1, p. 50, Wellington, N.Z., 1905 (1906). The following plants commemorate him: *Strangea* (Proteaceæ); *Eutaxia Strangeana*, Turcz =? and *Grevillea Strangea*, Benth. [For portrait see *Plate 12*].

Stuart, Charles (————). Hooker (3) says: "Mr. Charles Stuart has been employed in Tasmania in collecting at various times, chiefly, I believe for Mr. Gunn, ever since the year 1842. Many of his discoveries have been published by Dr. Mueller, and are included in this work."

I can get but few particulars of this admirable collector, and therefore I shall publish now the little I know, with the view to elicit further information. I will, of course, include him in my list of Tasmanian botanists. Bentham (B.Fl.) refers to his collections in New England, N.S.W. He seems to have collected about Timbarra, Tenterfield district, and other parts of northern New England. His specimens were carefully selected, numbered serially, and the information on his labels is concise and informative, and the handwriting that of an educated man. Most of his specimens that I have seen are in the National Herbarium, Melbourne. Miquel quotes him. He is commemorated in the following species :—

Bursaria Stuartiana, Klatt. = *Marianthus procumbens*, Benth.; *Diplopeltis Stuartii*, F.v.M.; *Spyridium Stuartii*, Reiss. = *S. coactifolium*, Reissek, var. *integrifolium; Acacia Stuartiana*, F.v.M. = *A. siculiformis*, A. Cunn., var. *bossiœoides*, Benth.; *Tephrosia Stuartii*, Benth. ; *Aster Stuarti*, F.v.M. = *Olearia Stuartii*, F.v.M. ; *Brachycome Stuartii*, Benth. ; *Eucalyptus Stuartiana*, F.v.M.; *Eurybia Stuartii*, F.v.M. = *Olearia Stuartii*, F.v.M.; *Euryomyrtus Stuartiana*, F.v.M. = *Bæckea diffusa*, Sieb ; *Helipterum Stuartianum*, Sond. = *H. floribundum*, DC. var. *Stuartianum ; Myriocephalus Stuartii*, Benth.; *Olearia Stuartii*, F.v.M.; *Polycalymma Stuartii*, F.v.M. = *Myriocephalus Stuartii*, Benth.; *Leucopogon Stuartii*, F.v.M. = *L. Fraseri*, A. Cunn.; *Grevillea Stuartii*, Meissn. = ?; *Isoetes Stuartii*, A.Br. – ?

Sweet, Robert (————). Author of "Flora australasica, or, a selection of . . . plants . . . of New Holland and the South Sea Islands" . . . the drawings by E. D. Smith, London, 1827-28, 8vo. A handsome work with 56 coloured plates (and descriptions) of Australian plants. For a list of Sweet's other works, see "Iconum Botanicarum Index" (Pritzel) xxix. The following Australian plant was intented to commemorate him :—*Pullenœa Sweetii*, Don. = *P. flexilis*, Sm.

Turner, George Edward, Revd. (1810-1869). Born at Corsham, Wilshire, England; died at Ryde, near Sydney, at his parsonage house, through injuries received from a fall from his horse, 10th January, 1869. I have a farewell sermon before me, addressed to the congregations of the parishes of Monkton Farleigh and South Wraxhall, Wilts, by their late Curate, Rev. G. E. Turner, S.C.L., appointed Chaplain in the Colony of Van Dieman's Land, and published at Ryde. England, in 1838. He was a member of the Committee of the Australian Museum from its inception. and Honorary Secretary of the Sub-committee which controlled the Botanic Garden for a few years. He took much practical interest in horticulture and also in Botany (he was an ardent microscopist), although I cannot trace any botanical publications from his pen. See a notice in *Hort. Mag.* (Sydney) vi. 41 (1869).

Vernon, William (1811 – 1890). Born at Epsom, Surrey, England, and died 6th January, 1890, at St. Ives, Lane Cove, Sydney. In England he was a gardener in the service of Lord Cornwallis. His son, W. H. Vernon, informs me that he was in charge of the Herbarium, Botanic Gardens, Sydney, in 1857, during von Mueller's visit to Sydney. He assisted Mueller in collecting for the "Flora Australiensis." Bentham mentions his name. Mueller says, in dedicating an Ionidium to him—

> "In choosing that (name) here adopted, the author wishes to express a mark of acknowledgment for much aid which, in forming collections of plants in the classical fields around Port Jackson, he received from Mr. W. Vernon of Sydney." (*Pl. Vict.* i. 223).

His son informs me that he was a constant correspondent of the Baron for 30 years. After leaving the Botanic Gardens he became gardener to Mr. T. S. Mort of Darling Point, whose garden was the finest private establishment

in Sydney at that time. *Ionidium Vernonii*, F.v.M., commemorates him. [For Portrait see *Plate 11*].

Vicary, N. (fl. 1835-53). Major, 2nd European Regiment, Bengal Army—

"Who seems to have been a very acute and indefatigable investigator of the New South Wales Flora, and a set of whose plants he has transmitted to Kew." (**3**).

I have seen some of his Australian specimens in Herb. Calcutta, so that he evidently sent some to India as well as to Kew. Mosses are credited, "Maitland (N.S.W.), Vicary" in Mitten's paper on 'Australian Mosses,' *Proc. R.S. Vict.* xix., 52. The following particulars are from (**1**) Author of "Botany of Sinde." *Ann. Nat. Hist.* i. 420. *Journ. Asiat. Soc.*, Bengal, xvi. 1152 (1847). "Small but very valuable herbarium at Kew." *Flora Indica* i. 70, *Royal Society's Catalogue*, vi. 147. He is commemorated in the genus *Vicarya*, Wall. = *Myriopteron*.

Walker, James (1794-1854). Died at Liverpool, N.S.W., and the following extract from the legend on the mural tablet in St. Luke's Church, Liverpool, contains most of the information I have concerning him—

"In memory of the Reverend James Walker, M.A., formerly Chaplain of New College Oxford, and Rector of Paddington, Somersetshire, England, subsequently Head Master of The King's School, and First Rector of All Saints Church, Parramatta, and finally during eight years Incumbent of St. Luke's in this town, where he fell asleep in Jesus, October 27th, 1854, aged 60 years."

Woolls acknowledged the assistance Mr. Walker gave him in naming some of the plants enumerated in his "Species plantarum Paramattensium." He possessed a considerable local reputation for his knowledge of New South Wales plants, but I cannot find that he published anything on the subject. Locally he is remembered as a

very humble-minded man. He is not commemorated by any plant ; I will try and rectify the omission some day.

Waterman, William (————). Overseer, Botanic Gardens, Sydney; 1st July, 1846. Soon after Mr. Moore's arrival in Sydney in 1848, Mr. Waterman was transferred to the Inner Domain, but he resigned to go to the gold-fields in 1852 or 1853.

Watling, Thomas[1] (—— ——). "The British Museum has lately acquired a very interesting volume containing drawings in colour of the animals and plants of Australia, made by Thomas Watling in 1788-1792. Watling was sent out by James Lee of Hammersmith (from whose great-grandson, bearing the same names, the collection was purchased), with a view to obtaining material for a book on the natural history of the country, but Lee's death prevented his plan from being carried into effect. Apart from its contents, the volume is interesting on account of the light which it throws upon an entry on p. 253, vol. 1 of Dryander's Catalogue of the Banksian Library: this runs, "Volumen foliorum 70, continens figuras animalium et plantarum pictas quas in Nova Cambria prope Port Jackson delineavit Edgar Thomas Dell." In Banks' copy the last four words are struck out, and a comparison in the volume with the one acquired from Mr. Lee shows that it is the work of the same artist. Watling was acquainted with John White (Surgeon-general to the Settlement), who sent plants to Smith, and published in 1790 his *Journal of a voyage to New South Wales ;* one or two of Watling's drawings were executed for White. The newly acquired volume contains several views of Sydney, which are of great interest." (James Britten in *Journal of Botany*, August, 1902, p. 302).

White, John (————). The in ormation in the following note is certainly not generally known to botanists:—

[1] I have included this artist as a special case, with the view of elucidating further particulars concerning him. Particulars of the Bauers will be found in my forthcoming "Life of Banks."

"In 1788, Mr. John White landed in Botany Bay, where, or at Sydney, he was resident for seven years as Surgeon-general to the new settlement. He collected a considerable number of plants, and made drawings of others, which were sent to Mr. Wilson, Mr. Lambert and Sir James Smith, and published by the latter botanist in 'A specimen of the Botany of New Holland,' 'The Exotic Botany,' etc., in White's 'Journal of a voyage to New South Wales,' and other works."

The first work referred to us is:—"Zoology and Botany of New Holland and the isles adjacent. The zoological part by George Shaw, M.D., F.R.S., etc. The botanical part by James Edward Smith, M.D., F.R.S., etc. The figures by J. Sowerby." A sub-title is, "A specimen of the Botany of New Holland by James Edward Smith. The figures by James Sowerby, F.L.S., vol. i., London. Printed by J. Davis, published by J. Sowerby, 1793." The work contains the following statement:—

. . . "The figures are taken from coloured drawings, made on the spot, and communicated to Mr. Wilson by John White, Esq., Surgeon-general to the Colony, along with a most copious and finely-presented collection of dried specimens, with which the drawings have in every case been carefully compared, December, 1793."

(At p. 36 Smith refers to *Pultenœa stipularis* having first flowered in London in April, 1794). White's connection with Surgeon Denis Considen in the matter of Eucalyptus Oil is explained above, p. 98. No Australian plant appears to have been dedicated to White's memory, and I will try and rectify the omission.

Wilcox, James Fowler (1823-1881). Born in Somersetshire, England, 2nd February, 1823; arrived in Sydney 1823; died at South Grafton, 11th July, 1881. He spent most of his time as a naturalist, giving special attention to botany and taxidermy. He accompanied Capt. Owen Stanley

in H.M.S. "Blazer," which conveyed Sir John Franklin on his last and ill-fated expedition in 1845. On his return he was on board H.M.S. "Rattlesnake," under Capt. Stanley as collector in the interests of the Norwich Museum, his period of service with this ship extending from December, 1846 to 1850. During the cruise he visited the north and north-east coast of Australia, the south coast of New Guinea, and part of the Arafura Sea. He also visited Brazil, Mauritius, the Cape and Tasmania, then went from Moreton Bay to Port Essington. His ship convoyed the Kennedy Expedition to Rockingham Bay and he remained with the ill-fated leader for 3 weeks. The "Rattlesnake" then went to the Louisades, New Guinea, etc., and the cruise was terminated by the death of Capt. Stanley in Sydney. Mr. Wilcox was then engaged in natural history pursuits in New South Wales, married in 1851, was engaged in business in Sydney for 5 years and went to South Grafton early in 1856, finally settling there in 1857. He was Commissioner at the Melbourne Exibition of 1866, and exhibited many specimens illustrative of the natural history of the Clarence, Richmond and Tweed Rivers at that Exhibition and also that of Paris, 1867. He was a correspondent of Mueller and a coajutor of Macgillivray and Carron. He made many expeditions on the northern rivers after birds and plants, and with his son, James Clarence, went to New Guinea in 1876 with the same objects in view. He is commemorated by the plant *Pleiococca Wilcoxiana*, F.v.M. I am indebted to Mr. D. J. Lobban, of Grafton for some of the above biographical information.

Woolls, William (1814-1893). Born at Winchester, England, March, 1814, and died at Burwood, Sydney, March 1893. Ph.D. (Gottingen), F.L.S. Arrived in New South Wales 1832; was immediately offered a mastership in the newly founded King's School at Parramatta. In 1873 he

was ordained a clergyman of the Church of England and was appointed Incumbent of Richmond. He wrote many poems, and contributed many papers and essays to newspapers and magazines. His botanical works are the following:—"Australian Ferns, No. 1," *Hortic. Mag.* iii., 262 (Nov. 1866), and continued in subsequent issues. In the same magazine he published a number of short papers on the native vegetation, especially between the years 1868-1870. He published a large number of papers in *Proc. Linn. Soc., N.S.W.* "A contribution to the flora of Australia," Sydney, 1867, 8vo. "The progress of botanical discovery in Australia; a lecture, etc." Sydney, 1869, 24mo. (Previously printed in *Hort. Mag.*) "Species plantarum paramattensium secundum ordines naturalium disposuit." G.W., Gottingæ, 1871, 8vo. "Lectures on the Vegetable Kingdom, with special reference to the "Flora of Australia." Sydney and Parramatta, 1879, 8vo. "The plants of New South Wales . . . with an introductory essay and occasional notes." Sydney, 1885, 8vo. "Plants indigenous in the neighbourhood of Sydney, etc." Sydney, 1880, 8vo. "Plants indigenous and naturalised, etc." (*i.e.* Ed. 2). *Ib.*, 1891, 8vo. "On double flowers," (*Vic.Nat.* i, 50). "On the sanitary properties of Eucalyptus," (*ib.* ii. 84). "Plants of New South Wales having medicinal properties" (*ib.*, iv, 103). "Notes on the distribution of aquatic plants in New South Wales" (*ib.*, vi, 176). "The destruction of Eucalypts" (*ib.*, viii, 75). His reputation as a botanist does not, however, rest on his published works. He collected very largely for Mueller, to whom he sent copious notes. His services were acknowledged by Bentham in the "Flora Australiensis" and by Mueller in the "Eucalyptographia" and other works. He had the greatest objection to obtrude himself in any way, and a still greater objection to make botanical observations which could in any way

be used in argument or even discussion. He communicated his opinions to his correspondents and there an end, as a very general rule. The consequence was that only his friends and pupils (of which the present writer was one) had any idea either of the depth of his knowledge or of the readiness with which he communicated it to enquirers. Much of his great knowledge of N.S.W. plants has gone down to the grave with him unrecorded. For biographical notes see Heaton's "Austalian Dictionary of dates," also **(6)**, and "Sydney Mail," 3rd May, 1890, *Vict. Nat.* ix, 185. [For portrait see *Plate 13*]. He is commemorated in the genus *Woollsia (Lysinema)* Epacridaceæ, and in the following species.:—

Enhydra Woollsii, F.v.M. = *E. paludosa*, DC.; *Eucalyptus Woollsii*, F.v.M. = *E. longifolia*, Link and Otto; *E. Woollsiana*, R. T. Baker = *E. odorata*, Behr., var. *Tylophora Woollsii*, Benth.; *Eremophila Woollsiana*, F.v.M. = *Pholidia Woollsiana*, F.v M.; *Prasophyllum Woollsii*, F.v.M.; *Alsophila Woollsiana*, F.v.M. = ?

On the ELASTIC SUBSTANCE OCCURRING on the SHOOTS and YOUNG LEAVES of *EUCALYPTUS CORYMBOSA* and some SPECIES of *ANGOPHORA*.

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

[*Read before the Royal Society of N. S. Wales, July 1, 1908.*]

When the buds and very young leaves of *E. corymbosa* are in active growth they are covered with an elastic substance, which, under favourable conditions, can be stretched to a considerable extent. The main structure of the leaf, beneath the substance, can be readily broken without detaching the coating. It has been thought that this elastic substance was peculiar to this Eucalypt, but I have found it occurring on the shoots and young leaves of both *Angophora lanceolata* and *A. intermedia.* This fact is particularly interesting as it adds another proof of the close relationship existing between the Angophoras and those Eucalypts which have a corresponding leaf venation. *E. corymbosa* is perhaps the best representative of this group of Eucalypts.

In a recent work by R. T. Baker and myself,[1] we were able to show a remarkable affinity between the "Bloodwoods" (to which *E. corymbosa* belongs) and *A. lanceolata*, judged by the chemical constituents of their oils as well as by their leaf venations. The evidence now submitted strongly supports our previous observations in regard to these two genera. I am not aware that any previous research into the properties or composition of this elastic substance has been undertaken. I was thus anxious to

[1] A Research on the Eucalypts. Government Printer, Sydney, 1902.

determine its affinities, and if possible its relationship to the later structure of the leaf.

There seems to be no strict regularity in the time of year when the formation of this elastic substance is most pronounced, and no fixed period appears to be necessary for its production. A few years ago, I gathered, early in December, some material from the young shoots of *Angophora lanceolata* at Sandringham, near Sydney. At the end of the following October it was plentiful on the young growth of both *E. corymbosa* and *A. lanceolata*, at La Perouse, near Sydney; two months later, however, none of the elastic coating could be detected. The formation thus appears to be largely due to climatic conditions, which cause the plant to send forth fresh shoots, and thus to give the tree new growth.

In the beginning of March of this year (1908) there was quite a marked and vigorous growth in the Eucalypts growing around Sydney, evidently due to the rainfall of the previous month. At this time the elastic substance on the shoots of both *E. corymbosa* and *A. lanceolata* was most pronounced. By the beginning of June it was difficult to find any of it remaining, and it was only evident in quantity on very few plants. As this appeared to be a very good opportunity to obtain sufficient material to carry out the investigation, a large quantity of the fresh shoots and very young leaves of both these plants was collected. The trees were growing together on the hills beyond Cook's River, near Sydney. The collection was a somewhat tedious process, as it was of little use gathering more than the terminal shoot with at most the two extreme very young leaves. The shoot at the end of the branchlet, before the leaves were unfolded, was entirely covered with the elastic coating. It was necessary to use considerable force to pull the shoot apart, as the elastic substance occurs

both within and without the shoot, giving it considerable strength. A very young shoot could often be stretched half an inch or more before breaking. The undeveloped leaves of the shoot are completely covered with the substance in their earliest stage, while they are quite green. As the minute and closely folded leaves of the shoots expand, and thus form separate leaves, they soon become bright red in colour, and in this early stage are still coated with the elastic substance, which also gives them a very glossy appearance, particularly on the upper surface. As the leaves grow larger the elastic substance quickly changes, and a stage is soon reached when it is difficult to detect any of it remaining on the leaf, particularly after the third small one from the end of the branchlet.

The substance is less pronounced on the under than on the upper side of the leaf, although in the earliest stages it covers the whole of it, as well as the petiole. The substance can often be entirely stripped from the upper surface of the very young leaves, thus proving that it is only a surface coating. It cannot be thus easily removed from the underside of the leaf, where the coating soon becomes very thin and difficult to detect, except on the midrib and around the edges. The changes which quickly take place seem thus to be more rapid on the underside of the leaf, and the varnish-like appearance of the young leaves soon disappears, the surface becoming quite dull.

Although the unfolded shoot consists so largely of this elastic substance, yet the coatings of the leaves are distinct in their earliest stage, and expand with them as they grow. To prevent them adhering together at this stage, their surfaces are coated with a white powdery resinous or waxy-like substance, which is very soluble in ether, and by which means its presence can readily be determined.

The elastic substance so quickly changing as the leaves grow larger, seems to indicate that it is required to act solely as a protection in some way to the young shoots. It is perhaps a remnant of conditions which maintained ages ago, and of which we at this time have no conception. The evidence which has accumulated, indicates that Angophora is the older genus, and that *E. corymbosa* is at the end of the Eucalypts next to the Angophoras. If the substance remained as an entire coating as the leaves grew larger, the ordinary functions of the leaf would be interfered with, and it was not far down in the sequence of species before nature discarded the elastic coating altogether. The shoots and young leaves of Eucalyptus species growing together with *E. corymbosa* gave no indications of the elastic substance by ordinary physical methods, although their young shoots were just as pronounced, and often quite as red. *E. pilularis*, *E. hœmastoma*, *E. eugenoides* and *E. botryoides* all gave negative results in this respect.

It hardly appears possible that the coating is reserve material to be used in the formation of the leaf, and the yield of essential oil from both *E. corymbosa* and *A. lanceolata* is so very small, that it is hardly likely to be used in the formation of oil constituents; it most probably undergoes oxidation, ultimately forming the powdery substance, with perhaps a little wax at the same time. That the alteration is in this direction is demonstrated by treating the older leaves with ether for three minutes, the white powdery substance being thus removed. From the method of extraction it must be on the surface of the leaf.

The following evidence obtained by treating the shoots and leaves separately supports this theory of alteration. The accompanying photograph, which is that of the end of one of the growing branchlets of *E. corymbosa*, gathered April 11th 1908, will assist in making this clear:—

No. 1 Centre shoot. This was bright green, very glossy, 13 mm. long, largely composed of elastic substance; was hard and compact.

Nos. 2 and 3. Two first leaves. These were almost opposite, green changing to red at places, very glossy, largest 36 mm. long, 4 mm. wide. Elastic substance covering both sides of the leaves.

No. 4. A single leaf. This was reddish-green to bright red in places, petiole red, leaf mostly shiny above except at outer end, under side of leaf dull, 88 mm. long, (without the petiole), 15 mm. wide. Only traces of the elastic substance could be detected on the under side of the leaf.

No. 5. Leaf 110 mm. long, 23 mm. wide, midrib and edges of leaf red, on other portion only reddish in places, only a very small amount of elastic substance could be detected on the upper side, none below.

No. 6. Leaf 127 mm. long, 24 mm. wide, dull green above and below, midrib, edges of leaf and petiole red.

A terminal shoot corresponding with No. 1 was crushed, spread out as much as possible, and treated with ether. (The elastic substance is quite insolnble in ordinary ether). A white powdery substance was extracted in small amount; this melted at 222° C.

The elastic coating was then stripped from some leaves corresponding to Nos. 2 and 3, and a small amount of the white powder soluble in ether was obtained; it melted at 225° C. A single leaf corresponding to No. 4 was treated with ether, it gave a quantity of white powder which melted at 215° C. The next leaf No. 5, gave a larger amount of the white powder to ether, this melted at 205° C. No. 6 leaf gave even a larger amount of powder to ether; this melted at 195° C. No. 10 leaf on the same branchlet, gave about the same amount of powder to ether as No. 6; this melted at 195° C. A leaf taken from the lower portion of the branch did not contain so much powder removable by ether, but it melted at 195° C. also.

These results were all obtained at the same time and are strictly comparable. The contact with ether was three minutes in each case. It is thus evident that as the leaves grow older, the white powdery substance (which is also present in the earliest shoots) increases in amount, the caoutchouc diminishing at the same time. This alteration was proved in another direction. After removing the substances soluble in ether from the shoots and young leaves they were spread out in the sun and air for 5 weeks. On extracting with chloroform for 5 days the "rubber" obtained was more soft and sticky than that extracted from the fresh material; it was also less elastic. When treated with melted sulphur it vulcanized fairly well, and

was then but little different from the vulcanized mostly unaltered "rubber."

The Vegetable Wax.—The melting point of the powder was found to decrease as the leaves grew older. This is apparently due to the formation of a small amount of a vegetable wax, of somewhat low melting point. I have extracted this wax in much larger amount from other species of Eucalyptus in which the caoutchouc does not occur, and it is largely due to the presence of this wax, together with the white powdery material, that the pulverulent appearance of the young growth of certain Eucalypts, as *E. cinerea*, *E. pulverulenta*, and allied species is due.

The amount of vegetable wax (melting at 59–60° C.) obtained from 500 grams of the fresh material of *E. corymbosa* was 0·112 gram. equal to 0·0224%. It was extracted from the ether residue by boiling with petroleum ether (45–50° C.) in which only the wax was soluble. It was finally purified from boiling alcohol in which it was fairly soluble, separating out again on cooling. Another determination was made on 800 grams of approximately the fifth and sixth leaves of the branchlets of *E. corymbosa*. These were collected and treated at once with ether for five minutes. The ether was but slightly coloured; it was distilled to a small bulk when a considerable amount of the white powder had separated. This was filtered off and the filtrate evaporated to dryness; it weighed 1·2 grams. It was then boiled in petroleum ether in which alone the wax was soluble. When purified from boiling alcohol the wax weighed 0·0784 gram, equal to 0·01%. The separated white powder, which when dry was like flour, weighed 5·5 grams, equal to 0·69%. The total extracted by ether from the 800 grams of these leaves (the 5th and 6th) was 6·7 grams equal to 0·84%. Although almost 1% of this white powdery

material is present on the surface of the green leaves of *E. corymbosa* and like species, yet, there is no signs of it upon the dull green leaves themselves, and it was only discovered on these by the systematic effort to locate the alteration product of the caoutchouc.

From 1000 grams of fresh young growth leaves of *E. cinerea*, steeped in ether for five minutes, 10 grams of solids were obtained, equal to 1%. This was finely powdered and extracted by petroleum ether (boiling 45–50° C.) in a Soxhlet for two days. The petroleum ether was distilled off and the wax evaporated to dryness. It was then boiled with alcohol until no more was extracted. The wax which separated on cooling was collected and melted into a cake by means of hot water. The total amount of wax was 3·55 grams, equal to 0·355%. It was identical with that obtained from *E. corymbosa*. It is thus evident that the pulverulent appearance of the young leaves of certain Eucalypts is due to the presence of the wax, and the absence of sufficient wax in the coating accounts for the want of this pulverulent appearance on the leaves of *E. corymbosa* and like species. I would like to reserve to myself the chemical investigation of this wax, together with its accompanying white powdery resinous-like substance.

The Caoutchouc.—For the determination of the elastic substance, the material of *E. corymbosa* was taken, as it was more robust and apparently contained more "rubber," but similar results were obtained with *A. lanceolata*, and the white powder from the leaves melted at the same temperature. *A. intermedia* also contains similar material. Two extractions with ether in the cold, each of 15 hours duration, appeared to entirely remove all the wax together with its associated white powder. 500 grams of the buds and young leaves were taken. As soon as the ether had evaporated, the material was treated with chloroform and

allowed to remain in this for 5 days. Previous investigation had shown that other ordinary solvents, such as benzene, ether, acetic-ether, alcohol, acetone, toluene and essential oils, had little action upon the caoutchouc in the cold, although it was much swollen by several of them; even carbon disulphide appeared to have little action upon it. Chloroform was the only solvent which was found to act at all satisfactorily. After 5 days the chloroform was mostly distilled off, the remainder transferred to an open vessel and allowed to evaporate spontaneously. The residue, when dry, was quite elastic and slightly coloured green from the presence of a small amount of chlorophyl. It resembled in appearance and ordinary general characters, the crude caoutchouc or "India-rubber" of commerce. Its chemical reactions were also found to be similar. The amount of substance extracted by chloroform after 5 days was, when dry, 0·785 gram, equal to 0·157%.

There still remained a considerable amount of the elastic substance attached to the leaves, and it was much swollen by its contact with the chloroform. It was largely recovered by the following process:—After the chloroform had evaporated from the material, it was steeped in a 5% aqueous solution of potash for 5 days. At the end of that time the structure of the leaf had become largely decomposed, or so much softened that by continued washing and kneading it was entirely washed away. The caoutchouc had been quite unacted upon by the alkaline solution, and it adhered together slightly so that it was eventually obtained in a fairly pure condition. The stalks and stems were easily squeezed or picked out as the mass was kneaded together in the hand. By this method 1·55 gram of elastic substance was obtained, equal to 0·31%. The chloroform extract represented the whole of the substance dissolved, but some of the remainder was unavoidably lost as the leaf

debris was washed away. The substance recovered from the aqueous alkali, when dry, was brownish in colour and was quite elastic. The several particles of the substance had adhered together but indifferently, so that when stretched the mass was of a stringy nature and not compact like the dissolved portion.

Following up this method for obtaining the caoutchouc, 500 grams of fresh material of *E. corymbosa* were thoroughly extracted by cold ether as before, and then, without treating with chloroform, placed directly in a 5% solution of potash, and left for 5 days. The material was then very soft, and by continued washing and kneading the whole of the leaf substance and the stalks were entirely removed, the caoutchouc adhering together sufficiently for it to be formed into balls. The substance as thus obtained appeared to be identical with that similarly procured previously. The amount of thoroughly washed and air dried caoutchouc, obtained from the 500 grams of material, was 7·44 grams, equal to 1·49%. The prior extraction with chloroform in the first attempt considerably weakened the substance, so that it broke up more readily, and consequently more was lost in the process of washing. The preparation by alkali direct enabled this to be largely overcome, so that the loss was much less. The amount extracted by chloroform in 5 days was equal to 9·5% of the larger portion obtained.

The caoutchouc extracted by chloroform was quite elastic, and when made into sheet form, by evaporating the chloroform solution to dryness on glass, resembled most markedly ordinary sheet-rubber made from the 'rubber' of commerce. Heated on platinum it melted at a high temperature—above 250° C. Heated below its melting point it recovered its elasticity at once on cooling. The melting point was considerably above that of the Museum specimens of crude Para rubber, crude New Guinea and other commercial

rubbers. On continued heating it ignited, burning with a very luminous flame which was less smoky than that from ordinary rubbers. When the carbon was burnt away a small amount of a dark coloured ash remained. Heated in a closed tube a light coloured liquid (which remained quite fluid when cold) distilled off, leaving a small amount of a carbonaceous residue. When treated with concentrated sulphuric acid the caoutchouc was eventually decomposed, forming a clear and slightly fluorescent solution. Nitric acid in the cold slowly acted upon it, eventually largely decomposing it with the formation of a yellow coloured solution. Dilute acids had no action upon it. When heated for some time in melted sulphur, it became vulcanized similarly to ordinary rubber. It was then more elastic than in the original state, and was grey in colour. The method adopted was necessarily crude, yet the result was sufficient to show that it would vulcanize very well.

An analysis of the caoutchouc extracted by chloroform and heated at 100 – 110° gave the following:—0·2001 gram gave 0·5846 gram CO_2 and 0·1925 H_2O. The ash left in boat weighed 0·0007 gram, equal to 0·349% so that 0·1994 gram was burnt away. The percentage of H = 10·73 and C. 79·9. The presence of 9·37% of oxygen indicates the rapidity of natural oxidation. Of course no formula can be arranged, as the alteration is evident, but it is worthy of notice that the hydrogen and the carbon still roughly approximate the terpene formula.

From the above investigations it is apparent that the elastic substance occurring in the shoots and young leaves of *Eucalyptus corymbosa*, *Angophora lanceolata* and *A. intermedia* is a good form of caoutchouc. There is a comparative absence of the viscous form which occurs in ordinary crude 'rubber.' This is indicated by its high

melting point, its indifferent action to ordinary solvents, and the fact that its elasticity is not destroyed by heating at a high temperature below its melting point. If Eucalyptus caoutchouc could be obtained in quantity it seems reasonable to suppose that it would have considerable commercial value. The small percentage amount, however, makes it, at present, of scientific value only, without taking into consideration the difficulty of collection, its rapid change, and that it only occurs at certain times of the year.

One cannot, however, refrain from the suggestion that from its composition and formation it must be closely associated with some of the members of the terpene group of essential oils found in the Eucalypts, particularly those boiling at a high temperature. If the polymerisation of these terpenes into caoutchouc could be accomplished—a result perhaps not impossible—then the supply of raw material in Australia would be practically unlimited, and obtainable from species of Eucalyptus at present unworked for their oil constituents.

Although found in plants belonging to numerous genera, this is probably the first time that caoutchouc has been shown to occur in any member belonging to the Myrtaceæ.

On the PINES of AUSTRALIA, No. I.—*CALLITRIS GLAUCA*, R.Br., "White or Cypress Pine."

By Richard T. Baker, F.L.S., Curator and Government Economic Botanist, and Henry G. Smith, F.C.S., Assistant Curator and Economic Chemist, Technological Museum, Sydney.

[With Plates XV. - XXIX.]

[*Read before the Royal Society of N. S. Wales, August 5, 1908.*]

Introduction.—The White or Cypress Pine, *C. glauca*, R.Br. has been taken first in this series of papers on Australian Pines, as it has the greatest geographical range on this island continent, of all the species of that most widely distributed genus *Callitris*, and it may therefore be regarded as the most representative of the group. Much attention was given to the question of the continental range of this genus in order to see if it extended beyond Australia, but the results proved, however, that it was quite endemic, and that such genera as Tetraclinis and Widdringtonia, of North and South Africa respectively, are quite distinct from it, vide Gen. Pl. and also Masters, Proc. Linn. Soc. London, vol. xxx, No. 205, p. 14 seq. vol. xxxvii, No. 260, p. 332. In the Flora Australiensis, Bentham synonymises *C. glauca*, R.Br. with *C. robusta*, R.Br. Its restoration here to specific distinction is the result of (1) an exhaustive examination of the *Callitris* material contained in the principal herbaria of Europe (*infra*) and (2) field investigation in Australia. In order therefore to definitely fix the species upon which this research has been made, a description of it accompanies these results.

Callitris glauca, R. Br., "White," "Cypress" or "Murray River Pine."

Syn.—*C. Preissii*, Miq. in Pl. Preiss, i, 643 ; *C. Huegelii*, ined.; *Frenela crassivalvis*, Miq., Stirp. Nov. Holl. Muell., i ; *F. canescens*, Parlat., in DC. Prod. XVI, ii, p. 448; *F. Gulielmi*, Parlat., l.c. 449.

It is an evergreen tree, varying in height according to environment. In the far interior it is stunted in growth, whilst towards the main Dividing Ranges it attains a height of over 100 feet with a diameter from 2 to 3 feet. The bark is hard, compact, furrowed, but lighter in colour than that of *C. calcarata*, R. Br., which forms with it the principal Pines of the interior.

Leaves at first triangular, then decurrent in whorls of three, glaucous; branchlets at first terete, the internodes being shorter than obtain in most species; the "teeth or leaf scales" short, acute, the decurrent portion only slightly rounded.

Male amenta small, two to four lines long, cylindrical oblong or ovoid, very numerous, occurring in general in threes at the end of the (leaf series); the stamens in whorls of threes, the scale like apex concave, cordate; anther cells two to four. Female amenta solitary or not often found in clusters, situated generally at the lower part of the branchlets.

Fruiting cones globular, rarely pointed at the top, about half inch, exceptionally three-quarter inch in diameter, slightly scabrous, valves six alternately large and small, the latter about a quarter less in size than the larger ones, valvate, channelled at the base; dorsal point scarcely perceptible. Seeds two or three winged ; the central columella under two lines.

Habitat.—It is perhaps quite safe to say that this species is *facile princeps* over its congeners in extent of geo-

graphical distribution, for it is found in all the States, but nearly always away from the coast.

Remarks.—The specific name is happily chosen as the leaves partake of this glaucous character more than those of any other species of *Callitris*. It is a feature that differentiates it in herbarium material from all its congeners and it retains it wherever the trees grow either in the eastern, central or western parts of the Continent irrespective of environment. The claims of this species to specific rank were apparent to us long before seeing Brown's original specimens, and had Bentham seen Brown's species (*C. robusta*, *C. glauca*, *C. tuberculata*, and *C. verrucosa*) in the field, he would not, we think, have synonymised them (B. Fl., vi, p. 237) under *C. robusta*. Cunningham also regarded them as distinct, as shown by his specimens and MS. in the British Museum. Each of these species is readily characterised by the fruits alone, and even the two species *C. verrucosa* and *C. robusta*, with warted cones cannot be confounded.

All the specimens collected by us and received from a very large number of correspondents go to show that this is primarily an interior species, although it does occur on the coast, for Moore's specimens labelled *C. glauca* at Kew were collected in 1854 at Moreton Island, and Cunningham also collected it at Rottenest Island. Its coastal localities would therefore appear to be quite limited, or perhaps further investigation may prove the two latter to be *C. arenosa* and *C. intratropica* respectively. Amongst other differences from *C. robusta*, *C. tuberculata*, and *C. verrucosa* may be noted its thin cone valves and paler coloured cones, those three each having a black outer surface. Both *C. arenosa* and *C. intratropica* have thin cone valves, but the pronounced columns and the parallel edges of the smaller valves of the former and in the fruits and timber of the

latter, along with other features, differentiate it from both these species. A special visit was made to Europe by one of us and the heads of the following Institutions kindly placed at our disposal for examination all the Coniferæ in their keeping.

Herbarium material examined.—

KEW—Robert Brown's specimens from Mount Brown, Iter Australiense, 1802-5, Allan Cunningham's specimen labelled by him, "Subtropical New Holland, Lieut-Col. Sir T. L. Mitchell's expedition." Allan Cunningham's specimen from Rottenest Island, 1835. A second specimen with same label but larger fruits. A specimen from Bald Island, labelled *C. Preissii.*

BRITISH MUSEUM—R. Brown's specimen with note "prevailing timber in Western Interior." Specimen from Coonabarabran, New South Wales, named by Miquel *C. crassivalvis.*

CAMBRIDGE UNIVERSITY—Lindley Herb., two specimens coll. by Sir T. L. Mitchell, Sub. trop. New Holl. 1846. A. W. Gray's specimen.

BRUSSELS NAT. HERB.—A specimen from Salt Lake near Tangulla, labelled *C. Preissii.*

All the above except where otherwise noted are labelled *C. glauca.*

PARIS NATIONAL HERBARIUM—Dr. Leichhardt's specimen from Moreton Bay 1845, probably came from further inland, for the term Moreton Bay would probably not be used at that time in so restricted a sense as understood to-day. It is labelled by Edward Spach and also by Brongniart as *C. Huegelii.*

Anatomy of the Leaves.—A section taken at the end of a branchlet between the internodes shows a structure that might for descriptive purposes be regarded as a modification

of a leaf of a *Pinus* (a leaf taken simply as typical of the Family) or a phanerogamous leaf in general.

The vascular bundle in *Pinus* is fairly evenly surrounded by parenchymatous tissue, whilst in *Callitris* such is not the case, for at the basal junction of the concrescences the meristele comes very closely to the cuticle or the outside air. However, in *Pinus* the vascular bundle forms the central column around which regular leaf tissue is sustained, and so in *Callitris* the ultimate portion of the branchlet forms the central vascular bundles supporting adnate leaf sections which collectively appear to form one whole leaf body, or at least that is our interpretation of this part of the tree for descriptive purposes.

In *Pinus* the vascular bundle is either simple or divided, and regarding then a section (*supra*) of *Callitris* as representing a terminal leaf, it is also found that the central column is simple or divided, but mostly the latter—three bundles predominating, although as many as six have been found. Taking then a three divided vascular bundle section, with three adnate cross sections attached, for description, and describing from the centre outwards, we find that each division of the bundle is wedge shaped, being separated by central and medullary thin-walled pith cells. The central xylem is succeeded by an orientated phloem, the relative position of these elements therefore is in accord with their final desposition in maturity of stem and branches. Subsiduary to these will be found near the base of each concrescence division and below the oil gland *a small bundle trace of the true decurrent leaf* with the phloem also orientated. These and the central bundles might thus be considered as corresponding to the midrib and veins of an ordinary bilateral leaf.

The xylem and phloem cells call for no special remark as they conform to the usual characters of such found in the

vegetable kingdom. Continuing then to view the section as that of a true leaf, we find that comparatively little transfusion or conjunctive tissue occurs in this species, and also that it does not surround the stele in so uniform a character as obtains in some other genera of the Order, in fact, the meristele can hardly be said to exist in the form so common in needles of other Conifers.

The phloem of the three-wedge shaped bodies or perhaps more correctly the stele, is surrounded by a mass composed of (1) endodermic cells, (2) transfusion tissue:—vessels which in the case of this and other species of *Callitris* appear to have no uniformity of arrangement when the section is taken either through, or clear of, the oil glands, as against the uniformity of such found in most other Conifers. When, however, oil glands are present, the endodermic cells are found to extend round and encircle these bodies, and also to form a group or cluster between the stele and the epidermis at the base of the cavity formed by the concave ventral surfaces of the concrescence. The endodermis may therefore be said to be not well defined in *Callitris* leaves and in this respect there is a resemblance to *Sciadopitys* of Japan. The walls generally are circular in section, or having a slight tendency to hexagonal form, and they show no involutions or infoldings, so characteristic of Conifer leaf cells in general.

In the preparation of the sections, their protoplasmic contents have been removed and so they invariably appear empty, and it is thus that they are easily differentiated from the cells with granulated content. These latter appear to take the place of, or to be an unusual form of transfusion tissue, if not then they are most probably fibre vessels. These play an important part in the metamorphosis of the leaf into cone scales; a subject that will be touched upon fully in a subsequent paper. The mesophyll needs

little comment. It consists of spongy and palisade parenchyma and both are clearly defined in Figs 1 to 14. The latter vessels consist of a single row having the long axis at right angles to the dorsal surface of each leaf, but cease at the ventral curve. The thick walled hypodermal cells are so to speak the epidermal cell companions of these, as they also only extend as far as the epidermic and palisade cells and gradually diminish in size and finally give out, as they approach the ventral surface. They are largest and thickest walled at the apex of the dorsal curve, and generally number about 100. The epidermal dorsal cells may be described as rectangular, and like the hypodermal ones are largest at the dorsal apex where the outer cell wall or cuticle is much thickened. They are not so numerous as the hypodermal cells, 50 being about the limit.

The cells of the ventral surface take quite a different form from that of the dorsal ones. As they turn, so to speak, to curve into the ventral surface, the thick cuticle wall gradually domes until in the centre of the ventral cavity of the concrescence they reach their maximum height, becoming quite conical in shape—the elongated apices appearing to resemble numerous processes. This unusual structure as far as we are aware has only been recorded in one other instance in Conifers, *i.e.*, *Sciadopitys verticillata*, S. and Z. of Japan.[1]

The functions of these elongated bodies (*sic* appendages) is probably (1) to assist the guard cells in the performance of their duties or duty. (2) They also indicate the presence of the stomata, being only found along with them. (3) A protective character for the stomata by closing over them as occasion requires during adverse climatic or other conditions. (4) Ovule protectors, for in the transition of the leaf terminations into cone scales, these elongated cells

[1] C. E. Bertrand, The Gnetaceæ et Coniferæ, pl. x, figs. 10, 11, 12.

interlock with those on the opposite leaf termination, like teeth of a cog-wheel and becoming ligneous, hold the cells together in a very firm grasp during the fertilisation and maturing of the ovules. The guard cells of the stomata call for little comment, being of the usual shape of such, relatively however to the size of the air cavities, they are larger than obtain in most phanerogams.

With the exception of one or two rarely occurring on the lower dorsal surface, stomata are only to be found on the ventral concave sides of the concrescence, where they occur in longitudinal irregular rows the whole extent of the ventral face of the concrescence as shown in Fig. 15. A few sometimes occur on the appressed lower part of the free portion of the concrescence. Being thus placed, they have the full advantage of the whole leaf substance as a protection against solar rays, rain or cold, and perhaps a secondary protective provision is provided as the edges of the individual leaf sections have the power of closing the entrance to the cavity when these adverse aerial conditions prevail, for the sections examined seem to support this theory, as the apertures are sometimes found open as well as closed, vide Figures. This of course can only be verified by assiduous field observations, but nevertheless we are at present under the impression that this may be one of the reasons for the decurrency in Conifer leaves, *i.e.*, that the maximum amount of protection for the transpiratory surface is obtained by the minimum amount of leaf movement.

The specific name was given by Brown on account of the bloom of the leaves. Francis Darwin,[1] states, "the position of the stomata in Conifers is very generally indicated by the existence of a glaucous bloom," but this is not so in the case of this species of *Callitris*, for the stomata

[1] Journ. Linn. Soc., Bot. ,vol. XXII, 1886, p. 99.

bearing surfaces are practically hidden, and cover too small an area to characterise the tree when so exposed. In this contention of ours, *i.e.*, accounting for the concrescence in *Callitris* and the functions of the conical epidermal cells and probable movement of the ventral surface, the following quotation, we think, rather strengthens our views. In the case of *Picea halepensis* "the leaves of this tree in warm sunny weather are fully separated, but if the sky became overcast they close partially; the sirocco produces a similar but more marked effect, but in rain the leaves collapse giving the tree a most melancholy aspect."[1]

Resin Cavities or Oil Glands.—When present these bodies are found to be situated in the upper portion of the concrescence and in the middle of the leaf substance. They are fusiform in shape, (Fig. 14) and a cross section showing a circle or an ellipse Figs. 7 to 9, and their limited length bars them from being classified as canals—a term used in describing identical bodies in other Conifers. To be more exact they occur in the centre of the spongy tissue and are not regularly distributed, sometimes one, and even two figures will be found in each leaf, whilst often only one or two of the sections may contain one. The glands or cavities are all lined with secretory cells, and may be classed as lysigenous. Under such circumstances no assistance was rendered by these for diagnostic purposes, as obtains in other Conifers, and cannot be used in a manner employed by Engelmann, who grouped the species of *Pinus* according to the position of their ducts. He also lays stress in the circumstance of the resin canals being surrounded by strengthening cells or devoid of such investment. These remarks, however, cannot be applied to *Callitris* as far as our observations go.

[1] Moggridge, Journ. of Bot., Feb. 1, 1867.

Chemistry of the Leaf Oil.—Somewhat comprehensive chemical results are here recorded for the leaf oil of this species. The material was all distilled at the Museum, and was gathered over a great extent of territory. The data obtained represent a period of over nine years. The object of this was to ascertain, from material belonging to one well defined species, the influence of locality, soil and climate, on the chemical constituents of the tree. It has been advanced by some writers that these influences are largely predominant with plants generally, and that, therefore, constancy of results can hardly be expected.

Our extensive researches on the oils of the Eucalypts, showed a remarkable constancy in the chemical constituents of individual species of that genus, so much so, that it was possible to advance the statement that material obtained from the same species of Eucalyptus would always give practically the same results, no matter where grown. This has been often questioned, but subsequent investigations have confirmed that statement. With the oils of the *Callitris* the same practical uniformity exists, although perhaps not so markedly as with the Eucalypts, as the rotation figures show more variation. This difference is largely accounted for by the varying amount of fruits present on the material distilled, as the oil from the fruits of *most* species of *Callitris*, has the opposite rotation to that obtained from the leaves, even when collected from the same tree, and the amount of ester is less also; the terpenes are, however, the same, only with opposite rotations. This fact is of considerable scientific interest, and the peculiarity has been conclusively proved in several instances, by carefully removing the fruits from the leaf branchlets, and distilling them separately. It was somewhat late in the research before this fact was discovered, so that the separate determination was not made with

material of *C. glauca;* but with both *C. robusta* from West Australia, and *C. verrucosa* from New South Wales—closely allied species—separate determinations were undertaken.

It will be noticed that in the results, obtained with the material of *C. glauca* from Narrandera, 25/4/07, the oil from one large tree (kept separate) varied by 6·7° from that obtained from trees growing alongside, and that the ester content was less also. The branchlets from the single tree had numerous fruits, and considerably more than were present on the general material. These differences, however, are so well under control, that it is practically possible to decide the species of *Callitris*, when judged from an investigation of the oil constituents, providing no mixture of material from various species has taken place. The advantages of this will eventually be self-evident when the complete results are published. The distillations were continued for six hours in all cases, except with No. 7, as it was found that a fair quantity of oil came over during the fifth hour.

The main constituents of the oils of all the samples of *C. glauca* were the same, and the higher boiling fractions in all cases were highly dextrorotatory, due to the presence of dextrorotatory bornylacetate and dextrorotatory borneol. The comparative uniformity of results with the several fractions, obtained with the five samples redistilled, can be seen from the tabulated results, Table II. The crude samples of oil were mostly slightly yellowish in tint, and only one or two were reddish in colour. The material was distilled in iron vessels. When cleared by dilute aqueous solution of soda, the oil was almost colourless, being slightly yellowish in tint. When rectified by steam, or by direct distillation, it was quite colourless. In both odour and appearance the leaf oil of this species of *Callitris* compares favourably with the better Pine-needle oils of commerce,

and the yield is also very good. Through the kindness of Messrs. Schimmel and Co., of Leipzig, we have received several samples of these Pine-needle oils. On analysing them for purpose of comparison, it was found that they were all lævorotatory, and that the leaf oil of *Abies pectinata* had a much less rotation to the left than had the oil from the cones of the same species. The ester content was also less in the cone oil.

On keeping the leaf oils of *Callitris glauca* for some time a resinous substance eventually forms and attaches itself to the sides of the bottles. This is evidently caused by light and oxidation as the specific gravity of the oil has slightly increased. The solubility of the oil in alcohol also rapidly diminishes on keeping. When freshly distilled the solubility was often as low as one volume of 90% alcohol, varying from that to ten volumes 90% alcohol. When aged it did not form a clear solution, at ordinary temperatures, even with ten volumes absolute alcohol. The solubility test appears therefore to be of little value in judging the crude oil of this species of *Callitris*.

Equal volumes of the crude oils of each of the seven samples here investigated were mixed together, and the product analysed. It was lemon yellow in colour and retained the original odour. Although some of the samples had been distilled a few years, yet, the alteration in any direction was not great. There was a slight increase in the specific gravity, and the increased insolubility in alcohol was marked. A very small amount of a phenol was extracted by aqueous alkali, it did not react with ferric chloride in alcoholic solution, and was perhaps the phenol common to the timber.

The specific gravity of the mixed oils at 16° C. = 0·8813. The rotation $a_D = + 27·9°$. The refractive index at 16° C. = 1·4771. The ester content by boiling was 13·82%; in

the cold, with three hours contact, it was 6·26%. These results compare favourably with those obtained with the Wellington sample under the same conditions. A portion was esterised with acetic anhydride in the usual way. The esterised oil had rotation $a_D + 28·1°$; it having slightly increased with the increased ester, indicated that the alcohol was borneol. The amount of ester was 18·94%, so that the amount of free alcohol as borneol was 4·63%. This result closely approaches that obtained with the Trangie sample.

Oil of Leaves.—No. 1.—Material was collected at Narrandera, New South Wales, 350 miles south-west of Sydney, 25th April, 1907. The terminal branchlets with fruits were steam distilled for six hours in the usual way, and in a manner corresponding to what would be done commercially. The amount of oil distilling from 784 lbs. of material was 70½ ounces, equal to 0·562%. This is a fair average yield of oil from this species.

Material was collected from one large tree and distilled separately, this was kept distinct so that the product from a single tree could be determined in comparison with that from general material. The bulk of the oil was obtained from the leaves of several trees as usual.

The yield of oil from the single tree was equal to 0·559%. It gave the following results:—Specific gravity at $\frac{18}{15}$° C. = 0·8671; rotation $a_D = + 21·2°$; refractive index at 18° C. = 1·4744. Freshly distilled oil was soluble in one volume 90% alcohol. Saponification number was 35·7, equal to 12·49% of ester as bornyl and geranyl-acetates.

The oil obtained from the mixed material was taken for the full investigation. It had specific gravity at 18° C. = 0·8729; rotation $a_D = + 27·9°$; refractive index at 18° C. = 1·4747. The freshly distilled oil was scarcely soluble in ten volumes of 80% alcohol, but was not rendered turbid by

excess; it was readily soluble in one volume 90% alcohol, but rapidly became less soluble on keeping. Saponification number was 47·03 equal to 16·46% of ester. In the cold with alcoholic potash, and with three hours contact, the sponification number was 24·5 equal to 8·57% of ester. This method of cold saponification has been found most satisfactory in the investigation of the oils of the several species of *Callitris*.

On redistilling practically nothing came over below 156° C.; between 156 and 160° 30% distilled; between 160 and 175° C. 45%; between 175 and 200° C. 8%; between 200 and 230° C. 12%. The specific gravity of the first fraction at $\frac{21}{15}$° C. = 0·8562 ; of the second 0·8571 ; of the third 0·8689; of the fourth 0·9415. The rotation a_D of the first fraction = + 30·4°; of the second + 27·2°; of the third + 21·0°; of the fourth + 32·4°. The fourth fraction contained 68·2% of ester. Both borneol and acetic acid were isolated and determined, so that the high activity is largely due to the presence of dextrorotatory bornyl-acetate, and to dextrorotatory borneol also. All the samples of oil of this species which have been investigated, contained this dextrorotatory ester. The refractive index at 21° C. of the first fraction = 1·4733; of the second 1·4736; of the third 1·4744; of the fourth 1·4723.

Terpenes.—The first and second fractions were mixed together and redistilled. Between 156 and 160° C. 42% distilled, and 29% between 160 and 161° C. The specific gravity of both fractions at 20° C. = 0·8549; the rotation a_D of first fraction = + 30·8°, or a specific rotation $[a]_D$ + 36·02° and the refractive index at 20° C. = 1·4733. The nitrosochloride was easily prepared from this fraction, and when finally purified from chloroform by precipitating with methyl alcohol, it melted at 103 – 104° C. The nitrosopinene was prepared from this, and when finally purified from

acetic-ether it formed good crystals which melted at 132° C. The low boiling terpene in the leaf oil of this species is, therefore, dextrorotatory pinene. The second fraction also consisted largely of this pinene. The third fraction (175 – 200° C.) consisted largely of dextrorotatory limonene together with dipentene. The presence of these terpenes in the leaf oil of this species was completely proved in the oil obtained from the material from Boppy Mountain. Sylvestrene was not detected nor were either cineol or phellandrene present.

Alcohols.—The fourth fraction (200 – 230° C.) was taken for the determination of the alcohols and the acids of the esters. 1·091 gram of oil req. 0·2128 gram potash, S.N. = 195·05 equal to 68·26% ester. The remainder was saponified by boiling in aqueous potash, and the oily portion separated. This oil had a marked odour of borneol. Sufficient borneol was present to form a semi-solid portion floating in the oil, this was separated and purified from petroleum ether and absolute alcohol. It formed well defined crystals, with a marked odour of borneol and melted at 202-3° C. The appearance, odour and melting point, together with its association, show this alcohol to be borneol.

Geraniol is also most probably present in combination with acetic acid. This is indicated by the fact that 8½% of the esters was saponified in the cold in three hours. In the investigation of the oil of *Eucalyptus Macarthuri* by one of us[1] it was shown that geranyl-acetate was completely saponified in the cold. We have used this method in the investigations of the oils of the *Callitris*, and have been able to follow the increase in the amount of geranyl-acetate in the oils of the several species, and the corresponding diminution of bornyl-acetate. The ester in one of the species of *Callitris* has been found to be almost entirely

[1] This Journal, 1900, p. 146.

geranyl-acetate, and from it the pure geraniol has been isolated and determined. Although geraniol has not been separated in a pure condition from the oil of *C. glauca*, as it was not thought necessary, yet, we think that the results justify us in considering it to be present. The fact of cold saponification, together with the odour, and also that there is a marked gradation in the constituents of the *Callitris* oils, increasing in the several species until a maximum is reached in one of them.

Over 60% of geranyl-acetate has been found in the oil of one species of *Callitris*. Geranyl-acetate as well as bornyl-acetate may thus be considered to be present in the leaf oil of *C. glauca*, as well as in that of most species of *Callitris*. 19 hours contact with alcoholic potash in the cold saponified less than two-thirds of the total ester in the oil of *C. glauca*, while readily saponifying the total ester in the oil of the other species referred to in three hours. The data at present available are not sufficient to enable the method of cold saponification to be considered of actual quantitative value, but of its indicative value there can be little doubt.

Volatile Acids.—The aqueous solution separated from the saponified alcohols was evaporated down, and distilled with sulphuric acid until all the volatile acids had come over. This acid distillate was exactly neutralised with barium hydrate solution, evaporated to dryness, the barium salt prepared in the usual way, and dried at 110° C. On ignition with sulphuric acid 90·67% of barium sulphate was obtained. As the theoretical amount for barium acetate should be 91·35% it is evident that a small amount of a volatile acid of higher molecular weight was present. During the distillation and preparation of the acids, there was a marked odour of butyric acid, so that probably it is that acid which is present with the acetic acid. The barium

salts, therefore, contained 95·87% barium acetate, and 4·13% barium butyrate. The indications for butyric acid have also been obtained with the oils of several of the species closely allied to *C. glauca*.

The oil of the general material from Narrandera, 25/4/07, was rectified by steam distillation in the ordinary way; the greater portion of the oil readily came over. When it distilled very slowly the receiver was charged, and the distillation continued for a considerable time. A small quantity of a yellowish oil was thus obtained. The bulk oil when dried was colourless, had a very refreshing Pine-needle-oil odour, and was bright in appearance. The saponification number was 39·13 equal to 13·7% of ester. The rotation $\alpha_D = +28·2°$; the specific gravity, at $\frac{24}{15}$° C., = 0·8682; the refractive index at 24° C. = 1·4720. It was insoluble in 10 volumes of 90% alcohol. Soluble in 1 volume of absolute alcohol, but becomes turbid with 2 volumes.

The smaller portion of oil was somewhat viscous, and gave saponification number 127·12 equal to 44·5% of ester by heating, and 38·81% by cold saponification, three hours contact. The rotation $\alpha_D = +19·5°$; the specific gravity at $\frac{23}{15}$° C. = ·9524; the refractive index at 24° C. = 1·4828.

It is thus evident that the whole of the ester is not easily redistilled by steam, although the greater portion comes over in the more readily obtained distillate.

* * *

No. 2.—This material was collected at Boppy Mountain, in the Cobar district, 440 miles west of Sydney, New South Wales, 25th May, 1903. The terminal branchlets with fruit were steam distilled in the usual way. The amount of oil obtained from 472 lbs. of material was 46½ ounces equal to 0·616%. The rotation α_D of the crude oil = +31·3°; specific gravity at $\frac{18}{15}$° C. = 0·8665; refractive index at 19° C. = 1·4779; saponification number = 34·19 equal to 11·966%

ester. Saponification in the cold, 20 hours contact, gave S.N. 22·07 equal to 7·725% ester. When freshly distilled it was insoluble in ten volumes 80% alcohol, but was soluble in one volume 90%. It, however, on keeping, soon became insoluble in ten volumes 90% alcohol.

On redistilling only a few drops came over below 156° C. Between 156 and 161° C. 30% distilled; between 161 and 165° C. 22%; between 165 and 200° C. 37%; between 200 and 228° C. 6%. The specific gravity of the first fraction at $\frac{15}{15}$° C. = 0·8545; of the second 0·8555; of the third 0·8649; of the fourth 0·9434.

The rotation a_D of the first fraction = + 32·6°; of the second + 32·0°; of the third + 30·7°; of the fourth + 33·5°. Another distillation was made with comparable results. The oil which came over below 161° C. was redistilled, and 66% came over between 155 and 157° C. The specific gravity of this at 15° C. was 0·8606; the rotation a_D + 34·5°; or a specific rotation $[a]_D$ = + 40·09°; the refractive index at 20° C. = 1·4731. The nitrosochloride was also prepared from it. These results show this terpene to be dextrorotatory pinene as in the previous sample.

To determine the limonene and depentene, the second and third fractions were again distilled, and 16% which came over between 172 and 175° C. (uncor.) was obtained. This had specific gravity at 15° C. = 0·8535 and rotation a_D = + 28·6°. The tetrabromide was readily prepared from it in some quantity. On complete purification this melted at 116° C. It was recrystallised, but still the same result. This indicated that both dextrorotatory limonene and dipentene were present. This high melting point of the tetrabromide has been met with in all the samples of *Callitris* from which it has been prepared. From the oil of one species of *Callitris*, which consisted very largely of dextro-limonene and dipentene, the tetrabromide was pre-

pared; this melted at 118° C. By fractional crystallisation of this from acetic ether, three separate sets of crystals were obtained, which melted respectively at 122° C., at 118 – 119° C., and 117° C. As dipentene tetrabromide is less soluble than that of limonene, this shows that both forms were present. That both dextrolimonene and dipentene were present was also shown by the activity of the tetrabromide when dissolved in acetic ether; this was strongly dextrorotatory.

The fourth fraction was saponified, and from the separated oil pure borneol was prepared. The acids of the esters were not determined, as this had been done in the previous sample.

* * *

No. 3.—This material was collected at Trangie, 320 miles west of Sydney, New South Wales, 28th November, 1902. The leaves were very dry at this time, as the State was suffering from a serious drought. This dryness does not, however, seem to interfere either with the yield of oil or with its constituents. 472 lbs. of material gave 46 ounces oil = 0·61%. The rotation a_D of the crude oil was + 30·8°; specific gravity at $\frac{24}{15}$° C. = 0·8631; refractive index = 1·4755 at 20° C.; saponification number 36·46 equal to 12·76% ester. The freshly distilled oil was soluble in two volumes 90% alcohol. A portion of the oil was esterised by boiling with acetic anhydride and sodium acetate in the usual way. The saponification number was then 52·09, equal to 18·23% ester. The free alcohol present was therefore 4·84% as borneol. On redistilling, 27% came over below 160° C.; 37% between 160 and 165° C.; 16% 160 – 180° C.; and 12% 180 – 225° C.

The specific gravity at 24° C. first fraction = 0·8477; of the second 0·8494; of the third 0·8561; of the fourth 0·9256. The rotation a_D of the first fraction = + 32·4°; of the second + 31·6°; of the third + 30·5°; of the fourth + 34·2°. The

constituents were identical with those of the previous samples.

* * *

No. 4.—This material was collected at Wellington, 250 miles west of Sydney, New South Wales, 17th March, 1903. 583 lbs. of branchlets gave $59\frac{1}{4}$ ounces of oil, equal 0·635%. The rotation a_D of the crude oil = + 28·4°; specific gravity at $\frac{17°}{15}$ C. = 0·8659; refractive index at 19° C. = 1·4774; saponification number 34·58 equal to 12·103% ester. When treated with alcoholic potash in the cold, with three hours contact, the ester value was 5·936%; with 19 hours contact the ester value was 8·095%.

On redistilling, 27% came over below 161° C.; 27% between 161 – 165° C.; 31% between 165 – 200° C.; 7% between 200 – 225° C. The specific gravity at 20° C., first fraction = 0·8550; of the second 0·8565; of the third 0·8664; of the fourth 0·9416. The rotation a_D of the first fraction = + 30·5°; of the second + 29·3°; of the third + 27·2°; of the fourth + 32·0°. The constituents of this oil were identical with those of the other samples.

* * *

No. 5.—This material was collected at Bylong, 240 miles west of Sydney, New South Wales, 2nd May, 1903. 511 lbs. of branchlets gave $46\frac{1}{2}$ ounces of oil = 0·569%. The rotation of the crude oil = + 31·25°; specific gravity at $\frac{19°}{15}$ C. = 0·8657; refractive index at 19° C. = 1·4749; saponification number 37·94 equal to 13·274% ester. Cold saponification, with three hours contact, gave 6·82% of ester, and with 19 hours contact 8·799% ester.

On redistilling, 28% came over below 160° C.; 28% between 160 and 165° C.; 32% between 165 and 200° C.; 7% between 200 and 225° C. The specific gravity at 19° C., first fraction = 0·8529; of the second 0·8537; of the third 0·8649; of the fourth 0·9322. The rotation a_D of the first fraction = +

32·2°; of the second + 31·7; of the third + 30·6°; of the fourth + 32·5°. The constituents were identical with those in the other samples.

* * *

No. 6.—This material was collected near Tamworth, 280 miles North of Sydney, New South Wales, 3rd March, 1908. 388 ℔s. of branchlets, containing some fruits, gave 35 ounces of oil, equal to 0·563%. Specific gravity, crude oil at 24° C. = 0·8665; rotation α_D = + 25·2°; refractive index at 24° C. = 1·472; saponification number 40·2, equal to 14·07% ester. These results are practically identical with those obtained with the other samples, and it was thus thought unnecessary to carry the investigation further.

* * *

No. 7.—This material was collected at Nyngan, 380 miles west of Sydney, New South Wales, 29th December, 1899. 358 ℔s. branchlets gave 30½ ounces of oil, equal to 0·532%. The distillation was continued for eight hours, but very little oil came over during the extra two hours; it was sufficient, however, to increase the specific gravity somewhat, although the ester content was but little improved. The specific gravity at 24° C. = 0·8782; rotation α_D = + 22·7°; refractive index at 19° C. = 1·4774; saponification number 40·61 equal to 14·21% ester.

Table I.—Crude Pine-needle Oils of *Callitris glauca* from New South Wales.

No.	Locality and Date.	Specific Gravity ° C.	Rotation α_D	Refractive Index ° C.	Ester per cent	Yield per cent.
1	Narrandera, 25/4/07 ...	0·8729@18	+ 27·9°	1·4747@18	16·46	0·562
2	Boppy Mountain, 25/5/03	0·8665 „ 18	+ 31·3°	1·4779 „ 19	11·966	0·616
3	Trangie, 28/11/02 ...	0 8631 „ 24	+ 30·8°	1·4755 „ 20	12·76	0·610
4	Wellington, 17/3/03 ...	0·8659 „ 17	+ 28·4°	1·4774 „ 19	12·103	0·635
5	Bylong, 2/5/03	0·8657 „ 19	+ 31·25°	1·4749 „ 19	13·274	0·569
6	Tamworth, 3/3/08 ...	0·8665 „ 24	+ 25·2°	1·472 „ 24	14·07	0·563
7	Nyngan, 20/12/99 ...	0·8782 „ 24	+ 22·7°	1·4774 „ 19	14·21	0·532

Table II.—Some redistillation results of five of the samples of Pine-needle Oils of *Callitris glauca*. Numbers as in Table I.

No.	1st.	2nd.	3rd.	4th.	1st.	2nd.	3rd.	4th.
1	156 - 160°	160 – 175°	175 – 200°	200 – 230°	·8562	·8571	·8689	·9415
	30%	45%	8%	12%	+30·4	+27·2	+21·0	+32·4
2	156 – 161°	161 - 165°	165 - 200°	200 – 228°	·8545	·8555	·8649	·9434
	30%	22%	37%	6%	+32·6	+32	+30 7	+33·5
3	Below 160°	160 - 165°	165 - 180°	180 – 225°	·8477	·8494	·8561	·9256
	27%	37%	16%	12%	+32·4	+31·6	+30·5	+34·2
4	Below 161°	161 – 165°	165 – 200°	200 – 225°	·8550	·8565	·8664	·9416
	27%	27%	31%	7%	+30·5	+29·3	+27·2	+32
5	Below 160°	160 – 165°	165 - 200°	200 – 225°	·8529	·8537	·8649	·9322
	28%	28%	32%	7%	+32·2	+31·7	+30·6	+32·5

Timber.—(*a*) *Economics.*—This is the most widely distributed species of the genus, and its timber therefore is more extensively used than that of any other *Callitris.* It is preferable to that of *C. calcarata*, R. Br., owing to its comparative freedom from knots, its straighter grain and lighter colour, and so is in general request for certain parts of house construction in the West and Central Divisions of the State. It is an easy working timber, and although usually possessing a quiet neat figure, it occasionally has some very handsome markings, which make it a valuable timber for some kinds of cabinet work, such as panelling etc. When polished on the flat it is very attractive, and the decorative characters are well brought out in turned stands or columns for busts, statuettes, etc. Some such adorn the landings of the Technological Museum and are a constant source of admiration to visitors.

The white ant or *Termites* is not particularly partial to it, and will attack it only as a *dernier ressort*, and this fact of course accounts for its utilisation for fence and foundation posts in which capacity it is reputed to be very durable. The supply unfortunately of this most useful timber is

gradually becoming less and less, and no steps are being taken for its propagation.

Transverse tests of specimens of *C. glauca* of standard size (38 in. by 3 in. by 3 in.) made by Mr. James Nangle, at the Technical College, gave the following results:—

	I.	II.	III.
Size of specimen	B = 3·02″ D = 3·03″ L = 36″	B = 2·968″ D = 3·025″ L = 36″	B = 3·005″ D = 3·02″ L = 36″
Area of cross section, square inches	9·15	8·998	9·06
Breaking load in lbs. per square inch	4850	4290	3050
Modulus of rupture in lbs. per sq. in.	9448	8529	6010
Modulus of elasticity in lbs. per sq. in.	1,016,470	1,133,160	875,675
Rate of load in lbs. per minute ...	485	451	210

Three smaller pieces 12 in. by 1 in. by 1 in. gave the following results:—1. broke at 900 lbs, deflection ·37 in.; 2. broke at 850 lbs., deflection ·28 in.; 3. broke at 690 lbs., deflection ·20 in.

(*b*) *Histology.*—Very little if anything appears to have been done to investigate the anatomical structure of the timber of Australian *Callitris*, or at any rate our researches through the Conifer literature at our disposal revealed little or nothing. The data now given should therefore prove of interest in the future study of this genus. Phylogenetically the results are of some value, for a connecting link so to speak was found to exist between these living *Callitris* and the fossil pine woods of North America, in that the tracheids of the xylem contain a similar substance; a circumstance that will be touched upon in a later paper.

A transverse section of the timber viewed under a low magnification as in Fig. 16, shows a more or less irregularity in the diameter and thickness of the tracheidal walls in the several medullary rows. This figure is interesting in that there is quite an absence in the picture of resin[1] in

[1] Although the term resin is used for the dark substance in tracheids of the xylem, a name generally applied to this body, yet in view of the chemical constituents present, and the absence of resin in the timber, it is very doubtful if it is correct to call it a resin.

any of the tracheids, this is an unusual occurrence, and it simply shows that it is possible to obtain a section without resin cavities. The line of smaller or closely packed cells marks the autumnal growth and the point of transition from that season's wood structure to that of spring.

Under a higher magnification ($\times 80$), as in Figs. 17 and 18, a rather more uniform size of cell obtains, for although the tracheids are of varying diameters, yet the walls may be said to be of a fairly uniform thickness; in Fig. 17 the black lines running from top to bottom are the parenchymatous cells of the medullary rays filled with resin—the "end-on view" of which is shown in Figs. 25 and 26. In 17 and 18 are more plainly seen the autumnal tracheids with their restricted growth, and which form a darker line across the lower portion of the plate; these vessels are slightly enlarged in Fig. 18. The gradual diminution in size of the tracheids during this period is well seen, as also is the sudden change to enlarged vessels of spring period.

In Fig. 18 there is a portion of a single circle of smaller tracheids, four or five cells distinct from the well defined autumnal ones, and which evidently indicates a cold snap. The resin cavities are plainly shown, but no resinous medullary rays are visible.

Fig. 19 is portion of Fig. 17 under a 210 magnification. The cells in the same row are of almost equal diameters, and on the lower radial walls of the fifth row from the top, bordered pits in section can just be seen, and the torus is also discernible. It will be noticed in several instances, portions of the inner cell walls are detached and protrude into the cell cavity. Whether this is natural or accidental in the cutting we could not decide. It hardly appears to be a case of tylosis.

Fig. 20 is an 80 magnification of a radial section of timber. The general character of the parenchyma cells of the

medullary rays are rather obliterated by the resin contents. However, the pictures define clearly that the outer cells of the rays are of identical structure to the inner ones and that the whole group may be classed as parenchymatous. This is a distinct difference of form or structure of the cells of medullary rays from some living non-Australian Pines. In the same figure it will be noticed that the narrow lumina of the autumnal wood are towards the right of the picture.

The numerous bordered pits are in single rows on the medullary walls of the tracheids, and are well brought out in both plates. The simple pits of the medullary rays are distinctly seen at the top right hand corner and the bottom of Fig. 20. The diameters of the bordered pits varies according to that of the tracheids, and the presence of resin in the tracheids is marked by the darkened content. Fig. 20 has only one resin cavity which is low down in the right hand corner, and Fig. 21 has three on the right hand centre of the field of observation, being the vertical views of the resin cells of Figs. 17 and 18.

Medullary Rays.—In addition to what has been stated under Fig. 20 it may be further remarked that these organs present novel features when compared with those of Angiosperms. In the radial and tangential sections they are found to consist entirely of narrow parenchymatous cells circular in form when viewed tangentially in the wood. Each ray is composed of a varying number of cells arranged in horizontal parallel strata only a single cell in breadth. Most of the outer and inner cells are filled with resin similar to the vertical cells, the radial walls being marked by the presence of simple pits, and cells void of resin are the exception. In Figs. 22 and 23 they are shown radially *in situ* in the wood substance, the varying length evidently due to the plane of cutting, the vertical diameter being almost equal in each case.

In the tangential sections, Figs. 25 and 26, a good end-on view is obtained of the medullary rays. They are the dark black coloured fusiform bodies embedded in the radial vertical walls of the tracheids, a single cell in breadth and ranging in number from two to twelve. The black colour is due to the presence of the resin cell content.

These two sections are of further interest in that they show distinctly a run of contiguous bordered pits in some of the radial walls—the greater magnification of Fig. 26 details fairly well the torus and closing membrane. Whilst resin cavities were found to be present in nearly all sections of timber cut as indicated by black patches or spots scattered throughout the xylem vessels, yet there was quite an absence of constancy in their positions, so that they were found to be of little value for systematic classification of the genus.

The Occurrence of Guaiol in the Timber.—The timber of this species was received from Narrandera, New South Wales. The odour given by the wood is quite pleasant, aromatic and characteristic. The log was cut into planks and these run through a planing machine, and the shavings thus obtained distilled with steam in the ordinary way. Distilling the shavings of this close, fairly hard wood, appeared to be the better method, as the sawdust balled considerably, and so the steam did not penetrate at all well. The weight of shavings taken was 79 lbs., and the amount of oily distillate was 9½ ounces, equal to 0·76%. The substance separated on the surface of the water in semi-solid masses, and as such was readily skimmed off. It was a camphor-like mass, and had a very marked odour of the "Cypress Pine" wood itself. It will be shown later that the odour of the wood is due to the liquid portion of the oil, because the solid crystalline substance, when obtained pure, was practically odourless.

The distillation was continued for eight hours, and even then the shavings had a strong odour of the wood. It is thus evident that more material could have been obtained by longer distillation. Another distillation of more lightly packed material was continued for nine hours, this gave 1·04%, and the product was even more solid than that from the first distillate. A third distillation, (8½ hours) gave 0·765%, while a fourth (8 hours duration) gave 0·725%, or a mean of 0·82% obtained during 8 or 9 hours.

The crude semi-solid oily product was squeezed through cloth, by which means the greater portion of the solid was retained. The cake of stearoptene was then placed between drying paper and subjected to pressure in a screwpress. A solid hard cake was thus obtained; this was dissolved in cold 90% alcohol, filtered, and allowed to crystallise. The crystals thus obtained were hexagonal prisms, terminated by obtuse rhombohedrons, and some were of a considerable size. They were of a glistening nature and brilliant in appearance. The material was repeatedly crystallised from alcohol. It was then dissolved in alcohol and water added to slight turbidity, crystallisation then rapidly took place, most of the material separating out in small crystals. This appeared to be a very good method whereby to purify the crystals, because they were thus obtained free from enclosures. They were finally re-crystallised from alcohol.

The facility of crystallisation of this substance may be illustrated by melting it either on water or on mercury and allowing it to cool slowly; as it cools, a minute trace of the solid is added, when crystalline threads shoot out in all directions, making a very fine exhibit. The melting point of the pure crystals was 91° C. On analysis the following results were obtained:—0·2273 gram gave 0·2385 gram H_2O, and 0·6756 gram CO_2; or 11·66% H and 81·07% C. A second analysis gave corresponding results. Theory for

$C_{15}H_{26}O$ requires H 11·71% and C 81·08%. A sesquiterpene alcohol was thus indicated.

The crystals were readily soluble in alcohol, even when somewhat dilute; also soluble in ether, in petroleum ether, in glacial acetic acid, in chloroform, in acetic ether and other organic solvents. The crystals were lævorotatory, and 0·5 gram, when dissolved in 10 cc. alcohol, had a rotation in a 1 dcm. tube of $-1·4°$, the specific rotatory power from this is $[\alpha]_D$ $-28°$. When boiled with acetic anhydride in the usual way a liquid acetate was obtained.

The crystals were heated with zinc chloride at 170 – 180° C., water was added when cold, and the solution steam distilled. A blue oil was thus obtained; this was at first a little green, but it became bright blue on standing some time. The blue colour faded slowly if the air had full access, but if the oil was covered with water it remained blue and unchanged for several weeks. When mixed with phosphoric anhydride and gently heated, the colour changed to bright red and purple. An odour resembling somewhat that of the wood was eventually given off.

We have obtained this crystallised alcohol from the wood of *C. intratropica* of Northern Australia, and also from the wood of the "Stringy Bark Pine," *C. Macleayana*. The wood of this latter species has little resemblance to the hard compact wood of the *Callitris* generally, although the chemical products are the same; and it may thus be assumed that this crystalline substance, together with its corresponding sesquiterpene, is common to all the *Callitris* of Australia. In the timber of *C. intratropica* the alcohol was so pronounced that it crystallised on the surface of the planed wood itself when freshly cut. It is probably also to the presence of these and other chemical products in the wood of the *Callitris* that this timber is so objectionable to the "White Ants," or *Termites*.

With concentrated sulphuric acid the crystals dissolved easily to a yellow colour which soon became orange, and on standing, to a pink colour on the edges. When dehydration was somewhat complete, a thick liquid separated. With strong nitric acid the crystals dissolved slowly to an oily mass, which after a short time became deep crimson, and purple to violet on the edges, the colour eventually fading away.

The above results show the crystallised portion of the oil of *Callitris* wood to be the sesquiterpene alcohol Guaiol, and a sample of this substance, kindly sent to us by Messrs. Schimmel and Co., gave identical reactions in every respect. Guaiol was originally isolated from the oil of Guaiac wood, or Guaiacum wood, which was first prepared by Schimmel and Co. and brought into commerce as a perfumery oil. It was distilled from the wood of *Bulnesia Sarmienti*, Lor., a tree belonging to the Zygophyllaceæ. It is known as "Palo balsamo" in Argentina, and is supplied under that name.[1] It is remarkable that this substance should be contained in the wood of trees so far removed as the *Callitris* (Coniferæ) of Australia, and the Zygophyllaceæ of South America.

Determination of the Oil.—The liquid portion of the distillate was removed from the guaiol by squeezing through linen. It was a somewhat thick, viscous and heavy oil, but no signs of further crystallisation were detected in it even on standing for months. It was dark coloured and had the characteristic odour of the "Cypress Pine" wood strongly marked. For commercial purposes, where this peculiar and somewhat agreeable odour is desired, this oil would be a useful article. In localities where the wood of these trees is in common use, the aroma in the houses built of it is considered by many to be quite pleasant, as is also

[1] Schimmel and Co's., Reports, April 1898, p. 28, and October, 1898, p. 29. Also Gildemeister and Hoffmann, "the Volatile Oils." p. 453.

that given by the wood when it is burned for domestic purposes. The specific gravity of this liquid portion at 16° C. was 0·9854. The rotation could not be determined as the light did not pass. It was soluble in an equal volume of 70% alcohol, but became turbid and milky with three or more volumes. It was easily soluble in 80% alcohol and became but slightly turbid with eight volumes.

The ester content was high, as the saponification number was 106·6. The acid number was also very high 68·8, but this was largely influenced by the presence of the phenol and other allied substances, as well as by the free acid. On distillation, the greater portion came over within a comparatively small range of temperature. Nothing distilled below 248° C. (cor.) except a little acid water; 60% distilled between 248 – 255° C. As the oil distilling at the latter temperature became a little blue the receiver was changed, and 21% of a bright blue oil was obtained distilling between 255 – 265° C. The third fraction, 10%, distilling between 266 – 296° C. was a deep indigo blue oil. The first fraction was again distilled when most of it came over between 250 – 252° C., this was but little coloured, was insoluble in 90% alcohol, had specific gravity 0·9266 at 15° C. and a refractive index at the same temperature 1·4926. Although evidently consisting largely of a sesquiterpene, yet this must necessarily have been far from pure. Further determinations will be made on the constituents of this very interesting oil from the timber of the Australian *Callitris.*

It was found that after determining the acid value, that the separated oil formed a crystalline mass after standing some hours. The crystals were found to be guaiol, and these had evidently been held in solution by the substances acted upon directly by the potash, or in combination with them. The oil separated from the saponification determinations and also crystallised readily on standing. No other crystalline body was determined besides guaiol.

The Phenol.—To isolate the constituents indicated in the determinations above, a larger quantity of the oil was saponified with alcoholic potash by boiling; water was afterwards added in quantity, and the separated oil allowed to crystallise. The crystalline cake was then removed and the solution slowly evaporated down to a small bulk to remove the alcohol. It was then filtered and rendered acid by sulphuric acid, when a dark coloured oil, which was acid to litmus, separated in some quantity. This was well washed and treated with an aqueous solution of carbonate of soda, when a portion, of an acid nature, went into solution, carbon dioxide being evolved. The solution was then thoroughly extracted by ether, and the ether evaporated. The oil thus obtained was but little coloured, was thick and somewhat viscous, and evidently from the mode of extraction and marked colour reactions was a phenol. When placed on ice it did not crystallise although it thickened considerably. It had most markedly the odour so characteristic of the timber. Undoubtedly this phenol is the principal constituent to which this odour of the wood of the *Callitris* is due. In alcoholic solution ferric chloride gave practically no reaction. When the phenol was dissolved in alcohol and bromine added, no colour was produced, but when the alcohol had evaporated the phenol changed to a deep purple colour, this colour was again destroyed by addition of alcohol. When dissolved in acetic acid and bromine added, the colour changed to red at once, quickly becoming a rich purple. On standing some time it eventually became indigo blue in colour. On boiling, the colour was not changed. This colour reaction is probably due to the hydrobromic acid given off in the formation of the bromide, because both hydrobromic and hydrochloric acids gave the same reaction, although slower. The colour was destroyed on the addition of water, a turbid solution being formed by the precipitation of the bromide. When

the phenol was dissolved in strong aqueous alkalis, and this acidified with hydrochloric acid, a red colour was also produced. When dissolved in acetic acid and few drops of sulphuric acid added, the solution changed immediately to red, soon becoming deeper in colour. Eventually the colour became a rich deep purple which was permanent for some days. If a drop of nitric acid was added with the sulphuric acid the changes through red to plum colour were more rapid, but eventually the same result was obtained. To a portion of the original phenol on a watch glass one drop of sulphuric acid was added, a red colour was produced, eventually becoming purple on the edges as with the acetic acid solution. When a little of the phenol was dissolved in acetic acid on a watch glass, and the vapour of bromine passed over it, a purplish colour instantly formed, soon becoming a rich purple. These marked colour reactions point to the origin of the indigo blue oil obtained on redistilling the crude product.

When the original thick crude oil was agitated with a 10% solution of aqueous soda, a semi-solid mass was at once produced. After a time some water was added, and the mixture agitated, the bulk of the oil still remained as a pasty mass, this was filtered off and washed. It was readily soluble in ether, and on evaporating the ether a thick oil remained which crystallised, and from which guaiol was obtained. The alkaline filtrate was treated with a large quantity of water when it was partly decomposed, an oil separating. After standing some time in an open vessel with repeated agitation, the aqueous liquid was thoroughly extracted with ether. On evaporating the ether the phenol was obtained. This gave all the reactions, and had the characteristic odour of the phenol as obtained previously after saponification. It would thus be necessary to extract the phenol with a strong alkaline solution, as the combination is a weak one, and is apparently decomposed

by carbonic acid. The phenol is readily soluble in acetic acid, in ether, alcohol, chloroform and similar organic solvents. From the results so far obtained this phenol appears to be new; if on further investigation this is found to be the case, then the name *Callitrol* is proposed for it.

The somewhat dark coloured alkaline solution, after removal of the phenol, was acidified, when a dark coloured oil separated. This was of an acid nature, was less viscid than the phenol, did not distil with steam, and did not crystallise. It will eventually be further investigated.

The volatile acids of the esters of the wood oil were only present in very small amount. On distilling these over, the odour of butyric acid was most marked. Acetic acid was also determined to be present. The barium salt was prepared in the usual way, and 0·1356 gram. of this gave 0·1116 gram. $Ba\,SO_4$, = 82·3%. From this determination there was in the salt 46·17% barium acetate, and 53·83% barium butyrate. The free acids obtained, however, were not sufficient to meet the requirements of the alcohol of the ester, judged from the saponification number.

Bark.—The most characteristic feature of the bark is the very large number and size of resin cells distributed throughout the entire bark, both cortex and bast. Macroscopically they appear, in a freshly transverse cut of the mass, as so many concentric rings, being more pronounced in the darker outer bark or cortex, where after the oil of the cell has been volatilised or removed, resin or sandarac as it is called, remains as a white solid, filling the cells and giving the effect of tangential parallel bands or rather rows. In the bast or inner bark the cell content is in a liquid condition, and on a cut being made into fresh specimens there flows at once a liquid, which however indurates into beads or tears as soon as the volatile portion has evaporated or volatilised.

Figs. 27 and 28—longitudinal sections, show these bodies to be cells rather than resin ducts or channels, and this is further proved by the small flow of liquid from a cut in the bark, which is quite a reverse order of things to that found occurring in the American Conifer bark and wood which yield the naval stores of that country, and give a continuous flow for a whole season when cut, thus proving that they are in that case canals that have been tapped. Microscopically these cells are found to be not quite so regularly arranged as appears macroscopically, but nevertheless their numerical strength is even then well emphasised as shown in the transverse sections in Figs. 29 and 30. The anatomical structure is interesting in that the variety of vessels is limited. The cambium is succeeded by tangential rings of three distinct characters.

The most noticeable tangential row is that composed of cells of bast fibre with their much thickened walls. These cells are generally only separated from each other by one or two layers of thin walled cells, mostly one—a circumstance that must be unusual as it does nor appear to have been observed before in others Conifers—the general rule being three or four intervening rows. At irregular intervals are tangential bands of collapsed cells, at least that is what they appear as far as our researches go, but they require further investigation. Irregularly scattered throughout the mass are tannin cells determined by a ferric chloride test. Altogether there is a regularity of successive layers of the different cells similar to that which appears to characterise the Conifers of the northern hemisphere. The medullary rays are not very pronounced as in the xylem, and these also require deeper investigation.

The Resins.—The oleo-resin of the *Callitris* is contained in the inner cells of the bark. When injured in some way this exudes, and when dry forms tears on the exterior of the

tree. It is then known vernacularly as "Pine Resin," and in appearance closely resembles the original sandarac resin of commerce. So far as we are aware, it has not yet been possible to devise a method for successfully injuring *Callitris* trees, so that the resin might be collected in masses, and thus obtained in quantity, as is the case with turpentine for instance. For the present, therefore, Australian sandarac will have to be gathered by hand, a somewhat laborious process.

Besides the numerous investigations into the composition of sandarac, recorded in the various scientific journals, Dr. Henry of London, published in 1901, an exhaustive research on the constituents of the sandarac resins generally, and isolated and determined their acid resins.[1] This paper contains (p. 1145) the following:—"There also appears on the market from time to time a similar resin, which, since it is exported from Australia, is commonly known as "White Pine Resin" or "Australian Sandarac". This substance is the natural exudation product of *Callitris verrucosa* and differs from the common sandarac chiefly in the larger size of the tears and its smaller solubility in alcohol." This statement may be taken as representing the generally accepted idea in Europe regarding Australian sandarac. It is not, however, quite correct as regards its origin, because Australian sandarac is not collected from *C. verrucosa* to any great extent, nor could it be obtained in commercial quantities from that species. The sandarac exported from Australia is collected from various species of *Callitris*, and for this reason it will be found to be variable in its characters, until care be taken to collect the resin from individual species. The constituents occurring in the oils of the several species of *Callitris* are very variable, although practically constant for each species, and

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[1] Journ. Chem. Soc., September, 1901, p. 1144.

the resins obtained from these trees also vary in agreement. Although in general appearance these "Pine Tree Resins" all appear to be similar, yet they vary in chemical behaviour.

The two main species occurring in New South Wales are *C. glauca* and *C. calcarata*, and it is these species which produce the greater portion of the sandarac sent from this State. The resin of the latter species is perhaps better for varnish making than that of the former, and more closely approaches common sandarac in chemical constitution. The resins of *C. calcarata* and *C. Macleayana* are practically soluble in alcohol, and contain no resin which is precipitated on dilution with alcohol. In the resins of *C. glauca* and of *C. verrucosa*, there is a considerable amount of resin insoluble in a large quantity of alcohol, and consequently the resins of these species are less soluble than ordinary sandarac. This difference in solubility in alcohol is evidently due to the varying amount of the two main resins—pimaric and callitrolic acids—and these again are governed by the constitution of the oil constituents of the plant. The difference in the amount of an acid resin, the potassium salt of which is insoluble in potash, also varies in the resins of the several species.

We have obtained the resins of most of the species of *Callitris*, and with some of them from numerous localities, We hope that the completed results obtained with these will allow some order to be evolved, and a classification made of the resinous products of the *Callitris* of Australia.

Summary of Results.—

1. The genus *Callitris* may now be regarded as endemic to Australia, the North African species, in recent years included under that name being classed as a distinct genus —*Tetraclinis.* Both are also distinct from the South African genus *Widdringtonia.*

2. The "White Pine" of New South Wales is *Callitris glauca*, R.Br., the old name *C. robusta*, R.Br. being retained for the West Australian species, with its large fruits, and other specific differences. The former has been found to retain a comparative constancy of botanical and chemical characters throughout its geographical range. The sections of the leaves show features distinctive from those of other Pines.

3. The microscopic structure of the timber of *C. glauca* is very interesting, and appears to demonstrate a geological connection with its progenitors.

4. The essential oil from the leaves of this species of *Callitris* is practically always the same, no matter where grown. The oil from *C. glauca* is comparable with the best "Pine Needle Oils" of commerce.

5. The rotation of the terpenes of the oil from the leaves of most species of *Callitris*, is in the opposite direction to that obtained from the fruits, even if collected from the same tree.

6. The oil obtained by steam distillation from the timber of this *Callitris*, contains the sesquiterpene alcohol guaiol in some quantity, the sesquiterpene is also present. The characteristic odour of *Callitris* timber is due to a phenol. This has distinctive colour reactions and is evidently new. The name *Callitrol* is proposed for it.

Explanation of Plates.

Fig. 1.—Transverse section, showing the earliest stage of concrescence in the leaf, and where the three divisions are beginning to individualise. × 80.

Figs. 2, 3.—These show the concrescent portions more distinctly, also the fuller development of the ventral surfaces, and the cuticle protuberances on them. The hypodermic cells are distinguishable in the lower part of Fig. 3. The leaf structure explained in the

text is well reproduced. The division of the median structure into three bundles by obtruding medullary pith cells, and the orientation of the phloem (indicated by the darker cells) are well brought out. × 80.

Fig. 4.—This section is interesting in that one or two elongated cuticle processes are seen on the lower of the assimilating surface. No oil glands occur in this or previous sections, where also the endodermic and transfusion cells are not arranged in any order. The ventral surfaces on the two left concrescences have edged together and so shut out any communication between the air and the stomata. × 80.

Fig. 5.—Oil cells together with the dark secretory cells of the walls in the lower and right hand concrescence are seen. The endodermic cells are here assuming some kind of order, and in Fig. 6 are clustered around the resin cells and at the base of the ventral surfaces. The bundle of each leaf is clearly seen below each oil gland. × 80.

Fig. 7—The ventral surfaces are here shown well exposed to the atmosphere, and three well formed resin cells form distinct objects in each concrescence. The various vessels of the leaf structure are clearly brought out. × 80.

Fig. 8.—An unusual form of concrescent leaf. × 80.

Fig. 9.—This is to show the unusual occurrence of two resin cells in a concrescence. × 80.

Fig. 10—Shows ventral surfaces of two concrescences exposed to the atmosphere. × 160.

Fig. 11.—The method of protecting the ventral surfaces from the atmosphere by the closing over of the edges of the dorsal surfaces is seen at top of the picture. The origin of the cuticle elongations are clearly seen in this picture. × 160.

Fig. 12.—The leaf structure is well defined, especially at the locality of the oil cell. × 160.

Fig. 13.—A much finer illustration of the remarks under Fig. 11. The cuticle prolongations are well marked. × 160.

Fig. 14.—Longitudinal section through a node showing an oil cell *in situ* in the concrescence and part of the free portion. × 55.

Fig. 15.—Longitudinal section through node showing position of stomata on the ventral surface. × 75.

Fig. 16.—Transverse section of timber showing two annual rings. × 50.

Figs. 17 and 18.—Transverse section of timber showing arrested growth of autumnal tracheids and resin scattered throughout the summer and spring tracheids. The dark lines are the resin (*sic*) in the vessels of the medullary rays. × 80.

Fig. 19.—Transverse section of spring tracheids showing pitted cells (in section) on radial walls. × 210.

Figs. 20 to 23.—Radial section of timber showing medullary rays with both inner and outer vessels filled with resin, and their single cells. Pitted cells are distinctly shown as well as resin in the tracheids. × 80.

Fig. 24.—Pitted cells *in situ* on radial walls. × 160.

Fig. 25 and 26.—Tangential section giving end-on view of medullary rays, which shows their fusiform outline and the resin content of inner and outer cells. Pitted cells of the radial walls are seen to be numerous, their varying shapes being close to the angle of section. An occasional pitted cell will be seen to occur on the tangential walls. (25) × 80, (26) × 160.

Figs. 27 and 28.—Longitudinal sections of bark to show that the resin vessels are not canals. × 43.

Fig. 29.—Portion of inner and outer transverse section of bark, the large oval spaces are the oleo resin cavities. × 80.

Fig. 30.—Transverse section of a portion of outer bark. The dark patches are tannin sacs. × 80.

We wish to express our thanks to Professor E. C. Jeffrey, Harvard University, for some of the sections of timber and bark, and to Mr. F. H. Taylor, of this Museum, for the remainder of the sections.

CONTRIBUTIONS TO THE FLORA OF AUSTRALIA.[1]

By ALFRED J. EWART, D. Sc., Ph. D., F.L.S., Government Botanist of Victoria and Professor of Botany at the Melbourne University, and JEAN WHITE, M. Sc., Government Research Scholar, assisted by J. R. TOVEY, First Herbarium Assistant, National Herbarium Melbourne. (Communicated by J. H. MAIDEN.)

[With Plates XXX.–XXXVI.]

[*Read before the Royal Society of N. S. Wales, August 5, 1908.*]

Aristida ramosa, R.Br., (Gramineæ). New for Victoria; Benalla, July 1906, and March 1908.

Baeckea Maideni, Ewart and White, (Myrtaceæ). After Mr. J. H. Maiden, Government Botanist of N.S.W. M. Koch, No. 1021. Cowcowing, W.A., 1904.

Shrub 1½ to 3 feet high. Leaves opposite, crowded towards the ends of the stems. Broad-linear, with a small petiole, the surface of the lamina, especially on the under side, well provided with glands. Somewhat thick, blunt at the tip, slightly incurved at the margin. Length 2 mm., diameter ·5 mm. Flowers solitary or in pairs. Sepals 5, petaloid with sinuous edges, perigynous, persistent, free. Length ·9 mm., diameter 1 mm. Calyx tube green and rugose, more prominently ribbed than in *B. crassifolia*, which it appears to resemble in certain other respects. Bracts 2, conspicuous, persistent, pointed, length about 1 mm. Petals 5, white, sinuous edges, almost globular, free, very shortly stalked, perigynous. Length 1·5 mm., diameter 1·5 mm. Stamens 10, one opposite the centre of each petal, and also one opposite the centre of

[1] Ninth Contribution, No. 8 in *Vict. Nat.*, Vol. xxiv, p. 190, 1908.

each sepal. Filaments slightly flattened. In the dried specimens all bend towards the centre of the flower. Length of filaments about ·5 mm., epipetalous; those which arise from the centre of the petals are surrounded at their bases by about four pointed hair-like appendages, which are not present at the insertion of those filaments which spring from the centre of the sepals. The connective gland is prominent. The anthers are large and four celled, ·4 mm. in length. Pollen grains triangular. The inferior ovary is prominently convex, and is very glandular. It is composed of three syncarpous carpels, in each of which are two collateral ovules with axile placentation. Style fairly long, and the lower end sunk in a depression in the ovary. Stigma capitate.

The plant belongs to the section Euryomyrtus. The leaves and short pedicels distinguish it from *B. diffusa*, and the ovary from *B. tetragona*. Its nearest affinities are to *B. crassifolia*, but it differs in the pedicels, persistent bracts, stamens and convexity of ovary. [See *Plate 30.*]

Bertya oleaefolia, Planch. (1845). Syn. *B. Mitchelli*, (1865). (Euphorbiaceæ).

Both species are retained in the "Census" but in Mueller's "Native Plants of Victoria," and "Key," *B. oleaefolia* is given as Victorian with the localities of *B. Mitchelli.* The two species do not appear to differ in any constant feature of specific rank and can hardly be recognized as varieties, the breadth of the leaves and the somewhat tapering or blunt topped ovary being variable characters. In the "Plants Indigenous to Victoria," and in the *Fragm.* iv, p. 35, Mueller proposed to join together *B. gummifera*, *B. rosmarinifolia*, *B. Mitchelli*, and *B. oleaefolia*, under the first name, but such fusion does not at present appear justifiable. Victorian specimens have been variously labelled *B. Mitchelli* (Herb. F. Reader) and B. *oleaefolia* (Herb. C. Walter).

Danthonia airoides, Nees. (Gramineæ), Soak Creek, W.A. F. A. Rodway, Sept. 1907. Identified by Prof. Hackel.

This species was only known previously from South Africa, and if really native to West Australia, it presents a unique case of distribution, although several South African genera are represented in Australia by allied species. Mr. Rodway points out that the district contains no aliens, and that the fact of the plant not occurring in more settled districts indicates an introduction in prehistoric times. Prof. Hackel comes to the same conclusion.

Diplachne loliiformis, F.v.M. (Gramineæ). Malcolm, W.A. F. A. Rodway, No. 158, April 1907. Determined by Hackel; new for Western Australia.

Eleaocarpus reticulata, Sm. var. *Kirtoni*, F.v.M. (Tiliaceæ). Distinguished by longer leaves, more serrated edges, etc. This variety, at first considered to be a species, was recognised by Mueller in 1885. The '*E. longifolia*' of C. Moore (Flora of N.S.W., 1893) appears to be practically identical with it, and in any case as the Kew Index already gives two valid species of *E. longifolius* (Blume, Wall.) a third one is inadmissible. Maiden and Betche raise this variety to specific rank as *E. Baeuerlenii*, Maiden and Baker (Proc. Linn. Soc. N. S. Wales, 1908, 33, p. 305), but this appears to be one of those doubtful cases in which so much depends upon individual judgment, and in such cases the reasons for retaining the first name given, whether as variety or species are especially weighty.

Eremophila Kochi, Ewart, *n. sp.* After the collector. (Myoporineæ).

A shrub one to two metres high, the younger branches white with a short scurfy tomentum, the older branches greyish and emitting a pleasant fragrance when broken. Leaves rather closely set, alternate, ovate or lanceolate,

mostly obtusely pointed, wrinkled and rather coriaceous, possibly somewhat fleshy when fresh, glabrous except on the very short petiole. Flowers $1\frac{1}{2}$ cm. long, single in the axils of the leaves. Calyx of five free segments, rather long pointed, corolla blue, spotted inside, slightly bilabiate, the anterior segment blunter than the others, all pointed. When young the corolla is white outside with a fine stellate tomentum, which cracks or spreads as the corolla expands, a few sparse long hairs are present on the throat and anthers, but a ring of numerous hairs occurs near the base. Stamens four, didynamous with spreading anthers on the curved ends of the filaments, but not expanding beyond the corolla. Style long and curved, persisting after the fall of the corolla, and the shedding of the pollen (the flower is protandrous). Ripe fruit not seen, but ovary bilocular. Cowcowing, W.A. Max Koch (No. 1204) (1904).

Specimens of the above plant have been compared, by Mr. Spencer le Moore, with the Eremophilas at Kew and at the British Museum, which include the lately described species of Diels and Pritzel. The plant appears to be best placed prior to *E. santalina* in the Section Pholidia, although linear placing is largely artificial, and this plant as well as others show the difficulty of keeping the sections *Pholidia* and *Eremophila* apart as separate genera (Index Kewensis and Benth. Fl. Aust.). Baillon's change of the name *Eremophila*, R.Br., adopted by Mueller for the whole series, to *Pholidia*, R. Br., on the ground of a paging priority, is a frivolous interference with established nomenclature.

Eremophila Woollsiana, F.v.M. var *dentata*, new variety, (Myoporaceæ).

This differs from the type in the leaves being smaller and having somewhat irregularly dentate margins, sparsely covered with minute hairs, and in the fruit being as long

as or longer than the calyx. In other respects it agrees closely with the type, and an older and less divergent specimen was queried by Mueller as *E. Woollsiana* var. Dr. Diels informs me that he found the same form as the above at Tammin in W.A., and also considered it to be a small form of *E. Woollsiana*. M. Koch, 1904, Cowcowing Lakes, W.A., No. 1259; Youndegin, York East W.A. 1893, Alice Eaton.

Gastrolobium Forrestii, Ewart, *n.sp.*(Leguminosæ). After the collector.

A shrub with nearly glabrous quadrangular stems becoming rounded when older. The leaves in whorls of four usually, but at the base of each branch a single pair only, and sometimes the same also on the tapering extremities of the branches. Short linear pointed stipules, the petioles 2 to 3 cm. long. Leaves with a prominent midrib on the under surface, obviously reticulate and darker on the upper, ovate-oblong, with a blunt or slightly bilobed apex, and usually a small terminal point, mostly 2 to 4 cms. long and 5 to 8 times as long as broad, broadest at the middle and glabrous or sparsely hairy beneath. Flowers in long rather loose slender racemes, often 2 to 3 inches long, the rhachis nearly glabrous, but the 2 mm. pedicels and the somewhat shorter calyx tubes covered with short hairs. The two posterior sepals united to form a bilobed tongue about as long as the tube, the three anterior sepals rather shorter and pointed. Pod ovoid, sharply pointed, 7 mm. by 4, flattened except for the bulging seeds, brownish-black, sparsely hairy, prominently veined, on a slender stalk 2 mm. long, each with one or two smooth black somewhat kidney shaped seeds. Blackwood River, W.A., Sir John Forrest; W. Aust. 1889; Gordon River in forest land, 1877.

This is one of the poison bushes, intermediate between *G. velutinum* and *G. bilobum*, distinguished from the latter

by the posterior calyx teeth and the inflorescence, and from the former by the leaves, pod, stipes etc. The specimens could not be matched either at the National Herbarium or at Kew; although no flowers were available it seemed advisable to describe the species, as no fresh material has been procurable since 1889.

Helipterum album, Ewart, *n.sp.* (Compositæ). Woorooloo, W.A. M. Koch, No. 1553 (1906).

An erect annual 10 – 40 cms. high, branching from the base upwards and ending in very numerous corymbose clusters of small elongated brownish-yellow heads, tipped with white. Stems slender, usually red or brown-violet, and covered together with the leaves, with a fine soft wool of long curling but somewhat sparse hairs. Leaves linear pointed mostly 2 to 3 cms. long, flat, but curling more or less regularly on drying. Heads about $\frac{1}{2}$ cm. long by 1 to $1\frac{1}{2}$ cm. broad, usually in clusters of 3 to 6 or more. The bracts nearly yellowish-brown, glabrous or a few sparse woolly hairs at the edges, long and narrow, the outer scales with obtuse ends, the inner with small white nearly erect laminas. Florets about 10, all tubular and hermaphrodite, ovary silky, hairy when adult, pappus of more than 10 fine plumose bristles. The size of the plant is sufficient to distinguish it from *H. pygmaeum*, and it differs from any of the recently described Helipterums of Spencer le Moore and of Hemsley. From *H. corymbiflorum* var. *microglossa* it is distinguished by the smaller, narrower, more crowded and numerous heads, the erect white laminas etc. The same features distinguish it from *H. polyphyllum*, and in addition the achenes are less hairy and the outer bracts are nearly or completely glabrous. It is perhaps more closely allied to *H. corymbosum*, Benth., but the bracts are pale and yellowish instead of reddish-brown, the florets are fewer, the pappus hairs are more numerous and finely

plumose, the white tips to the inner laminæ are prominent and the heads narrower and cylindrical.

Helipterum Guilfoylei, Ewart (Compositæ). Additional localities—Near Mount Moore, W.A., Edwin Merral, 1889; near Fraser's Range, W.A., J. Batt, 1896.

These were amongst some specimens recovered from the late Baron Mueller's executors, after eleven years (November 1907). The former specimen was provisionally labelled *Helipterum exiguum* by Mueller, but both specimens differ from that species in the number of florets, in the achenes, pappus, and in the fact that some of the bracts have laminæ and are differently coloured.

Helipterum heteranthum, Turcz., var. *minor*, new variety (Compositæ). Cowcowing, W.A., Max Koch, No. 1108 (1904).

Plant usually 4 – 6 inches high with smaller heads, and the laminæ and edges of the bracts purplish-red at least when fresh.

Isotropis atropurpurea, F.v.M. var. *alba*, Ewart, *n. var.* (Leguminosæ). Near Lake Austin, W.A., King and Lefroy 1890.

It is less prominently rusty tomentose than the type specimens, the leaves are narrower and rather longer, the sepals are also slightly longer, and the standard though striate is pale or white.

The specimens could not be matched at the National Herbarium nor at Kew, but the differences are not sufficient to justify the establishment of a new species. Probably the species would show considerable variation in the colour of the flower if cultivated.

Kochia Atkinsiana, W.V.F. (Salsolaceæ). *Journ. W. A. Nat. Hist. Soc.*, 1904, p. 31.

A low intricately branched perennial undershrub about 1 to $1\frac{1}{2}$ feet high. The younger parts covered with whitish hairs becoming sparsely scattered or absent when older. Leaves thick fleshy, obtuse, narrowed at the base, rarely exceeding a centimetre in length, drying tuberculate with rather large scattered hairs. Flowers closely sessile in the axils of the upper leaves. Fruiting perianth enlarging to a continuous brown glabrous horizontal wing 15 – 18 millimetres diameter. Of the 5 central slightly raised lobes of the perianth tube, the two lateral ones bear each a pair of erect more or less toothed appendages, blunt or somewhat tapering. Of the remaining 3 lobes one of the anterior pair bears a single similar appendage, the posterior lobe and the other anterior one have none, so that the five appendages are really asymmetric.

This plant was first described and the name issued in MS. A specimen submitted to Mr. Fitzgerald was however marked by him as *K. Atkinsiana.* "Differs from type in somewhat larger leaves, and in the appendages being free and not 4 connate in pairs and free." This cryptic statement is somewhat incomprehensible, but the plant tallies closely with Fitzgerald's original description and is evidently the same; the red colour of the perianth probably fading in dried specimens. To avoid possible error a full and complete description is given.

In the erect appendages the plant shows a relationship to *K. lanosa*, from which in all other points it differs widely. In the horizontal wing it resembles *K. villosa*, Lindl., of which species it at first seemed to be a variety. Though nearly circular the margin is always a little irregular and sometimes distinctly lobed, so that the plant forms an interesting connecting link between the first section of *Kochia* with vertical sinus appendages and with free horizontal wing lobes, and between the *villosa* section without

vertical wings but with a complete circular horizontal one. Watheroo, near salt lake W. A., 1905, Max Koch, No. 1371; Nannine and Gwalia, 1903, W. V. Fitzgerald.

Podocoma nana, Ewart and White, *n. sp.* (Compositæ).

A small somewhat shrubby herb, the average height of the specimens measured being 5 centimetres. The stems are stiff and narrow and rather sparsely covered with short stiff hairs. The majority of the branches rise from the base of the plant. The leaves are glandular alternate and pinnatipartite, length without the petiole about 1 cm., the basal ones provided with a fairly long petiole, those springing from higher up on the stem are almost sessile. The peduncle usually bears a small single falcate bract some distance below the head. The receptacle is only slightly convex; the involucre is almost hemispherical, the bracts being situated in 3 to 4 rows. Those of the outer row measure about ·4 cm., and are densely covered with rough brown glands like those of the peduncle. The inner bracts measure about ·7 cm., and are membranous, glabrous, and lanceolar. The inner bracts project out about as far as the bristles of the pappus, and are slightly coloured at the tips. There were no young flowers in the specimens examined. The achenes are slightly bean-shaped and glabrous, being about 1·5 mm. in length, and ·5 mm. in breadth. The base of the achene is blunt. The beak of the achene is hair-like, 2·5 mm. long, and slightly swollen where the bristles of the pappus arise. There are usually 15 bristles in each pappus, each bristle being 3 mm. long and white, with pointed teeth.

Mount Lyndhurst, S.A., Max Koch, 1899, Nos. 347 and 348; Torrens Plain, R. Tate, 1893. The latter specimen is marked by Tate as either a variety of *P. cuneifolia*, or a new species.

Pterostylis reflexa, R. Br., (Orchidaceæ).

In *Proc. Roy. Soc. Vict.*, xx, 1907, p. 84, it was shown that *P. praecox*, Lindl., must be reduced to a variety of the above species, and that many of the connecting forms could be grouped into a special variety (var. *intermedia).* Another connecting link is afforded by the *P. constricta* of O. H. Sargent (*Journ. W. A. Nat. Hist. Soc.* No. IV) with its numerous related forms. We have no proof of the hybrid origin of the very numerous intermediate forms, and hence it is at present only possible to make *Pterostylis reflexa*, R.Br., include as well as the type form and the variety *intermedia*, var. *praecox* (*P. praecox*, Lindl.) var. *constricta*, Sargent (*P. constricta*, Sargent) and all the forms joining these varieties together. Additional unrecorded locality for *P. reflexa*, var. *constricta*, Cowcowing, W.A. M. Koch, No. 1073 (1904).

Ptilotus (*Trichinium) Kennediœ*, F.v.M., inedit. (Amarantaceæ) = *Ptilotus calostachyus*, var. *Kennediœ*, F.v.M.

The sole specimen is a scrap only. On reference to Kew, Mr. Farmar considered it to be an undescribed species. It has apparently no intrastaminal scales, but this character appears to vary somewhat in *P. calostachyus* and the trifling difference in the bracts is hardly sufficient to establish a new species, at least until fuller material is available. Tandarlo viâ Wilcannia, Darling River, N.S.W. 1886, Mrs. W. B. Kennedy.

Rhagodia crassifolia, R. Br. and *R. spinescens*, R. Br. (Salsolaceæ).

In their extreme forms these are distinguished by the former having no spines, and rather long narrow leaves, while the latter has shorter and broader more or less deltoid or orbicular leaves and is commonly spiny. The fleshiness of the leaves is not a reliable character, many specimens of *R. spinescens* having leaves quite as thick and fleshy as any of *R. crassifolia*. In addition many specimens with

the elongated leaves of *R. crassifolia* are spiny, and with some of the spiny specimens it is a matter of choice as to whether they are placed in one species or the other. There can be no doubt that in this case two species have been recognised as distinct before the intermediate forms between them have become extinct, and that *R. spinescens* must be classed as a variety of *R. crassifolia.*

Salicornia Donaldsoni, Ewart and White, *n.sp.* (Salsolaceæ). After F. M. Donaldson.

Shrub much branched with greyish coloured woody stems, dotted at intervals with dark structures which may be glandular. The segments of the stem are conspicuous and concave above, with a prominent border and opposite free projections arranged in a decussate manner; the length of each free projection is about 1 mm. The fertile segments are shorter than the others, the length of the former being about 3 mm. and of the latter about 8 mm. In most of the flowering spikes examined there were two whorls of flowers open at the same time, but occasionally there were three or even four. The flowers of the successive whorls are alternately superimposed. On the concave, upper surface on each side of each fertile spike, there are two flowers almost wholly immersed in the concavity of the segment, though as a rule the upper parts of the anthers and styles are exserted. Each flower is surrounded by a membranous perianth which is attached below to the inside wall of the expanded part of the segment, and is divided above into generally about six short pointed processes. Flowers hermaphrodite. Inside the perianth of each flower are three stamens, the filaments of which measure from ·5 to 1 mm. in length and are free from each other. The anthers are conspicuous and two lobed, dehiscing loculicidally, and measure 1·5 to 2 mm. in length. The three brownish, flattened styles are 3 mm., and have both surfaces

papillose and stigmatic. The ovary is single and contains a single anatropous ovule. Cowcowing, W.A, 1904, M. Koch, No. 1147.

Salicornia Lylei, Ewart and White, *n. sp.* (Salsolaceæ). After Professor Lyle.

An undershrub from 1½ to 2½ feet high, very much branched, the branches being woody and greyish in colour. The smaller branches are conspicuously longitudinally ribbed. The segments are dilated and concave at the top, with opposite projections arranged in a decussate manner. The average length of each segment is about 3 mm. and of each free projection about ·8 mm. The length of the fertile segments is about 2 mm. On each flowering spike there are from 8 to 12 fertile segments, each bearing a whorl of 6 flowers, with projecting styles and anthers. Each flower consists of a single stamen and carpel, the filament and ovary being surrounded by the somewhat fleshy perianth, which has a prominent marginal ridge, and a narrow opening at the top continued along the ventral side of the flower, through which, at the top, the stamen and style project. The anther is relatively large, two-lobed and nearly spherical, about ·5 mm. in diameter, and dehisces loculicidally; the filaments are 1 mm. in length. The style has papillose, brown, stigmatic surfaces; as a rule there are two branches, but occasionally three. The ovary is relatively large and hollow, and contains a single anatropous ovule, whose funicle is attached to the axis of the spike. Six fruits are developed in each whorl and they are surrounded by the persistent, fleshy perianth; the styles also are persistent. The ovary is swollen and contains one seed attached to a long stalk. The fruits of successive whorls are alternately arranged. Cowcowing, near Salt Lakes, W.A., 1904; M. Koch, No. 1051.

Senecio Gilberti, Turcz. (Compositæ). Darling Ranges, W.A. M. Koch, 1907, No. 1692.

Very rare; the herbarium contained only one imperfect specimen (Drummond, 325, Swan River). The heads, as pointed out by Bentham, resemble those of *Erechtites arguta*, DC., but have no ligulate female ray florets, all being tubular.

Tetratheca hirsuta, Lindl., (Tremandreæ). Darling Range, W.A. M. Koch, 1906, Nos. 1410, 1410*a*.

The specimens shew all degrees of transition from alternate to verticillate leaves, and in other respects also bear out Mueller's reduction of *T. viminea*, Lindl. (and also of *T. pubescens*, Turcz.) to varieties of *T. hirsuta*. A white flowered form (Woorooloo, W.A., M. Koch, 1907, No. 1711) belongs to the same species, although it differs from Oldfield's white flowered variety in the leaves and in being less hairy (variety *alba*).

Tillaea exserta, F. M. Reader, (Crassulaceæ).

This species though close to *T. Sieberiana*, Schultz, can be distinguished by the larger carpels when in fruit. The accompanying figure was prepared by Eckert under Mr. Reader's direction at Baron von Mueller's request, in order that he (Mueller) could describe the plant, which Mr. Reader did after the Baron's death, but the figure not being available was unpublished. Additional localieties are, Near waterholes, Polkemmet, Victoria, 1898, F. Reader; Oakgrove, Little Desert, 1897.

Tillaea acuminata, F. M. Reader, *Vict. Nat.*, 1878, Vol. xv, p. 96 = *T. Sieberiana*, Schultz, (*T. verticillaris*, DC.) var. *acuminata*.

On Mr. Reader's original specimen the label is also changed so as to reduce the species to a variety of *T.*

verticillaris, which is a synonym of *T. Sieberiana*, but apparently the correction is hitherto unpublished.

Zygophyllum ovatum, Ewart and White, *n. sp.* (Zygophylleæ).

Herbaceous with branching stems, and height of about 11 cms. Petiole flattened, and two apical leaflets which are cuneate, with usually an indented mucronate tip. Length of leaflets about 10 mm. and of the petiole about 5 mm. Flowers four-merous, hypogynous, very small and inconspicuous. Calyx green, sepals glabrous inside, lanceolar, pointed, and 2 mm. long, roughened on the outer surface, free. Petals four, white, stalked, about half the length of the sepals, free, entire. Stamens eight, free, inferior, about as long as the petals, with broad winged bases. Anthers two celled, versatile. Carpels four, angular, with a very short appendage at the tip of each. Fruit, a capsule with four chambers, dehiscing loculicidally with two seeds in each chamber. The fruit is four angled and rounded at the top, being somewhat wider at the top than at the base. Ovate or obovate in shape with a blistered surface and divergent veins. Calyx persistent, reflexed. Watheroo rabbit fence, W.A.; M. Koch, 1905, No. 1674.

From *Z. iodocarpum* it differs in the small, four-merous flowers, and in the presence of two seeds in each cell. It is nearest *Z. ammophilum*, but the fruits have rounded instead of truncate tops, and the stamens are winged at the base as in *Z. iodocarpum*.

Introduced Plants.

Datura metel, L., (Solanaceæ). Loddon River, Victoria, A. Simon, 1896. Probably only a garden escape.

Galenia secunda, Sond., (Ficoideæ).

This South African weed introduced with ballast is now well established on the shores of Port Phillip Bay from

Geelong to Williamstown (T. Heathcote 1907), A specimen sent to Mr. Maiden and identified as *G. secunda* was recorded by Mr. Walter in *Vic. Nat.* vol xix, p. 159 in 1903. Mr. Reader received specimens from Messrs. Pescott and Williamson from Corio Bay and identified them as *Galenia pallens*, Walp., and made the note that the plant was the same species as that previously collected at Geelong, and that it required to be seen whether the two species were synonymous or not. A specimen examined by me shewed four-partite calyces and hence was referred to *Galenia pallens* (*Vict. Nat.*, xix, 1902, pp. 191, 194). Further material shewed that the calyces were mostly five partite, and on reference to Kew the specimens were determined as *G. secunda*. *Galenia pallens* also has occasionally a five-partite calyx, and there are no constant essential features in the flower to distinguish either it or *G. spathulata* from *G. secunda*. The lessening hairiness is of no value, since it is also shewn by some forms, ("*Aizoon contaminatum*, E. and Z.") already included under *G. secunda*. Probably therefore, *G. pallens* and *G. spathulata* should be reduced to varieties of *G. secunda*. In any case our plant occurs in two forms which have a very dissimilar external habit, one being strongly hairy, the other, possibly as the result of the presence of salt, being very much less hairy, so that the leaves shew as pale green and appear glabrous until examined with a lens.

Hibiscus Trionum, L. (Malvaceæ). Victoria, Borung, F. M. Reader (1904), Kerang District (1908).

This species was recorded as new to Victoria by F. M. Reader in *Vict. Nat.*, xxi, (1905) but no locality was given. It appears to be naturalized.

Lycium Afrum, L., "Caffir-Thorn," (Solanaceæ). County of Follett, Victoria, F. M. Reader (1908).

Probably only an escape from cultivation.

Melilotus alba, Desr. (Leguminosæ). "Bokhara Clover."

Naturalized by cultivation in Victoria and now widely spread.

Moraea xerospatha, Mac Owan, (Irideæ Fl. Capensis 1897). Near Adelaide, S.A., Tate (1881); North Adelaide, S.A. O. Tepper (1886); Newarpurr, Victoria, Miss Thurmann (1905); near Melbourne, Victoria, W. R. A. Baker (1905).

The identification has been confirmed at the Cape of Good Hope. This plant was introduced into Australia from South Africa, long before it had been described as a species in South Africa. It appears to be naturalized.

Oxalis tetraphylla, Cav. (Geraniaceæ). Gippsland, Victoria, C. French, Jnr. and C. J. Goodman (1908).

It appears to be naturalized.

Viola tricolor, L. (Violaceæ). Watts River, Victoria, C. Walter (1898).

Probably introduced with agricultural seed, or a garden escape.

Erroneous Records of Naturalized Aliens.

Avena sativa, L. (Gramineæ). Recorded in the *Journal of Pharmacy* (1887) by F. M. Reader as naturalized. We have no evidence of the common cultivated oat *A. sativa*, L., establishing itself as a naturalized alien.

Bidens cernua, L. (Compositæ) recorded in the *Vict. Nat.* vol. xviii, p. 103 (1901) by the late C. Walter, was wrongly determined. It should be *Bidens tripartita*, L. (native). The same correction was made by Mr. Walter on the original specimen now in the National Herbarium.

Chenopodium triangulare, R. Br. (Chenopodiaceæ). Recorded as new to Victoria by Mr. C. Walter in *Vict. Nat.*, ix, p. 5 (1902), but wrongly identified. It should be *Rhagodia nutans*, R.Br. (native). Walter's specimens

evidently have the red and succulent pericarp of *R. nutans*, which is already recorded as native to Victoria. Apart from the pericarp the two plants are very difficult to distinguish. *C. triangulare*, has only been recorded from New South Wales and Queensland.

Explanation of Plates.

Plate XXX.—1. Back of foliage leaf showing glands. 2. Flower. 3. Vertical section through the flower. 4. Single petal and sepal removed, showing insertion of stamens. 5. Single stamen showing the hair-like processes present at the insertion on the petal. 6. Gynæcium. 7. Transverse section of the ovary, showing the ovules.

Plate XXXI.—(*a*) Leafy flowering branch 14 cms. in length. (*b*) Flower enlarged and corolla opened within calyx. (*c*) Transverse section of young ovary. *Kochia Atkinsiana*, fruit from under (*e*) and upper (*d* and *f*) surface; (*f*) with the appendages spread apart showing ovary and bilobed stigma.

Plate XXXII.—1. Plant about natural size. 2. Ripe fruit and pappus. 3. Leaf. 4. Receptacle enlarged.

Plate XXXIII.—1. Flowering spike. 2. Portion of a branch. 3. Flower cut open and seen from the back. 4. Flower cut open and seen from the side with nearly ripe seed. 5. Style and stigma. 6. Ovule. Figures 1 and 2 slightly, 3 and 4 eight times, and 5 and 6 highly magnified.

Plate XXXIV.—1. Flowering spike (× 4). 2. Side view of flower (× 15). 3. Gynæcium (× 30). 4. Transverse section through a fruiting spike (× 14).

Plate XXXV.—1. Plant natural size. 2. Enlarged. 3. Flower from side. 4. Flower from above. 5. Stamens. 6. Pollen grains. 7. Ripe carpel. 8. Seed. 9. Seed in section.

Plate XXXVI.—1. Leaf, natural size. 2. Flower, mag. about 5 times. 3. Stamen, mag. about 25 times. 4. Fruit, mag. about 3 times.

THE DISCHARGE OF ELECTRICITY FROM GLOWING CARBON.

By J. A. POLLOCK, Professor of Physics in the University of Sydney, and A. B. B. RANCLAUD, B. Sc.

[*Read before the Royal Society of N. S. Wales, September 2, 1908.*]

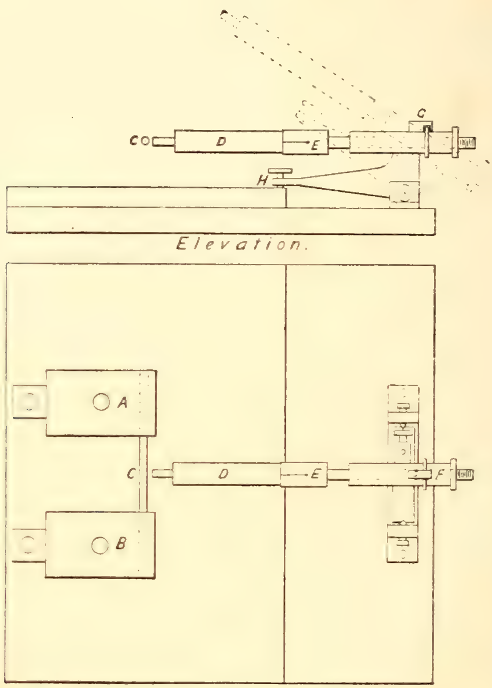
1. Introduction.—The experiments, of which a description is here given, were undertaken in connection with an investigation of the phenomena associated with the relighting of the carbon arc. For the object in view an arrangement was required in which carbon rods should be situated somewhat as they are in an arc lamp, and in which the temperature of one of the rods could be readily controlled. The plan adopted was as follows:—a cylinder of carbon, 4·5 centimetres long and 0·5 centimetres in diameter, was electrically heated, and a circuit arranged to include an air gap, of a few millimetres, between the middle point of the heated cylinder and the end of a comparatively cool carbon rod. The currents in the circuit have been measured for different temperatures of the carbon cylinder, and for various voltages across the air gap up to the point at which an arc forms, with a view to finding the conditions under which the change from the non-luminous to the luminous discharge occurs in the case of hot carbon in air at natural pressure. The conditions for the similar change in connection with a hot lime cathode in air at low pressure have been investigated by Professor J. J. Thomson.[1]

2. Experimental detail.—The apparatus is shown in plan and elevation in figure 1. *C*, the hot carbon cylinder, is

[1] "The Conduction of Electricity through Gases," 2nd edit., p. 477, 1906; see also Horton, *Phil. Trans.* A., 207, p. 149, 1907.

held by large blocks of carbon *A* and *B*, (not shown in elevation), through which the heating current passes. The cool carbon rod *D* is fixed in a holder *E* which can be moved

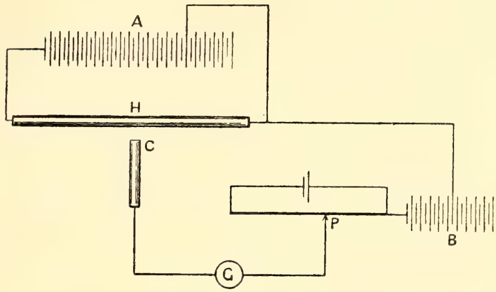
Fig. 1.



in the direction of its length by turning the nut *F*, the latter being prevented from longitudinal movement by the stop *G*. The holder *E* is attached to a cross piece provided with an adjustable stop *H*, the cross piece working on pivots so that the cool carbon rod *D* can be very quickly placed in position before the heated cylinder *C* or readily removed.

A scheme of the connections is shown in figure 2, where *A* and *B* are storage cell batteries, *G* a galvanometer, and *P* a potentiometer; by this arrangement any difference of potential desired could be set up between *H* and *C*, allow-

Fig. 2.



ance being made, of course, for the potential gradient in the hot rod due to the heating current. A fine wire fuse was used to protect the galvanometer from excessive currents.

When the cold carbon is close to the hot one its temperature rises, and the current varies with time. To secure uniformity, measures have been taken in the following way: with the cool carbon removed, the hot cylinder was brought to its full temperature; then by tilting the holder *E*, figure 1, the cool carbon was put quickly into position at the required distance from the cylinder; in 6 to 10 seconds after this the galvanometer deflection became fairly steady, and all observations have been taken within these limits of time.

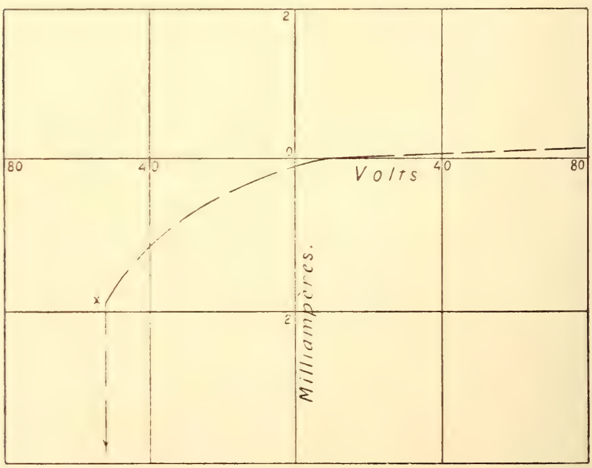
The heated carbon cylinder was a piece of the carbon rods supplied by Messrs. Siemens Brothers for use with their Lilliput arc lamps, while the cooler carbon was a portion of Conradty arc lamp carbon, turned down at the end as shown in the figure.

The temperature of the heated carbon was found with the aid of a Holborn-Kurlbaum optical pyrometer, calibrated at the Reichsanstalt. The temperatures are given as observed, they are therefore in all cases the equivalent black body values.

To get an estimate of the temperature of the cool carbon when currents were measured, the junction of a thermo-electric thermometer of platinum and platinum-iridium wires, 0·5 millimetres in diameter, was placed in the position of the end of the carbon rod, the rod being temporarily removed. The temperature given by the thermometer, under any circumstances as to distance of the junction from the heated cylinder and length of time in position close to it, is considered to be that of the end of the carbon under similar conditions.

3. Flow of negative electricity from the hot carbon.—The general form of the relation, without reference to exact scale, between potential difference and current for temperatures of the hot rod in the neighbourhood of 1800° C. is shown in figure 3, where ordinates represent currents, and abscissæ potentials of the hot relatively to that of the cool carbon.

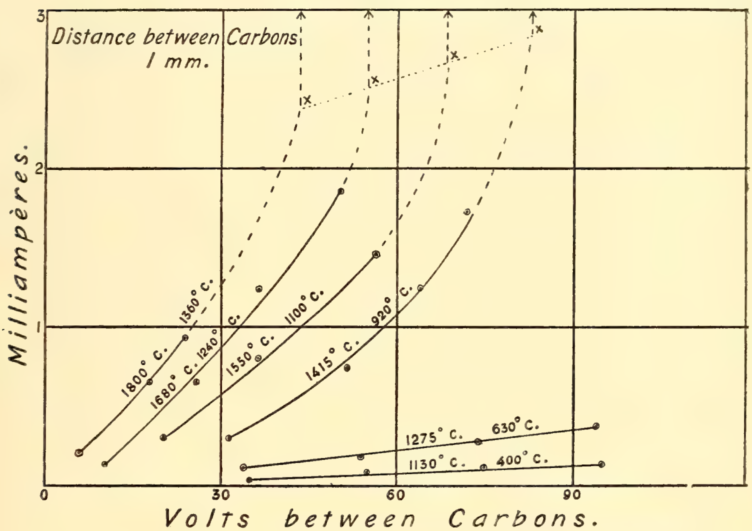
Fig. 3.



General form of the relation between potential difference and current.

For the flow of positive electricity from the hot carbon it is sufficient to say that any increase, above the value for zero current, in the potential of the hot carbon, gives a much smaller current than a decrease of the same amount. This smaller current, however, under the circumstances of our experiments, is not the definite measure of the stream of positive ions from the hot carbon; it is the resultant of such a stream and one of negative ions from the cooler electrode.

Fig. 4.



The current of negative electricity from the hot carbon depends on the temperature of the carbon, on the potential difference between the electrodes and on the distance separating them. At low voltages the current is of the order of a milliampère and is not accompanied by any luminosity. As the potential difference increases, a critical value, depending on the temperature and on the distance between the carbons, is reached at which an arc forms, and the current jumps instantly from milliampères

to several ampères; the critical points are shown at × in the figures.

Fig. 5.

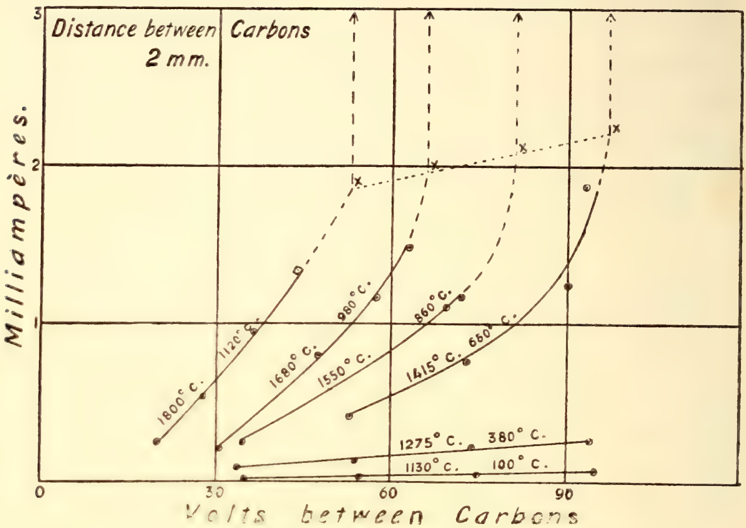
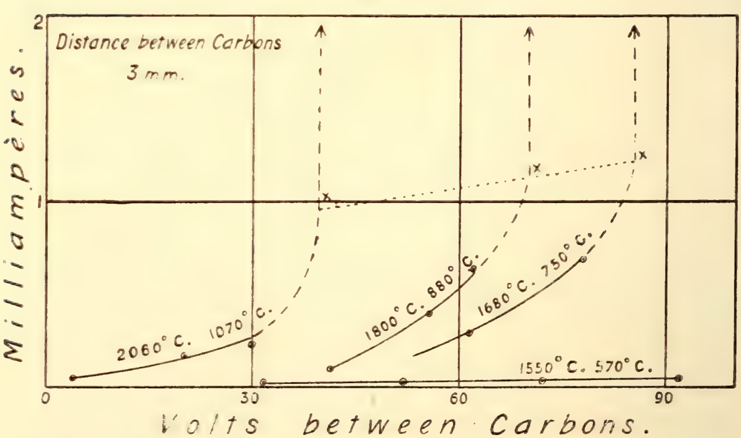


Fig. 6.



To exhibit the form of the connection between potential difference and current, for the non-luminous régime, when

the hot carbon is negative with respect to the cool one, the relations between them, for distances separating the carbons of 1, 2, and 3 millimetres, are shown in figures 4, 5, and 6. The final portions of the curves have been drawn vertical, the abscissæ of the vertical parts being the values of the voltages at which arcing just occurred. The numbers attached to the curves are the values of the temperatures of the hot and cool carbons respectively.

4. Critical values.—The phenomenon of an abrupt change from a non-luminous to a luminous discharge is described by Professor Thomson[1] for the case of a gas at low pressure. A similar sudden change takes place in air at normal pressure, and under the circumstances of our experiments the alteration, from the one régime of current flow to the other, can be brought about by a change in the potential difference between the carbons of about a volt.

The currents just before arcing occurs can be deduced by graphical extrapolation, as shown in the above diagrams; the approximate values so found are collected in table I.

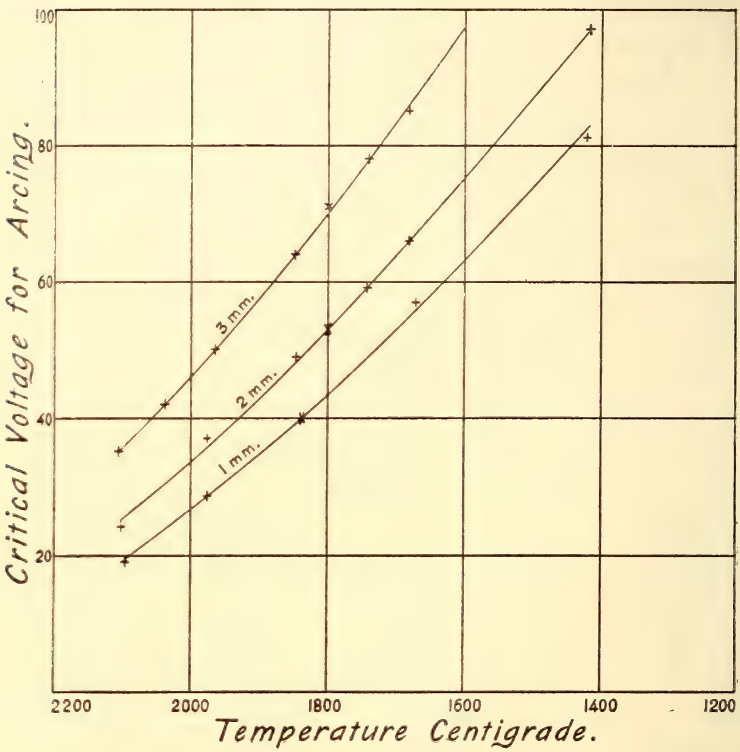
TABLE I.

Distance between carbons.	Temperature.		Critical voltage for arcing. Volts.	Current just before arcing. Milliampères.
	Hot carbon.	Cool carbon.		
1 mm.	1800° C.	1360° C.	43·5	2·37
,,	1680	1240	55·0	2·50
,,	1550	1100	68·5	2 66
,,	1415	920	83·0	2·82
2 mm.	1800	1120	53·0	1·85
,,	1680	980	66·0	1·95
,,	1550	860	81·0	2·07
,,	1415	650	97·0	2·20
3 mm.	2360	1070	39·5	0·97
,,	1800	880	70·0	1·12
,,	1680	750	85·0	1·20

[1] *Loc. cit.*

The relation, as given by our observations, between the temperature of the hot carbon and the critical value of the potential difference between the electrodes necessary to start arcing, is shown in figure 7 for distances of 1, 2 and 3 millimetres between the carbons.

Fig. 7.



The relation between the temperature of the hot carbon and the critical value of the potential difference between the electrodes necessary to start arcing, for distances of 1, 2 and 3 millimetres between the carbons.

All the observations given in this paper, with the exception of those in the following table, refer to the case where the hot and cool carbons are in the same horizontal plane.

The potential difference necessary to start arcing, however, depends very considerably on the position of the hot relatively to the cool carbon, and we give in table II measurements of this quantity taken with the hot carbon vertically below, and with it vertically above, the cool positive; in the lower part of the table are given the values of the critical voltage with the hot carbon vertically below the cool one, and with it in the same horizontal plane as the other electrode.

TABLE II.

Distance between carbons.	Temperature.		Critical voltage for arcing.		Difference.
	Hot carbon.	Cool carbon.	Hot carbon, below.	Hot carbon, above.	
3 mm.	1930° C.	1420° C.	56·0 volts		18·0
,,	,,	346		74·0 volts	
,,	2110	1510	39·5		15·0
,,	,,	650		54·5	
,,	2230	1550	26·5		12·5
,,	,,	860		39·0	
,,	2460	1620	12·5		8·0
,,	,,	1240		20·5	
1 mm.	1930	1580	36·0		8·0
,,	,,	1280		44·0	
2 ,,	,,	1530	42·0		10·0
,,	,,	840		52·0	
3 ,,	,,	1420	56·0		18·0
,,	,,	346		74·0	
				Carbons in same horizontal plane.	
1 ,,	1930	1580	36·0		6·0
,,	,,	1500		42·0	
2 ,,	,,	1530	42·0		4·0
,,	,,	1200		46·0	
3 ,,	,,	1420	56·0		3·5
,,	,,	1000		59·5	
,,	2230	1550	26·5		3·0
,,	,,	1240		29·5	

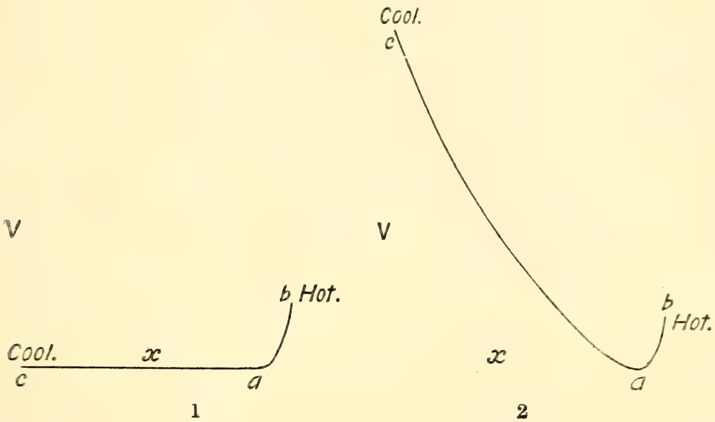
It is seen from the table that the potential difference required for arcing is less when the hot carbon is vertically

below the cool one than when it is vertically above, or than when the two carbons are in the same horizontal plane.

5. Distribution of potential between the carbons.—It is well known that from the surface of hot carbon, electrons and positive ions are projected. The rate of emission of the latter is small and its consideration may be neglected in the discussion of the present experiments when the hot carbon is negatively electrified. The electrons collide with molecules of the surrounding gas, at somewhat various distances from the hot carbon surface, the average of which may be called the average range of projection. The collisions result in the creation of molecular negative ions, which, if they are not removed, accumulate near the surface of the carbon, thus establishing a potential gradient through the average range of projection and a consequent movement of the ions towards the hot surface. Such a distribution of potential can be realized with the apparatus previously described, by applying between the carbons the potential difference requisite, at any temperature, to make the current in the circuit zero, the hot carbon, in this case being positive relatively to the cool one. This distribution may be represented, from a merely illustrative point of view, by the curve 1 in figure 8, where V is the potential and x the distance from the cool carbon, the hot carbon rise of potential $a\ b$ being supposed to take place through a distance comparable with the average range of projection of the electrons.

If the hot carbon is made slightly less positive than the value required for zero current, $a\ c$ in curve 1 will slope a little upwards; those few molecular negative ions formed near the surface of the hot carbon beyond the point a will be drawn by the field to the cool rod, though the great majority will still go to the hot carbon. A further stage, with the hot carbon negative with respect to the cool one

Fig. 8.



Representation of the distribution of potential between the carbons.

is illustrated by curve 2. As the potential difference between the carbons increases, the hot carbon rise of potential *a b* becomes less and less, and the proportion of the negative ions carried to the cool carbon becomes greater. It the potential difference rose to such a value that the hot carbon potential rise disappeared, the current would be saturated; in our experiments an arc forms long before this stage is even approached.

The deduction of an analytical expression for the relation between potential difference and current in the case under consideration, presents difficulties; it involves a statement of the circumstances of the appearance of the molecular negative ions near the hot carbon, and requires a knowledge of the relation between the mobility of the ions and distance from the hot surface, which depends on the temperature gradient existing between the carbons.

6. Change from the non-luminous to the arc discharge.— In the carbon arc there is a very characteristic cathode fall of potential which indicates an accumulation of positive ions near the cathode surface. In view of the fact that,

in the experiments under discussion, the arc forms long before the current is saturated, while there is yet a potential *rise* at the cathode and therefore no possibility of ionisation by collision near the hot surface, one must look to the anode for the origin of the change from the non-luminous to the arc discharge. As a confirmation of this view, we have noticed that the change to the luminous régime of current flow is always heralded by the appearance of a small white hot spot somewhere on the face of the positive carbon. After the advent of the spot, the development to the full arc takes place too rapidly for its phases to be followed by the eye, although, if the circuit is immediately opened, the formation of the luminous discharge may be prevented.

If I is the current of negative ions, E the potential gradient at the anode surface and λ the length of the last free run of the ions, at the end of which they collide with the anode, the energy reaching the anode surface per second is $IE\lambda$; it is here suggested that for the arc to form, the potential difference between the carbons must reach a value necessary to make the magnitude of $IE\lambda$ sufficient to raise a portion of the anode surface to such a temperature that positive ions are somewhat freely emitted. These ions, in travelling to the cathode, first annul the hot carbon rise of potential, and then by accumulating near the cathode surface create a cathode fall of potential. With a cathode fall the positive ions bombard the cathode surface with considerable energy thereby raising its temperature; as a result, the electrons are projected in greatly augmented numbers, and with enhanced velocity, their speed being still further increased during the free flight in the now reversed field. When the velocity of the electrons, at the end of their average range, reaches the value of $2{\cdot}6 \times 10^8$ centimetres per second, it may be considered, as

suggested by one of us,[1] that the arc discharge is fully established.

In our experiments, the currents when arcing commences have been estimated, but we have been unable to deduce the magnitude of the potential gradient at the anode surface. The value of this latter factor will include a part due to the projection of electrons from the surface of the anode, which will be greater the higher the anode temperature.

In the above description it is considered that the development of the arc from the non-luminous discharge takes place in two stages; the first one commences with the somewhat copious emission of positive ions from the anode surface, when the energy of its bombardment by negative ions reaches a critical value; the second one begins when the velocity, at collision with gaseous molecules, of electrons projected from the cathode, commences to increase on account of the presence of positive ions near the cathode surface; it is completed when this velocity is such as to start a mode of conduction through the vapour column, characteristic of the fully developed arc, in which, perhaps, electrons are handed on from atom to atom through the column, as suggested in the paper just mentioned.

The view we have taken of the origin of the change from the non-luminous to the arc discharge receives some support, we think, from the observations of the differences in the voltages required for arcing given in table II. When the hot carbon is vertically below the cool one, the flow of molecular ions is helped by the convection current of hot gas, whereas in the reverse position the flow is opposed by the current; the value of $IE\lambda$ may thus, for the same potential difference, be different in the two cases. In

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[1] Pollock, *Proc. Elect. Assoc. N.S.W.*, 1908-9.

addition, the temperature of the cool carbon when below the hot one is much lower than when above it; the value of $I E \lambda$ may, therefore, have to be higher for arcing to start in the former case than in the latter. If the change to the luminous discharge is considered to originate near the cathode surface, the observed differences in the arcing voltages, due to alteration in the relative positions of the hot and cool carbons, would be difficult to explain.

7. Summary.—The flow of negative electricity from hot carbon, in a circuit containing an air gap, up to three millimetres in length, between a hot and a cool carbon rod, has been investigated for temperatures of the hot rod from 1100° C. to 1800° C., and for various voltages up to the point at which an arc forms between the carbons, the experiments being made in air at natural pressure.

If I is the current of negative ions, E the potential gradient at the anode surface, λ the length of the last free run of the negative ions at the end of which they reach the anode, it is suggested that arcing commences when $I E \lambda$ attains a value sufficient to raise a part of the anode surface to such a temperature that positive ions are somewhat freely emitted.

THE RELIGHTING OF THE CARBON ARC.

By J. A. POLLOCK, D. Sc., E. M. WELLISCH, M.A., and A. B. B. RANCLAUD, B. Sc.

[With Plate XXXVII.]

[*Read before the Royal Society of N. S. Wales, September 2, 1908.*]

1. Introductory.—When the arc between fixed carbons, in a hand-fed lamp, burns itself out, it may be restarted if too great an interval of time is not allowed to elapse, by lessening the distance between the carbon terminals but without bringing them into contact. Again, if the circuit is broken and reclosed after a short time, the arc may re-establish itself without the carbons being moved.

In connection with this latter point, Mr. Upson[1] has given observations of the maximum times of interruption of the circuit within which the arc will restart, for different arc lengths and for various previous currents, with carbon-carbon, and with copper-carbon arcs in air, and states that in the circumstances of his experiments copper-carbon arcs in coal gas and in hydrogen did not restart.

The relighting of the arc after a given time of interruption depends, however, not only on the previous current and on the arc length, but also on the potential difference established between the electrodes at the moment of reclosing the circuit, and the object of our experiments has been to find the relation between this latter factor and the time interval, for carbon-carbon arcs in air at natural pressure, under various conditions.

The maximum time of interruption of the circuit, under given conditions, within which the arc will reform on

[1] *Phil. Mag.*, xiv, p. 126, 1907.

remaking the connections, is astonishingly well defined, and could in our observations be determined to ·002 second. If the interval between the break and the make of the circuit exceeds what may be called the critical time for the given circumstances, after reclosing the circuit a small non-luminous current passes between the carbons; the heating effects associated with this current are not sufficient to maintain the electrodes at their high temperatures, and the current soon dies away as the temperatures diminish. From considerations advanced in a previous paper[1] with reference to the establishment of the cathode fall of potential which is such a characteristic feature of the developed arc, one is led to think that, on reclosing the circuit, this smaller current always precedes the larger one of the fully formed discharge; the problem of critical relighting is then essentially that of the change from a non-luminous to a luminous current under the circumstances of the experiments.

In the relighting of the arc, both carbons are at a high temperature, and the conditions are complicated by the presence, at the moment of reclosing the circuit, of ions at the anode surface as well as near that of the cathode. Simpler conditions are associated with the change of current régime when only the negative carbon is incandescent; this case, involving, previous to the formation of the arc, the flow of negative electricity from a hot to a cool carbon, has been investigated by two of us,[2] and an explanation reached which seems to account for the phenomena observed.

In the present experiments it will be seen that the flow of negative electricity at the moment of reclosing the circuit is not always from a hot to a cooler carbon; the

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[1] Pollock and Ranclaud, this Journal, p. 201.

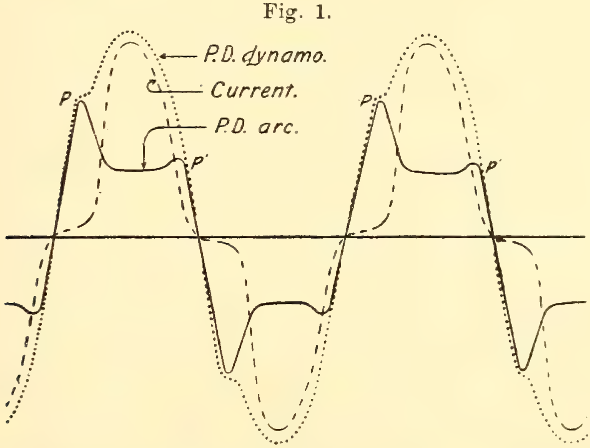
[2] Pollock and Ranclaud, *loc. cit.*

conditions of the change from the non-luminous to the luminous discharge are, therefore, in some instances, more complicated than those in the case previously considered, and the explanation of the development of the arc suggested in the paper just mentioned is not sufficient to account for all the features observed in this investigation. Further data are required before a complete description can be given.

The conditions associated with a change from the non-luminous to the luminous discharge, in the case of the ordinary carbon arc, are seen in the wave forms of current and potential difference in connection with alternating current arc lamps.

Figure 1, showing curves of the volts at the brushes of the machine, of current in the circuit, and of the potential difference between the carbons of the lamp, is copied from figure 14 of a paper by Mr. Duddell and Prof. Marchant on "Experiments on Alternate Current Arcs by aid of Oscillographs,"[3] in which many other illustrations will be found.

Fig. 1.



Waves of current and potential difference in connection with an alternating current arc lamp.—Duddell and Marchant.

[3] *Journn. Inst. Elect. Eng,*, xxviii, p. 1, 1899.

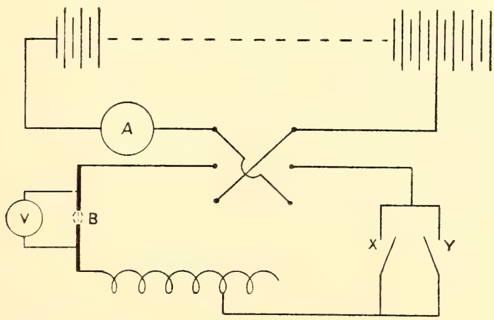
The curves may be described by saying that the potential difference between the carbons rises from zero, while the current keeps low and non-luminous, until the potential difference reaches the value, p, necessary to change the state of the current to that of the arc discharge. The current then rises very rapidly, while the potential difference falls so that a greater electromotive force may be available along the rest of the circuit, a necessary condition if the increase in the current is to be maintained. On the falling side of the wave, the second maximum of the potential difference seems to be connected with the gradually diminishing current, rather than with any abrupt change in the nature of the discharge.

The current curve is unsymmetrically placed with reference to the zero points of the potential difference curve, because on the rising side of the wave the change is from a non-luminous to a luminous discharge, when on account of the smallness of the previous current the temperatures are low, whereas on the falling side the change is in the opposite direction, when owing to the previous larger current, the temperatures are higher.

2. Experimental detail.—For all the experiments Conradty carbons, marke C, were employed; both positive and negative were solid, each 13 millimetres in diameter ; the lamp being hand-fed. A heavy pendulum, operating two switches when allowed to swing, opened and again closed the circuit. The distance between the switch levers could be readily altered. The time interval between the opening and the reclosing of the circuit for different lengths between the levers was carefully determined by separate experiments carried out as follows:—the switches were arranged to open and close the circuits of two electromagnetic scribers which marked a smoked plate fixed to the pendulum; the records for various distances between the switch levers

were then compared with that on the same plates of a style attached to the prong of a standardised tuning fork. A third key, also worked by the pendulum, enabled the battery connections to be reversed in the interval between the break and the make of the circuit, if desired.

Fig. 2.



Scheme of connections.

A scheme of the connections is shown in figure 2, where *A* is an ammeter, *V* a voltmeter, *R* a variable resistance, *B* the arc, and *X* and *Y* the two switches. An observation consisted in finding, for a given potential difference between the carbons at the instant of the reclosing of the circuit, the greatest distance between the switch levers for which the arc would relight. This maximum distance could be determined to within two millimetres, which corresponds to a time interval of about ·002 seconds. The time interval corresponding to the maximum distance may be called the critical time for relighting under the given conditions. This time, under otherwise fixed circumstances, varies considerably with the carbons used, and the results are only directly comparable when they refer to the one pair of carbons.

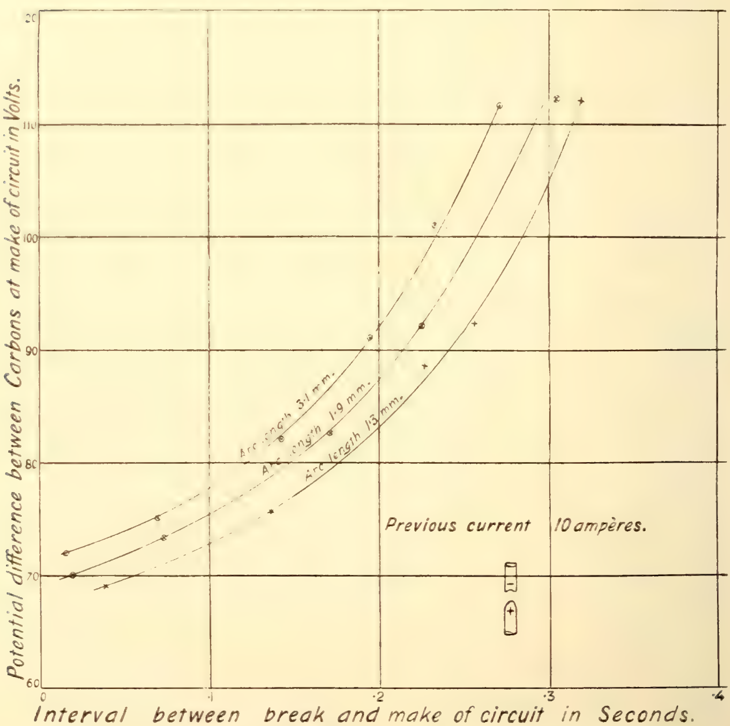
The observations were made in all cases with 'normal' arcs.[1] The lengths of the arc were measured, on images

[1] Mrs. Ayrton, "The Electric Arc," p. 104.

of the carbons, vertically from the point of the negative to a horizontal line passing through the edge of the crater, the values obtained being reduced according to the magnification of the image.

3. Relighting with carbons in normal positions when potentials are reversed.—When the connections from the battery are reversed during the interval between the opening and closing of the circuit, so that at the remake of the circuit the still existing crater becomes negative to the previous cathode, the crater being on the upper carbon, the phenomena are simpler than in other cases and will therefore be the first described.

Fig. 3.



Relation for critical relighting; carbons in normal position, potentials reversed.

In figure 3 is shown the relation between the minimum potential difference for relighting and the interval between the break and the make of the circuit, under the condition of the reversal of the potentials of the carbons, for a previous current of 10 ampères. Three curves are drawn, from observations with the same pair of carbons, for arc lengths of 1·3, 1·9 and 3·1 millimetres respectively, the upper electrode being the positive before the break of the circuit.

In this instance, on reclosing the circuit, the hot is negative to the cooler carbon; the conditions under which the arc is formed are therefore nearly allied to those in the simple case previously investigated, see section 1. The longer the interval between the break and make of the connections, the lower are the temperatures of the carbons at the moment of reclosing the circuit; taking the fall of temperature of the carbons after the arc is extinguished as nearly proportional to the time, the curves in figure 3 may be considered as giving, approximately at least, the form of the relation between the critical potential for relighting and the temperature of the hot negative, the temperature of the other electrode being of less importance in this particular case. From this point of view one would expect the curves in figure 3 to be like those in figure 7 of the previous paper[1] which give the exact form of such a relation under somewhat the same conditions as those under consideration. A comparison shows that the two sets of curves are similar in shape.

Under the conditions of the experiment, the first effect of reclosing the circuit is no doubt a small current of negative ions flowing from the hot to the cooler carbon, and from this non-luminous current the arc may be considered to develop. In the fully formed arc the cathode

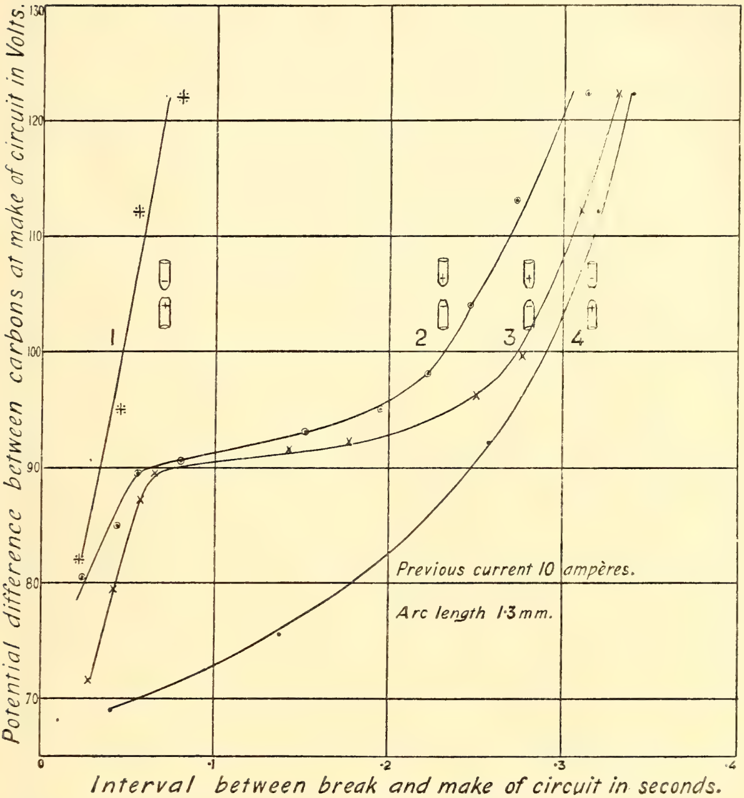
[1] This Journal p. 208.

fall of potential indicates an accumulation of positive ions near the cathode surface. These positive ions, in the growth of the discharge from the non-luminous current, must come in the first instance from the anode. If I is the current of negative ions, E the potential gradient at the anode surface and λ the length of the last free run of the ions at the end of which they collide with the anode, the energy reaching the anode surface per second is $I E \lambda$; following the suggestion contained in the paper referred to, it is considered that for the arc to form, in the circumstances here contemplated, the potential difference between the carbons, at the moment of reclosing the circuit, must have the value necessary to make the magnitude of $I E \lambda$ sufficient to raise a portion of the anode surface to such a temperature that positive ions are somewhat freely emitted.

For this particular experiment the suggestion seems sufficient to account for the phenomena observed, but it will be seen that it is not of itself adequate to completely describe the features of the relation in other cases, even where, on reclosing the circuit, the hot is negative to the cooler carbon.

4. Effect on the relighting of changes in the relative positions of the carbons.—The form of the relation between the minimum potential difference for relighting and the time interval between the break and the make of the circuit is influenced by many conditions. With the carbons in a vertical plane they may be situated, before the circuit is broken, either in the normal way, with the crater above, or in the reversed position with the crater below the negative electrode; in addition, the connections to the battery may be reversed during the interval between the break and the make of the circuit, or left unaltered, so that there are four cases to be considered in connection with the relative positions of the carbons and the direction of the potential difference on the remake of the circuit.

Fig. 4.



Relation for critical relighting as affected by changes in the relative positions of the carbons.

In figure 4 are shown the relations between the minimum potential difference for relighting and the time interval of interruption of the circuit for the four cases mentioned, the current having been 10 ampères when the connections were broken and the arc length 1·3 millimetres. The diagrams of the carbons drawn beside each curve indicate by their shape the relative positions of the electrodes before the circuit was opened, while the signs of the potentials, on the reclosing of the circuit, are shown by the usual

symbols. All the observations were taken with the same pair of carbons so the curves are strictly comparable.

Case 4 is the one just discussed in section 3. It is seen that for small time intervals between the break and the make of the circuit it requires greater potential differences to restart the arc in the cases 1, 2 and 3 than in that of 4, and that cases 2 and 3 approximate to that of 4 for large intervals of time. Considering that the arc develops from a small non-luminous current of negative ions, an idea which we think must form the basis of any explanation of the critical relighting, in searching for a description of the differences between the curves it has to be noticed that in some cases the negative electrode, on the remake of the circuit, is hotter than the positive, in others the reverse; it is also essential to recognise that in some instances the negative stream of ions is opposed by the convection current of hot gas, while in others it is helped by it, as it has been shown in the previous paper that a change in the relative directions of the stream and current considerably affects the potential difference necessary for arcing.

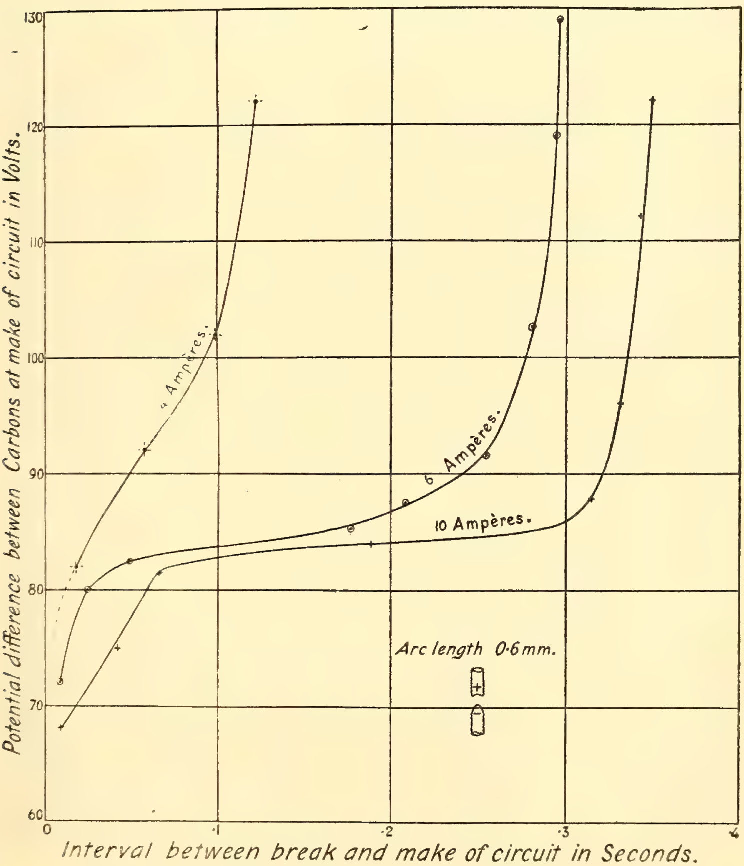
The feature of the relations is the evidence, shown by the curves for cases 2 and 3, of a critical change in the conditions for relighting occurring when the potential difference attains the value of 90 volts. After reaching this value the minimum potential difference requisite to start the arc remains for some time practically constant in spite of the fact that for increasing time intervals between the break and the make of the circuit the temperatures of the carbons are diminishing.

The excess of the potential differences for relighting required in case 1 over those in case 4, for the same time intervals, may be accounted for, perhaps, by the much lower temperature of the negative electrode on the reclosing of the circuit in the former instance, but we have been

unable to find, with the data at hand, an explanation of the critical characteristic of the curves for the other cases.

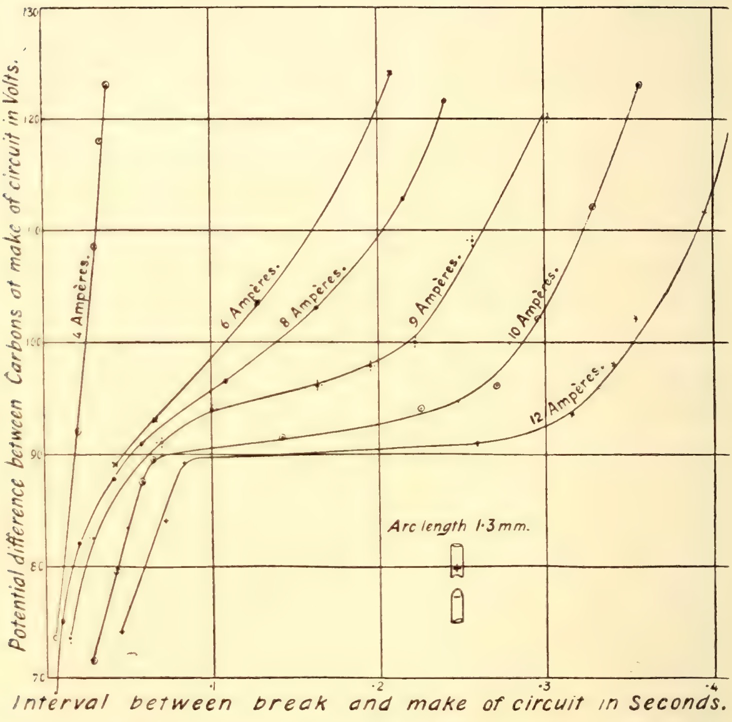
5. Critical characteristic as affected by arc length and previous current.—With a view to finding the influence of arc length and previous current on the critical characteristic of the curves just mentioned, further observations have been made in connection with case 3, in which the carbons are in the normal position and the battery connections remain unaltered during the interval between the break

Fig. 5.



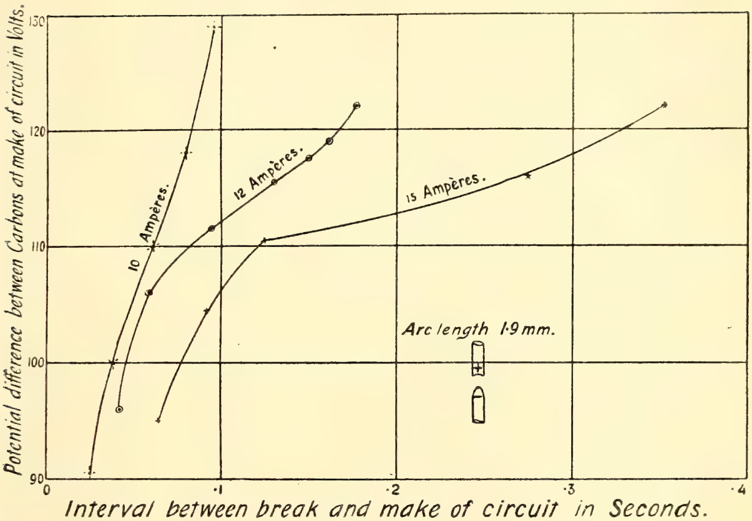
and the make of the circuit. The measurements are given in Figures 5, 6, and 7, the currents previous to the break of the circuit being marked on the curves. The observations were interlocked, with reference to change of carbons, so the curves are comparable.

Fig. 6.



A comparison of the relations given in Figures 5, 6, and 7, shows that the characteristic bend in the curves is more pronounced the higher the previous current. Greater currents mean larger masses of heated carbon with consequent higher temperatures for equal intervals between the break and the make of the circuit. It is also seen that the greater the arc length the higher the potential difference at which the characteristic bend occurs.

Fig. 7.



6. Photographs of the relighting.—By arranging an additional lever, in connection with the pendulum apparatus previously described, to open the shutter of a photographic camera at a short interval after the remaking of the connections of the arc circuit, photographs showing stages in the development of the arc have been obtained. The growth of the arc takes place in such a short time that a definite adjustment of the lever was found to be impossible, and the photographs given are only a few of many that have been taken, the remainder showing either no arc or the arc fully developed.

Figures 1 to 7 in *Plate 37*, show stages in the growth of the arc when the circuit is opened and reclosed without alteration of the battery connections, while figures 8 to 11 refer to cases where, on the reclosing of the circuit, the still existing crater is negative to the previous cathode. In both instances the glow is seen to develop from the electrode which is positive on the remake of the connec-

tions, a fact which seems to support the view taken in this and the previous paper as to the mode of growth of the arc from the non-luminous discharge. Figure 12 is an example of many of the photographs, showing that, in the case of the reversal of the connections, the new crater commences on cool rather than hot carbon.

7. Summary.—In connection with the relighting of the carbon arc, without movement of the electrodes, when the circuit is opened and reclosed, the relation between the potential difference, established between the carbons at the moment of the remaking of the connections, and the maximum time of interruption of the circuit, within which the arc will reform, has been investigated for cases differing as to the relative positions of the carbons before the opening of the circuit, and as to the direction of the potential difference after the reclose of the connections. The problem is that of the change from a non-luminous to a luminous discharge in air at normal pressure, of which an explanation, in the case where negative electricity flows from a hot to a cool carbon, has been given in a previous paper. In the present experiments both carbons are at a high temperature and the conditions of the change are complicated by the presence, at the moment of reclosing the circuit, of ions at the anode surface as well as near that of the cathode. In some of the cases examined, the relations show a critical characteristic, but sufficient data are not available to enable an explanation of this result to be given. Photographs have been taken showing stages in the formation of the arc; it is seen that the glow grows from the electrode which is positive on the remake of the circuit, a fact which seems to support the view taken in this and the previous paper as to the mode of development of the arc from the non-luminous discharge.

We are indebted to Mr. H. L. Watkins, B.A., and Mr. L. A. Cotton, B.A., B.Sc., for help in connection with the earlier part of the investigation.

EVIDENCE OF RECENT SUBMERGENCE OF COAST AT NARRABEEN.

By T. W. EDGEWORTH DAVID, B.A., F.R.S., Professor of Geology, University of Sydney, and GERALD H. HALLIGAN, F.G.S., Hydrographic Officer, Public Works Department.

[With Plates XXXVIII., XXXIX.]

[*Read before the Royal Society of N. S. Wales, September 2, 1908.*]

I. Introduction.—IN view of the general physical features of the coast line of New South Wales for some distance to the north and south of Sydney, as well as of evidence supplied by bores and shafts in the neighbourhood of our coastal areas, it seems clear that one of the most recent movements of the coast line had been a negative one, that is sea level had risen in relation to the land. To state it otherwise, there had been recently a positive movement of the ocean.

In a paper contributed to the Royal Society of New South Wales by Messrs. R. Etheridge, J. W. Grimshaw, and T. W. E. David,[1] a description was given of a submerged forest at Shea's Creek, near where Cook's River enters Botany Bay. The trees of this submerged forest grew at a depth of 15 feet below high water, being in position of growth with numerous roots extending out over 12 to 15 feet from the parent stem. The trees all belong to species which are now found in the immediate neighbourhood. In places the old forest was found to pass into a bed of peat. Three aboriginal tomahawks were discovered in association

[1] R. Etheridge, T. W. E. David and J. W. Grimshaw, On the Occurrence of a Submerged Forest with the Remains of a Dugong, at Shea's Creek, Sydney, this Journal, xxx, 1896, pp. 158 – 185, pl. viii. – xi.

with these peat beds. The peat beds and trees were covered by estuarine beds containing an abundance of marine shells. Reference was made in the same paper to the discovery of the skeleton of a large Dugong a little above the horizon of the submerged forest, the bones showing evidence of having been hacked by stone tomahawks.

The evidence thus supplied was conclusive as to recent submergence in the neighbourhood of Botany Bay of at least 15 feet. The evidence about to be given shows at Narrabeen a probable recent submergence of over 50 feet.

II. Evidences of recent submergence deduced from general physical features.—It has long ago been pointed out by the late Rev. W. B. Clarke, the late Government Geologist, Mr. C. S. Wilkinson, Mr. E. C. Andrews,[1] and one of the authors,[2] that the numerous deep inlets along the coast, such as those of Lake Macquarie, Tuggerah Lakes, Broken Bay, Port Jackson, Botany Bay, Port Hacking, etc., were distinct evidence of recent coastal submergence. As the result of the submergence the old land valleys, such as those of Cook's River, Parramatta River, Hawkesbury River, etc. were betrunked through the lower ends of the valleys being drowned, as the consequence of the sea water creeping further and further inland as the subsidences progressed.

The physical features along our coast, particularly those of the Narrabeen Lagoon and its neighbourhood, show that this submergence, though recent from a geological point of view, must date back many hundreds of years, probably many thousands of years into the past. This is obvious from the large amount of reclamation work accomplished

[1] *Proc. Linn. Soc. N. S. Wales.*

[2] T. W. E. David, Summary of our present knowledge of the Structure and Origin of the Blue Mountains of New South Wales. This Journal, xxx, 1896, pp. 33 – 69, pl. i – iv.

by the wind, the waves, and the currents along the coast line near Narrabeen. In places the old estuaries, as at Narrabeen and Deewhy, have been converted into lagoons through the pushing out of sand spits chiefly from their southern ends and directed northwards. In other cases as at the Curl Curl Lagoon, about two miles northerly from Manly, the reclamation is so mature that all the old lagoon is now obliterated through silting, with the exception of the comparatively small area occupied by the modern Curl Curl Lagoon.

A glance at the geological map of Sydney and its neighbourhood, including the County of Cumberland, recently issued by the Geological Survey of New South Wales, shows that the rocky hill of sandstone between the Freshwater and Curl Curl Lagoons, in recent times formed an island previous to the complete silting up of the old estuary which separated it from the main land. The same remark applies to the Quarantine Ground near Manly, as well as to that long strip of sandstone cliff and hill which stretches from South Head to Ben Buckler near Bondi; obviously this area has in recent times been an island before the Strait, now occupied by the silt beds of Rose Bay and the sand hills of Bondi, separated it from the mainland of Bellevue Hill and Bondi. Still further north in the neighbourhood of Lake Macquarie and the delta of the Hunter the general configuration of the country supplies conclusive evidence of recent submergence. Lake Macquarie itself is obviously an old drowned valley, and so is the Hunter estuary between Newcastle and Port Stephens.

III. Evidence supplied by bores, shafts, etc.—In addition to the case of Shea's Creek already quoted, probable evidence of recent submergence of the coast line was afforded by the trial shaft for the North Shore Bridge made between Dawes' Point and MacMahon's Point. At a depth

of about 90 feet below high water mark, in sinking by means of a caisson at this spot, highly carbonaceous clays, with abundant remains of plants, mostly in a fragmental condition, were found to underlie the sandy shell-bearing estuarine beds, of the type commonly met with on the bottom of our harbour. This section was examined at the time by Mr. H. Stanley Jevons and Professor David, and it appeared to them that these loamy muds with plant remains were strong evidence of the harbour at the time of their formation having its water surface much lower than at present. In other words, these loamy beds are evidence of recent submergence of Port Jackson to the amount probably of 90 feet. Then, too, in sinking the cylinder to form a pier of the present Hawkesbury Bridge, on the side nearest to Mullet Creek, the trunk of a large tree was struck by the shoe of the cylinder, and the cylinder in consequence was carried so much out of plumb that it had to be built up anew from below the level of low tide up to the base of the bridge. The horizon, where this timber was struck, is about 109 feet below sea level. Obviously this is not conclusive evidence of submergence, but is very suggestive of the surface of the estuary having been very much lower than it is at present at the time when the Hawkesbury River was able to roll down in flood time and embed in its flood silts these large logs.

In sinking the shaft for the Stockton Colliery numbers of stumps of large trees associated with coarse water-worn river gravel and shingle were struck at a depth of about 160 feet below sea level. Obviously these river gravels could have been laid down only under conditions where the level of the Hunter River approximated to the present level of that gravel; this implies a submergence there of 150 to 160 feet. A continuation of these gravels has been traced to still greater depths at the Anna Bay Bores and at the bore recently put down by the Perpetual Trustee

Company north of the Cemetery, 3 miles beyond Stockton, Newcastle. The last mentioned bore proved the old estuarine beds of the Hunter to lie there at a depth of over 200 feet below sea level. Also it may be mentioned that in the case of the remarkable washaways in the Borehole Seam, which led to some loss of life at the Ferndale Colliery some years ago, we have an example of an old channel of the Hunter River eroded out of the Borehole seam at a spot where that seam is now 100 feet below sea level. The existence of a bed of recent peat with erect stumps of trees in position of growth at Fingal Bay near Port Stephens, the said peat bed being traceable to below the level of low tide, is evidently good evidence that this submergence is probably still in progress.

With a view to seeking further evidence on the subject of this recent coastal submergence, through the kindness of the Under Secretary for Public Works, Mr. J. Davis, M.I.C.E., a small hand-boring plant was placed at the disposal of the authors on 1st August, 1904. With the help of about twenty of the University students, under the superintendence of the authors, an attempt was made to put a bore down close to the bridge at Narrabeen Lagoon, at the spot shown on *Plate 38*. Considerable difficulty was experienced in forcing the lining pipes, by hand, down through the quick-sand, and the first bore had to be abandoned without any definite evidence being obtained. The second bore proved more successful, for at a depth of 52 feet below the surface, and about 49 feet below the level of high water, clean sea sand with shells, which up to that time had been the dominant material in the bore, suddenly gave place to a dark carbonaceous sandy clay. The general section of the bore is shown on *Plate 39*. It will be noticed that these dark clays at about 57 feet below the surface contained a number of Gasteropod shells of shallow water habit.

At 62 feet numbers of roots of trees and charcoal were met with embedded in a carbonaceous sandy clay, and at a total of 65 feet a perfect cone of Casuarina was brought up by the sand pump. At 56 feet the formation became a dark peaty sand, probably of terrestrial or lacustrine origin; at 71 feet this gave place to dark peaty sand passing downwards into sharp clean sand, with occasionally white quartz pebbles, one-third to one-quarter inch diameter associated with fragments of plants. The last 4 feet of the boring was in coarse gravelly sand with pebbles of Hawkesbury sandstone up to 1 inch in diameter, with occasional fragments of lignite.

As the bore progressed we were careful from time to time to test the water which came up in the bore for saltness with a view of deciding to what depth the layer of freshwater bearing sand extended. We were somewhat surprised to find that the water in the sands was fresh to a depth of about 14 feet below high water. This is obviously due to the fact that there is a considerable mass of water bearing sand forming a broad and high bank on the seaward side of the bore; this bank rises to a height of about 35 feet above sea level, and it is no doubt the slow movement under hydraulic pressure of the water from this sand bank seawards that forces back the salt water. We were informed by residents in the neighbourhood that after a prolonged drought the top of the salt water zone comes within about 4 feet of the level of high water.

With reference to the various organisms obtained from this bore, Mr. C. Hedley, F.L.S., has examined the Mollusca and other Invertebrates, and reports:—

(1) The species are all recent.

(2) And are all components of the mud fauna.

(3) They belong to between tide marks and to the zone immediately below low water.

"Such forms as *Balanus* and *Ostrea* indicate rocky ground within a short distance. *Nassa*, *Pyrazus* and *Cantharidus* are suggestive of a mangrove swamp dry at low tide. These might, however, be washed thence down to the bed of the stream. So I would prefer to dwell on the evidence of *Spisula* and *Choclodesma*, and consider that at the period of deposition the horizon of these shells was the bed of a muddy estuary about 15 to 20 feet deep. Nothing of the ocean beach fauna appears. The fossils point decisively to the fact that the sea had not free access to the spot. If, when the 50 feet horizon was deposited, the land had stood higher than the sea, obviously the shells would have been fluviatile or terrestrial, not the mangrove fauna produced. On the contrary, if then the land stood as low or lower than it does now, and *if* the sea had free access to the spot, another fauna would have prevailed there. Conclusion, the environment of these specimens was exactly the condition of the present Narrabeen Creek. An hypothesis, that the creek maintained its level relative to the sea, by raising its bed with sediment and so balancing subsidence against accumulation, would agree with the condition and position of these shells."

In regard to the roots of trees and other fragments of fossil wood, many of these were found to be distinctly charred, probably as the result of a bush fire. Certainly the conversion into charcoal is not due to ordinary decomposition, such as brings about the conversion of wood into lignite. Some of the fragments recovered by us from the bore were a couple of inches in thickness, and 4 to 5 inches long. This wood having been sectioned for microscopic examination, Mr. J. H. Maiden, Director of the Botanic Gardens, was good enough to examine the sections, and he reported that on examination he could not detect the medullary rays characteristic of the Proteaceæ or Casuarina

and considers that "it is probably Myrtaceous or Leguminous, probably Eucalyptus."

From this report it is clear that the species of wood all belong to recent types. The evidence of the roots and other remains of plants, taken in conjunction with that of the estuarine shells, is in the opinion of the authors conclusive proof that we have here a very definite piece of evidence of a recent subsidence of the coast line to the amount of about 50 feet. This subsidence, from the evidence quoted earlier in the paper, appears to have been somewhat widely extended, inasmuch as the area from Port Hacking to Port Stephens can certainly be included in the submerged area, that is a belt of coast about 90 miles in length.

Tide gauge observations at Fort Denison are unfortunately, up to the present, not very reliable, but as far as the evidence goes it is insufficient to justify the statement that our coastline at the present moment is undergoing an appreciable depression or elevation. The evidence collected by Mr. H. S. W. Crummer, shows that at Vaucluse and parts of Middle Harbour crusts of Cirripedia and Balanidæ are found there a few feet above the level of high water. It is possible that these indicate a slight upward joggle of the coastal plain. The evidence, however, cannot be implicitly relied upon in view of the fact that older conditions along the coast line, and the shape of the shore line, lead to the waves at times splashing up higher than at others. It is quite sufficient for the growth of Cirripedia and Balanidæ that they shall be bathed by the waves at least every high tide.

It is to be regretted that with the appliances available we were unable to carry the bore below the 70 feet level. It is highly probable that further traces of submerged land or swamp surfaces would have been met with at these

deeper levels, surfaces corresponding with the old level of the Hunter River channel near Newcastle. If the subsidence is still in progress it must be exceedingly slow, at all events if it extends as far inland as the great earth fold at Glenbrook to the west of Penrith. Accurate measurements taken by Mr. G. H. Knibbs, with a dumpy level, show that if movement at all is taking place in the way of the hinging down of the coastal strip between Penrith and the sea it must be something of the order of $\frac{8}{100}$th to $\frac{12}{100}$ths of an inch in the year.

We would venture to suggest, with a view to the further elucidation of the question whether our coast at present is rising or falling, that a number of bench marks might be made along the coast, carefully levelled to, as was suggested at the Meeting of the Australasian Association for the Advancement of Science at Dunedin in 1904.

Our thanks are specially due to the Under Secretary for Works, Mr. Davis, M. Inst. C.E., for having so kindly placed the boring plant at our disposal, and also to the students of the University who rendered splendid service in the practical work of boring.

On the INFLUENCE of INFANTILE MORTALITY on BIRTHRATE.

By G. H. Knibbs, F.S.S., F.R.A.S., Commonwealth Statistician.

[*Read before the Royal Society of N. S. Wales, October 7, 1908.*]

1. A general survey of the vital statistics of any country discloses the fact that, on the whole, with an increase of infantile mortality there is an increase of birth-rate. These rates are ordinarily measured as follows:—

Denoting the average total population during the period under review by P, the total number of births during the same period by B, and the total number of infants dying by M, the birthrate denoted by β, is B/P; and similarly the rate of infantile mortality denoted by μ, is M/B, since it is the ratio of the number dying to the total number born in the period.

In order to make strictly comparable the results at different periods and of populations differently constituted in respect of sex and age, the birthrates should be referred to the number of women of childbearing age, and so standardised as to express uniformity in respect of natural fecundity or fertility. If, however, the constitutions of populations are sensibly identical in regard to sex and age, the corrections necessary are small and may for the present purpose be disregarded.

2. Suppose that μ be taken as the independent variable, and the mean of a group of values of β be formed for the corresponding small ranges of values of μ. The result would be what may be called a *mean birthrate* B_n say, related to a mean rate of infantile mortality, μ_n say these

two quantities being given by the formulæ:—

$$B_n = [B]/[P] \ldots\ldots\ldots (1)$$

$$\mu_n = [M]/[B] \ldots\ldots\ldots (2)$$

the square brackets merely denoting the sum of the quantities written within them (as in the notation ordinarily used in least squares).

Repeating this process for a series of small ranges of μ, successive mean birthrates are obtained corresponding to a series of mean rates of infantile mortality, and, if these be plotted as ordinates and abscissae respectively, the succession of points will afford some indication *whether on the whole* the birthrates increase with increase of infantile mortality. This has been done for a number of countries and the results are shewn on Fig. 1 hereinafter.

3. That *a priori* some such increase is to be expected may be shewn as follows:—

Let it be supposed that β' denotes the ratio say of the number of births, not to the total population, but to the number of women of childbearing age; and μ the ratio of the number of infant deaths to the total number of infants born: then the ratio of the number of infant deaths to the women of childbearing age is $\beta'\mu$.

In a community containing n married women of childbearing age, the annual number of births would be $n\beta$ and the annual number of deaths of infants $n\beta'\mu$. If it be assumed that all other conditions remain constant, the problem resolves itself into ascertaining what would be the consequence to the birthrate of the rate of infantile mortality changing, say from μ to μ'.

The only way in which an increase in the rate of infantile mortality can be assumed to directly increase the birthrate, other circumstances remaining constant, is by increasing the number of childbearing women at risk, viz. the number likely to give birth to children. It may be assumed there-

fore that some definite proportion, q say, of the women whose children have died, may be added to the number of childbearing age who are equally likely to increase the total number of births.

The maximum value of q is of course 1, that is its value when every woman whose infant has died is at risk. This *proportion* may on the whole be supposed characteristic of a country, or of a particular period.

The total number of women at risk will be therefore,

$$n - n\beta' + nq\beta'\mu = n\left\{1 - \beta'(1 - q\mu)\right\}$$

Thus the ratio of births to this number will be

$$n\beta'/n\left\{1 - \beta'(1 - q\mu)\right\} = \beta'/\left\{1 - \beta'(1 - q\mu)\right\} \text{.........(3)}$$

If at some other period the rate of infantile mortality is found to have changed to the value μ' the total number of women at risk will similarly be $n\left\{1 - \beta'(1 - q\mu')\right\}$ ......(4)

Since *ex hypothesi* all other conditions have remained unchanged the ratio of births to the total number of women at risk will be as before, and the total number of births under the changed rate of infantile mortality will consequently be :—

$$n\left\{1 - \beta'(1 - q\mu')\right\} \cdot \frac{\beta'}{1 - \beta'(1 - q\mu)} \text{.........(5)}$$

that is to say, the original birthrate will have to be multiplied by the factor :—

$$\frac{1 - \beta'(1 - q\mu')}{1 - \beta'(1 - q\mu)} = 1 + (\mu' - \mu)\frac{q\beta'}{1 - \beta'(1 - q\mu)} \text{.........(6)}$$

Since the difference of the *rates* of infantile mortality must always be a small fraction, and β' is itself also a small fraction, it is obvious that the birthrate cannot be *greatly* modified by infantile mortality.

Retaining for the present β' as denoting $[B]/[W]$, in which W denotes the number of women of childbearing age,

suppose for example that, $\beta' = 0{\cdot}250$; $q = 1$, and $\mu = 0{\cdot}100$; the last rate becoming later $\mu' = 0{\cdot}200$. Then the term $(\mu' - \mu)\,q\beta / \left\{ 1 - \beta'(1-\mu) \right\}$ is identically

$$\frac{(0{\cdot}200 - 0{\cdot}100)\,q\,.\,0{\cdot}250}{1 - 0{\cdot}250\,(1 - q \cdot 0{\cdot}100)} = \frac{0{\cdot}025}{1 - 0{\cdot}225} = 0{\cdot}03226.$$

Thus the original rate $0{\cdot}250$ could become at most (*i.e.*, when $q = 1$) only $0{\cdot}250 \times 1{\cdot}03226$, viz. $0{\cdot}25806$, or say 258 per 1000 instead of 250; or in other words the doubling of the rate of infantile mortality, would on the assumption made, affect the birthrate by increasing it the small amount of about $3\frac{1}{4}$ per cent.

4. Reverting to equation (6) the result deduced may be put in the form $\beta_{\prime}' - \beta' = b\,(\mu' - \mu)$ ....(7)

where $b = q\beta'^2 / \left\{ 1 - \beta'(1 - q\mu) \right\}$ ....(8)

$\beta_{\prime}'$ denoting the birthrate as modified by a change in the rate of infantile mortality. The above expression (7) is the equation of a straight line making with the angle of abscissæ an angle whose tangent is b, the abscissæ being values of μ and the ordinates values of β'. This result shews that b is essentially positive, a matter to which reference will be made later on.

One may thus suppose that an ultimate birthrate β_0 could be deduced which would represent that rate when infantile mortality was reduced to zero, and that any actual birthrate may be put in the form

$$\beta = \beta_0 + b\mu \text{ ....(9)}$$

in which, as may be seen from (8) above, b must be very small and theoretically should always be positive.

The result deduced may be expressed as follows:—

(i) *When either all mothers of deceased infants, or any constant proportion thereof, may be regarded as subject to equal risk of fecundity* (i.e. equally likely to bear chil-

dren) *then equal increases in the rate of infantile mortality tend to be followed by equal though relatively small increases in the birthrate.*[1]

(ii) *The influence of infantile mortality on the birthrate must always be very small.*

5. In order to test these propositions, the appropriate graphs for a number of countries have been prepared. In these the infantile mortality rate is taken as corresponding to the year following the birthrate. Widely divergent as are individual points, the results on the whole are definite enough. The graphs are shewn in Fig. 1, and the results are as shewn in "Table I" hereunder.

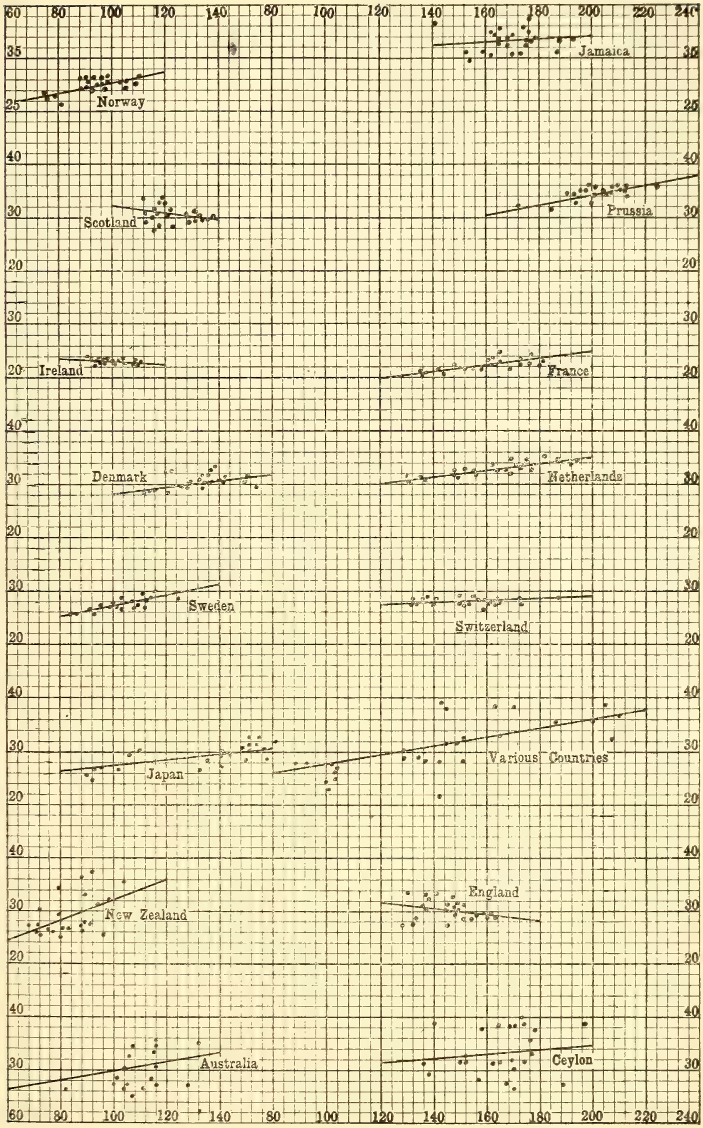
In order to get a fairly wide range of values of infantile mortality and birthrate the period covered has in most cases been 25 years: but in addition to this the data for all countries have been plotted for a single year, this implying the relation which might be assumed to exist for the group of countries, considered as a whole, at the beginning of this century.

It may be remarked as curious, that the relation for the various countries tabulated for 1901 (1902) is sensibly identical with that for the period 1887 – 1905 (1888 – 1906) for the Commonwealth of Australia.

6. Looking through the table it is seen that the birthrate for Switzerland and Jamaica are sensibly unaffected by the rate of infantile mortality, while for Ireland, England and Wales, and Scotland, it actually decreases with increase of infantile mortality. The fundamental assumption consequently, however correct on the whole, may clearly be modified by other factors, the tendency of which in some other direction, may preponderate sufficiently to mask that

[1] See last paragraph Section 8 hereinafter in regard to the limitation of this proposition.

Birthrates, *i.e.* number of births per 1000 of the population.



RATES OF INFANTILE MORTALITY.
(Deaths of infants under 12 months of age, per 1000 births.)

Fig. 1.

TABLE I.

Influence of the Rate of Infantile Mortality on the Crude Birthrate.

Country.	Period.		Value of β_0 and b in $\beta = \beta_0 + b\mu$	
	Birth.	Mortality.		
New Zealand ...	1881 – 1905	1882 – 1906	13·2	+0·191
Commonwealth...	1887 – 1905	1888 – 1906	16·8	+0·118
Sweden... ...	1881 – 1904	1882 – 1905	17·1	+0·100
Norway ...	1881 – 1905	1882 – 1906	20·5	+0·100
Prussia... ...	,,	,,	19·1	+0·085
Various countries for one year	1901	1902	19·4	+0·083
Netherlands ...	1881 – 1905	1882 – 1906	22·6	+0·063
France	,,	,,	12·7	+0·061
Denmark ...	,,	,,	22·4	+0·060
Japan	1881 – 1904	1882 – 1905	22·3	+0·053
Ceylon	1881 – 1905	1882 – 1906	26·4	+0·042
Jamaica ...	,,	,,	34·3	+0·022
Switzerland ...	1881 – 1904	1882 – 1905	25·3	+0·018
Ireland	1881 – 1905	1882 – 1906	25·8	−0·026
England & Wales	,,	,,	38·6	−0·058
Scotland ...	,,	,,	38·9	−0·068

The infantile mortality rate (μ) is expressed by the number of infants dying per 1000 of infants born.

The crude birthrate (β) is the number of births per 1000 of the total population.

of collateral increase. That the tendency may thus be easily masked is however not remarkable, since the influence of variations in the rate of mortality is always small.

The unweighted mean of the above results, and the weighted mean, taking the respective populations at the middle of the birthrate periods as weights, are:—

Unweighted Result $\beta = 23{\cdot}73 + 0{\cdot}0507\,\mu$.........(9a)

Weighted Result $\beta = 22{\cdot}76 + 0{\cdot}0333\,\mu$.........(9b)

7. There is no reason to suppose that the absolute magnitude of the birthrate is significantly affected by the way in which the rate of infantile mortality is associated therewith. This is indicated by the fact that its influence upon

the birthrate is sensibly the same for France, with a very low birthrate, as it is for the Netherlands and Denmark with relatively high birthrate, viz. rates nearly double that for France. There may however be other circumstances affecting the relation between infantile mortality and birthrate not considered in the fundamental assumption which shewed *a priori* that the linear relation equation (9) was justified.

8. Reverting to equations (1) and (2) the purview may be extended to all the countries for which fairly accurate statistics are readily available, viz. for the following countries:—

Austria, Belgium, Chili, Ceylon, Denmark, England and Wales, France, Ireland, Italy, Jamaica, Japan, Netherlands, N. S. Wales, New Zealand, Norway, Queensland, Russia, Scotland, S. Australia, Spain, Sweden, Switzerland, Tasmania, Victoria, West Australia.

This will reveal the relation for this group of countries, on the assumption that, if definite at all, the characteristics of the relation do not fluctuate during the whole period under review, that is to say, the relation is not a function of the elapsed time.

There is, of course, a fundamental objection of some weight to this procedure, viz. that it supposes that the groups are comparable in all other respects and are homogeneous. Doubtless such a large country as Russia might be divided into smaller units in which the range of mortality even for a single year would be considerable. And, in general, the characteristics of rural and urban populations are sensibly different. They nevertheless, fall under one grouping by inclusion in the statistical results for the whole of a country. These defects minimise the precision with which such statistical groupings represent the intel-

ligible fact, or such a result say as could be expected when the total area considered was divided into approximately equal areas with homogeneous populations.

Neglecting these defects and forming groups for approximately every change of 5 units in the rate of infantile mortality, as ordinarily reckoned, viz. deaths per 1000 born, the following results are obtained :—

TABLE II.

Effect of Infantile Mortality on Birthrate.

Infantile Mortality per 1000 births.	Crude Birthrate per 1000 population	Population (millions)	Births (thousands)	Infantile deaths, (hundreds)	Infantile Mortality per 1000 births.	Crude Birthrate per 1000 population.	Population, (millions)	Births (thousands	Infantile deaths, (hundreds)
68·8	34·14	2·9	99	68	206·4	36·73	218·4	8022	16557
71·0	26·32	3·8	100	71	211·5	37·15	268·7	9983	21117
76·9	31·58	22·1	698	537	217·9	36·81	106·0	3902	8503
82·3	30·30	13·4	406	334	221·3	37·96	69·1	2623	5805
87·7	28·15	13·0	366	321	226·0	37·96	133·5	5068	11454
91·8	26·33	163·3	4300	3948	230·0	37·52	26·2	983	2261
95·9	26·23	125·6	3294	3158	237·2	38·68	68·2	2638	6258
101·8	26·50	115·2	3053	3108	240·6	46·55	143·1	6662	16026
106·7	28·90	96·3	2783	2970	248·0	47·77	167·9	8021	19892
111·3	29·47	98·7	2909	3237	251·4	49·95	280·0	13426	33749
116·9	30·92	54·3	1679	1963	255·9	47·63	104·6	4982	12747
123·2	29·80	114·4	3409	4198	260·1	47·91	99·0	4743	12335
127·6	28·44	163·9	4661	5947	265·1	48·64	95·4	4640	12299
131·7	30·37	383·9	11658	15351	272·8	46·74	287·9	13457	36713
137·0	27·89	514·2	14339	19638	277·1	48·32	186·1	8993	24921
142·0	27·35	570·6	15608	22170	280·0	49·52	93·6	4635	12978
147·4	29·90	402·6	12038	17750	289·0	48·60	92·0	4471	12920
151·9	29·72	687·1	20423	31028	292·0	35·67	3·0	107	312
156·6	29·11	360·1	10484	16422	304·0	36·33	3·0	109	331
161·8	27·69	466·9	12927	20910	307·0	46·41	96·1	4460	13692
166·3	28·93	433·5	12543	20859	313·0	36·67	3·0	110	344
172·4	29·86	224·3	6697	11547	329·0	34·52	3·1	107	352
176·2	30·62	205·0	6278	11064	332·5	39·26	5·4	212	705
183·0	32·00	279·7	8951	16381	337·0	35·81	3·1	111	374
186·8	34·98	165·8	5800	10832	344·0	33·87	3·1	105	361
192·4	36·41	189·9	6915	13306	349·0	37·42	3·1	116	405
197·4	35·92	275·4	9893	19532	366·0	36·25	6·4	232	849
203·2	36·00	257·8	9280	18854	412·0	38·15	2·7	103	424

These results are shewn in Fig. 2 in which curve *A* (firm lines) represents a simple type of curve closely conforming to the results and having regard to their weights, and curve *B* (broken lines) a more complex type still more closely

representing the weighted results. Seeing that the origin of the curve must necessarily be the zero of both co-ordinates, the point 0, curve A, is not expressible by any simple relation capable of rational interpretation, much less is curve B in Fig. 2. Moreover, equations (6) and (9) though well representing the relation within certain limits, cannot be regarded as quite general, forasmuch as they imply that when β falls to β_0 there would be no infantile mortality whatever, whereas actually μ and β must become zero together, and further it is not essential that for any value of β there must be a corresponding value for μ.

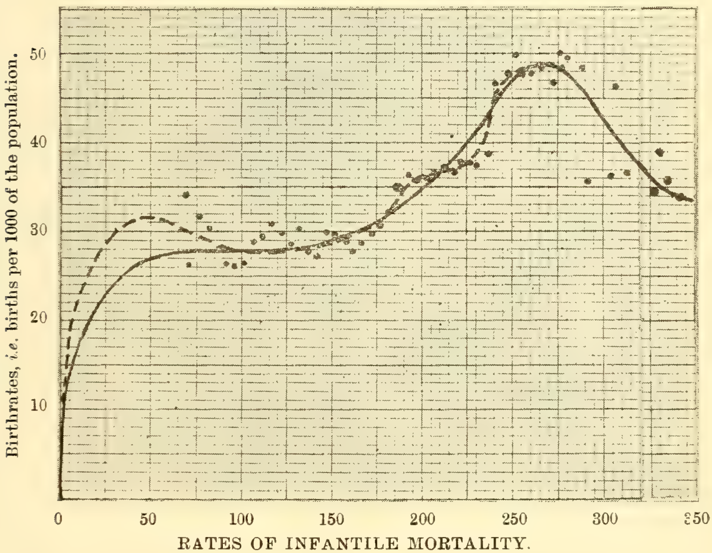
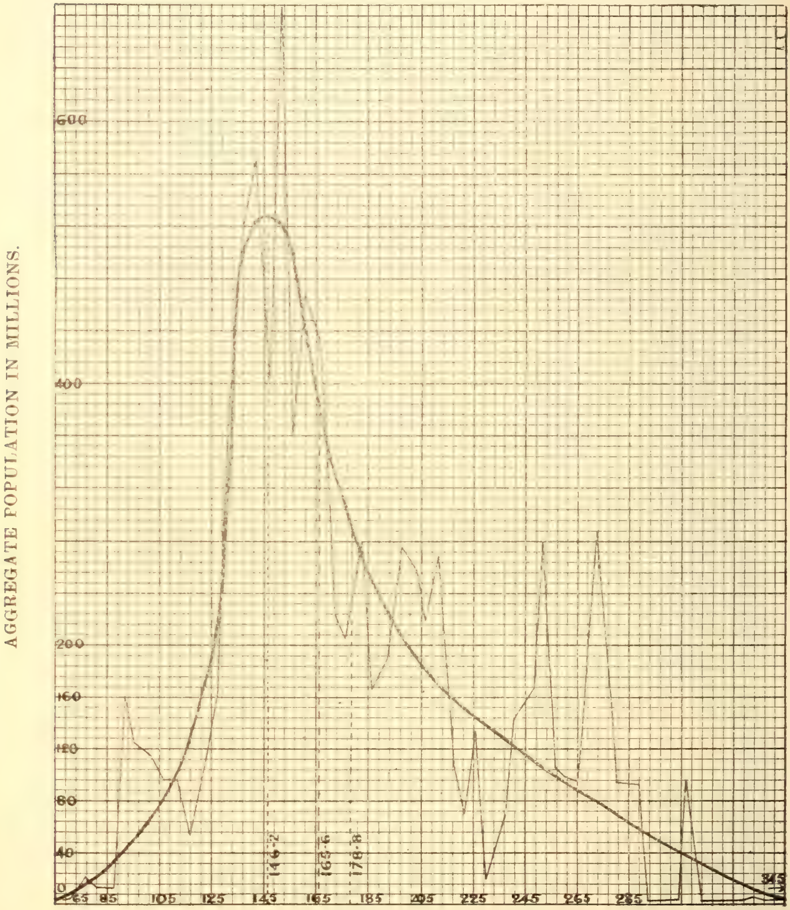


Fig. 2.

Propositions (i) and (ii) in section 4 are consequently true only for individual countries, and between the restricted limits of actually occurring rates for their entire populations.

9. Subject to the defects pointed out in the preceding section (3rd paragraph thereof) it will be possible to get some idea of the way in which infantile mortality of any

given magnitude is distributed throughout the total of the 25 countries referred to, by plotting the total populations exhibiting particular infantile mortality rates as ordinates, against the rates as abscissæ. The results may be expected to be somewhat erratic owing to the objection indicated,



RATES OF INFANTILE MORTALITY.
(Deaths of infants under 12 months of age per 1000 births.)
Fig. 3.

but will nevertheless disclose something of the nature of the relative frequence of different rates of infantile mortality for the entire population group represented. The thin lines in Fig. 3 shew the results as given, while the heavy line indicates the curve (of same total area) which may be taken to represent the general result.

10. It will be seen from Figure 3, that in so far as the graduated result can be taken to exhibit the frequency of any particular rate of infantile mortality, it would appear that the dominant rate (the mode) is 146·2, and the median is 165·6. The centroid vertical of the curve corresponds to a rate of infantile mortality of 178·8.

As already pointed out, however, the various populations are not subdivided so as to constitute homogeneous groups, and hence the curve should be regarded as furnishing only a rough indication of the true characteristics of the distribution of infantile mortality in the group of countries under review.

11. In deducing the linear equation representing the influences of infantile mortality on birthrate, the crude rate, should strictly be corrected for differences in the sex and age constitution of the population, in order that the results may be strictly comparable. The irregularities indicated however are so large in comparison with any correction for reduction to a common basis, that such correction would have very little significance, and in fact, may be ignored. The linear variations of birthrate as related to variations of infantile mortality deduced herein, are abundantly accurate for the purpose of eliminating this element for comparisons requiring such elimination. Secular changes in the correction factor b in (8) and (9) are of course to be expected, but can be deduced only by observation of very long periods. These may perhaps disclose that the theoretical linear law is only an approximation to

the actual. This indeed is suggested by the fact, that while the weighted mean gives

$$\beta = 22{\cdot}76 + 0{\cdot}0333\,\mu \ldots\ldots\ldots (10)$$

the results for various countries for 1901-2 gives

$$\beta = 19{\cdot}4 + 0{\cdot}083\,\mu \ldots\ldots\ldots (10a)$$

which, if it means anything at all, would imply that the correction is becoming more significant. For individual countries the factor b could be taken from Table I, and the birthrate corresponding to an absence of infantile mortality as given by

$$\beta_\circ = \beta - b\mu \ldots\ldots\ldots (11)$$

in which b is the tabular factor, and μ the rate of infantile mortality for the preceding year.

12. The actual deductions made as to the influence of infantile mortality on the birthrate of any country should perhaps be regarded merely as a general indication. The theoretical deduction gives the elementary law, but to obtain the actual coefficient b it would be necessary to be assured that no other source of variation in the relation investigated, was operating. A thoroughly satisfactory investigation demands the proper subdivision of population into homogeneous groups, and the elimination of other influences. The present investigation should be regarded as an indication of the way, rather than as a final solution.

NOTE ON PUCHERITE FROM WEST AUSTRALIA.

By E. Griffiths,
Caird Scholar, University of Sydney.

[Communicated by J. A. Schofield, Acting-Professor of Chemistry, University of Sydney.]

[*Read before the Royal Society of N. S. Wales, November 4, 1908.*]

During 1907 a few grams of concentrates from an oxidised quartz reef at Niagara, 115 miles north of Kalgoorlie, W.A., were forwarded to the Chemical Laboratory from Mr. C. F. de J. Grut, M.A., B.E., of Kalgoorlie, with the suggestion that they might contain Pucherite, a Bismuth vanadate. Mr. Grut stated that the quartz reef occurred in the typical so-called "diorite" (more strictly amphibolite) country.

The concentrates consisted largely of grains of silica, magnetite, pieces of metallic sulphides and metallic bismuth. In addition to the above there was a mineral which occurred in the form of approximately cubical, crystalline grains about $\frac{1}{2}$ mm. diameter, chrome yellow in colour, brittle and with a resinous lustre. These were picked out by hand with the aid of a lens. On crushing in an agate mortar a lemon yellow powder was obtained. The mineral dissolved in sulphuric and hydrochloric acids yielding a red solution. On warming the hydrochloric acid solution chlorine was evolved. On passing H_2S through the HCl solution and filtering, a deep blue filtrate was obtained, which on evaporation with HNO_3 yielded a dark red fusible residue, having the properties of vanadium pentoxide. The mineral gave a light green borax bead in the reducing flame. On charcoal in the reducing flame it fused and yielded a metallic bead of bismuth.

The specific gravity, determined on the original grains by means of a pyknometer was 5·7.

Analysis gave the following results:—

Bi_2O_3	=	73·77%
V_2O_5 (including trace of P_2O_5)	=	25·31%
Fe_2O_3	=	·36%
Residue insoluble in HCl ...	=	·81%

The method of analysis was as follows:—The mineral was treated with hydrochloric acid, the insoluble residue removed by filtration, and the bismuth precipitated as sulphide. The sulphide was dissolved in nitric acid, the solution evaporated almost to dryness and treated with water in order to obtain the bismuth oxynitrate; this was ignited to oxide and weighed. The chloride solution containing the vanadium was converted into a nitrate solution by evaporation with nitric acid. The iron was precipitated by adding a slight excess of sodium carbonate, the precipitation being repeated four times. The small quantity of vanadium still retained by this precipitate was removed by fusing with sodium carbonate and extracting with water, the extract being added to the main solution, The vanadium was precipitated from the slightly alkaline solution as mercurous vanadate by means of mercurous nitrate. The precipitated vanadate was ignited to the pentoxide and weighed as such.

The analysis and physical properties agree fairly well with those recorded in Dana's Mineralogy for Pucherite, Bismuth vanadate. So far as I have been able to ascertain this is the first recorded instance of the occurrence of Pucherite in Australia.

In conclusion I desire to thank Acting-Professor Schofield for affording me the opportunity of working on the mineral and also for much useful advice during the work.

THE RAINFALL OF AUSTRALIA.

By John Barling.

[With Plates XL. - XLI.]

[Read before the Royal Society of N. S. Wales, December 2, 1908.]

In bringing before your notice the rainfall charts now exhibited, and which are designed to shew at a glance the rainfall system of Australia, giving its chief characteristics, I must ask your indulgence if my explanation of them is not at once clear. The time involved in getting together such details, so as to present a comprehensive view of the whole, not being at the disposal of many, will, I trust, make such a compilation as that now before you interesting and valuable. Before going further I have to make my acknowledgments to the official heads of the Meteorological Stations of Sydney, Adelaide, Brisbane, Perth, Melbourne, and Hobart, for much of the information given on the charts, and, without which, these could not have been made.

I am treating the subject from the standpoint of a non-scientific man. I can claim to be nothing more than this myself, but the non-scientist can collect data for the scientist, and I trust this compilation will prove to be valuable.

On the map of Australia I have shewn the annual rainfall as it occurs in characteristic places on its surface—by shewing more places I should only have cumbered the chart with superfluous details—places intermediate have generally such a rainfall as one would presuppose after looking at the map. The spaces between the concentric rings represent 10 inches in every case, and each ray a year, the

length of the ray equals the total rainfall for that year, and each ray is dated. Thus a comparison of the amount of rain in various places for any year is at once apparent. It will be seen that the lowest rainfall known in Australia is that in the vicinity of Lake Eyre. This lake bed, now mostly dry, is below sea level. In contrast to this low rainfall, you will see represented, by a long line, the greatest annual rainfall known in the world, that of the Khasi Hills in Assam, India, where more than 500 inches in one year has been frequently recorded. As to how the climatic conditions, and state of the country in the vicinity of Lake Eyre have undergone a marvellous change in, geologically speaking, recent times, let the abundant fossil remains found there testify.[1]

These remains are of extinct marsupial herbivores of different sizes; Diprotodons, some equalling or surpassing a rhinoceros in bulk; near these are the remains of huge birds, kangaroos, and other animals. No vegetation now existing in those parts could provide sufficient food for these creatures, and yet, strangely enough, analysis of the supposed contents of the stomachs of these huge animals, shews that they fed on Salsolaceous plants,[2] and this kind of vegetation is still represented on their old runs, perhaps

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[1] See *Mem. Roy. Soc., South Australia*, Vol. I., part i, by E. C. Stirling, C.M.G., M.A., M.D., F.R.S., and A. H. C. Zietz, F.L.S.

[2] Salsolaceous plants in Australia seem to be a characteristic of its dry parts, and these plants have been shewn to be food for "Diprotodon." Our western pines *(Callitris robusta)* apparently flourished there also at that time, so that, perhaps, the scant rain conditions of the present time, also obtained in the remote past, in the Lake Eyre district. Professor Stirling has suggested that *Diprotodon* was a swamp-haunting animal, if only we may reasonably suppose that in time past heavy rains such as those referred to, were not infrequent, and also that they fell over the watershed of Lake Eyre, then periodical inundations of the lake country must be a consequence—thus producing swamp conditions and vegetation which would perfectly suit huge, slow moving animals, such as *Diprotodon* apparently was.

on a much smaller scale. By the courtesy of Professor Stirling, Director of the South Australian Museum, I am supplied with a drawing of a "Restored Diprotodon," a copy of which is now shewn, together with other details. Diprotodons appear to have been very widely distributed over Australia. Does the time when these animals lived, synchronize with the time when the now deeply buried forests were growing on the surface? These forests were described by the writers of the paper recently read by Prof. David and Mr. G. H. Halligan, referring to land subsidences. Is this change still operating?

The very dry parts of Australia seem to be chiefly confined to a belt of country extending in a west-north-west direction from Lake Eyre. At Cossack, on the coast of West Australia, the year 1891 was practically rainless, whilst at same place, the year 1900 experienced a rainfall of 40 inches, but the yearly average there is very low. The large extent of country in Australia, now subject to a uniformly low rainfall, seems remarkable. Coming to the east coast of Australia, some very irregular falls have occurred; on the hills near Brisbane in February 1893, the rainfall for four successive days was, on the first over 10, on the second over 20, on the third over 35, and on the fourth over 10 inches. This constitutes a record for Australia during historical times. In the same locality some years have had a total of less than 20 inches. Is it unreasonable to suppose that similar heavy rains may have occurred in the past and over a much larger extent of country?

There would then be no difficulty in accounting for large inland lakes and swamps. I would also refer to the heavy rainfall at "Dry Lake," near Wilcannia, at no distance from Lake Callabonna. Dry Lake is a great depression never known up to 1885 (?) to contain water, but one day's rain

converted it into a large lake. On this occasion (I have not been able to ascertain the exact date) it is reported that 8 inches of rain fell. About this time also, the Paroo River discharged its flood waters into the Darling River, an event before unknown by white men, and not since repeated. But great as these rains were, they are small when compared with those on the Khasi Hills, already referred to, there 30 inches of rain for five successive days have been recorded.

Compare this with what are called heavy rains in Great Britain and elsewhere. At Camberwell near London on 1st August, 1846, some 3 inches of rain fell in two hours seventeen minutes; in London on 13 April, 1878, $4\frac{1}{2}$ inches; in Cumberland, on 27 November, 1878, $6\frac{1}{2}$ inches; at Joyeuse, France, in 22 hours, 31 inches; at Genoa, in 24 hours, 30 inches; at Gibraltar, in 26 hours, 33 inches; at Sydney, the greatest fall in any one day, was on 25th February, 1873, when 9 inches was recorded, and on 28th May, 1889, when 8 inches of rain fell.

Going further north, we find that Geraldton, Queensland, holds the record for uniformly great rainfall for all Australia. The falls there going up as high as 212 inches in 1894, whilst the lowest recorded there was 70 inches in 1902. No wonder that engineers look with longing eyes to the water power at present going to waste at the Barron Falls in the locality. On the adjacent coast of Papua a remarkable variation in rainfall is to be noticed. Port Moresby has a comparatively small rainfall, whereas at a few miles on either side—at Daru, near the mouth of the Fly River, on the one side, and at Samarai on the other, the fall is large. Does the deficiency at Port Moresby in any way account for the excess at Geraldton? Coming round to Palmerston in the Northern Territory, the rainfall there is good and with marked regularity, the first and last three months of

the year being very wet, whilst the middle six months are extremely dry.

The coast from Perth to Albany has a good and sufficient rainfall, but from Albany all round the Australian Bight the rainfall is very scanty. For Adelaide I have shewn a wind chart, and this seems to be an illustration of a well known law, viz., "If the winds, even though having traversed a large extent of Ocean, yet on arriving at the land proceed to lower latitudes or regions markedly warmer, the rainfall is small or nil."[1]

It will be seen that the best rains in the wheat growing area near Adelaide occur in the middle six months, when wheat crops require good rain; then, the winds are chiefly northerly, and but little rain falls in the first and fourth quarters when the winds are chiefly from the Southern Ocean; this reverses the conditions at Palmerston. In some few cases I have shewn in which part of the year the greatest rain falls—at Palmerston, Geralton (Q.), Adelaide and other places.

To get a true estimate of the rain conditions, the quarterly returns should be shewn in each case, or better still, monthly returns. With this information supplemented by temperature records, one could determine with much accuracy what crops would be suitable for cultivation in any given part, always supposing that the soil is good. I should like to see such work undertaken by the Commonwealth Government. It would greatly benefit intending settlers from other countries.

Coming to Tasmania, a very remarkable irregularity appears in the rainfall. Whilst a small part near the north-west coast has an annual rainfall up to 145 inches, at Hobart there has never been more than 40 inches, and that

[1] *Encyc. Brit.*

quantity but once since records have been kept there. Somewhat similar, is the annual rainfall in parts of Mauritius, at Gros Caillou, viz :—30 inches. At Cluny, only 16 miles distant, we have 146 inches.

Going inland from Sydney along the railway, Bathurst shews a low rainfall, whereas on either side of that city, at Katoomba and Orange, the rainfall is high. The railway section shewn in the margin, probably explains this curious fact. Bathurst is at the bottom of a deep basin, whilst Katoomba and Orange are on its rim. Apparently showers do not follow the contour of a country.

So far, it seems that our records extend over too short a time to determine if there be any rainfall cycle in operation or not. I look forward with confidence to a time when something definite in this respect will be observed. Such a consummation will be invaluable. It would appear that in very ancient times in Assyria, the early cultivators of the soil believed in the certainty of forecasting the weather and in the periodicity of similar seasons. What their system was, and what results were obtained, history does not disclose, "and there is no new thing under the sun." Our meteorologists now can give forecasts for a day or two in advance, but this is of little use to the man on the land —a whole year's forecast is what he requires to know, to do him much good, and I confidently look forward to the time when the meteorological department will supply this information. Judging by the rainfall as shewn, there seems to be an immense extent of country in west and north-west Queensland, in the Northern Territory and in the northern part of West Australia which will in time to come carry a large population—a white one it is to be hoped.

On the second chart (4 sheets[1]) I have shewn on the main part of it, the daily rainfall for Sydney since 1857, and up

[1] Not reproduced.

to date. The chart is divided into columns giving the 365 days of the year and the horizontal lines across the chart give the inches of rain. By plotting each year's rain track and starting at the left hand top, a comparison can be made for any day of the separate years. In parts, the crossing and recrossing of the tracks looks confusing, but by using the final figures of each year, for the traverse, the course of any year's rain track can be followed, thus for the year 1860, the two figures 60 are constantly repeated to shew its track, and so on. Those days in which no rain falls, must, of course, be shewn as a horizontal track.

The difference in the rain track of 1888 and 1860 is very startling. Apparently we have in these years, a minimum and maximum rainfall for Sydney; and yet up to 22 July, the years 1864, 1867, 1874 and 1900 had a greater rainfall than 1860, whilst the year 1890 had a greater rainfall than 1860 up to 15 November. Taking a period of say 10 years, there is a marked similarity in the distribution of rain all over New South Wales, that is to say, if a series of years, not individual years, give a high rainfall for Sydney, so will the same series shew a high rainfall over the State generally and vice versa. To shew this, another diagram is needed. The black discs on the chart shew when half of the year's total rain had fallen. Generally, it will be seen that the first six months of the year has more rain than the latter half. This year 1908, however, is one of the exceptions; it already shews that the last six months must have more rain than the first half of the year.

In columns below you will see the rainfall for the separate months for all years, grouped, and also the monthly fall for each year in other columns,—April the greatest, closely followed by June, whilst December shews the lowest. I think these diagrams are very interesting as bearing upon the *Water Supply of Sydney*. It seems to demonstrate

that although the total rainfall for years may be lower than what is called the average, still there may be, and, in fact, mostly is, an abundant rainfall for supplying Sydney with water from the present watershed, if only what rain falls on it is conserved, instead of allowing so much to go to waste after every little flood, and this even with the great possible increase of population foreshadowed by Mr. Keele in his paper,[1] and the increased quantity per head which should be provided for all in the Metropolitan area.

Mr. Deane drew attention in his paper read 5th July, 1899, to the fact that a low total rainfall for a long period might still be sufficient for a water supply. The pressing need for the conservation referred to above, has already been insisted on by Mr. Keele, and I think cannot be too strongly put. I am assuming that the rainfall on the catchment area is not less than that of Sydney, and figures shew that this is a safe assumption. In proof of these statements I would give the following particulars :—

In 1862, with a total rainfall of 2,398 points or 24 inches,

On the 8th and 9th February, ...	271 points fell
,, 23rd June...	129 ,,
,, 3rd and 4th	152 ,,
,, 15th December	190 ,,

These showers must have given a large run off.

In 1865, with a total rainfall of 3,629 points or 36⅓ inches,

On the 13th February	180 points fell
,, 14th February	120 ,,
,, 8th, 9th, 10th June ...	265 ,,
,, 3rd and 4th November ...	365 ,,
,, 26th November	395 ,,

In 1866, with a total of 3,681 points or 36¾ inches,

On the 29th January ... ... 191 points fell

[1] This Journal, XLII., p. I.

On the 15th and 16th February ... 264 points fell.
,, 16th and 17th May ... 268 ,,
,, 13th, 14th and 15th June 391 ,,
,, 12th July ... ... 300 ,,

In 1888, Drought year, rainfall for year 2,301 points, or 23 inches. There would still have been a little caught.

On the 3rd July ... ... 122 points fell
,, 28th July ... ... 91 ,,
,, 8th August ... ... 117 ,,
,, 1st December ... ... 275 ,,
,, 16th December ... ... 265 ,,

In 1880, another dry year, with 2,951 points or 29½ inches

On the 29th and 30th March ... 215 points fell
,, 2nd April ... ... 123 ,,
,, 16th September ... ... 204 ,,
,, 27th September ... ... 149 ,,
,, 21st October ... ... 102 ,,
,, 9th November ... ... 123 ,,

In 1863, with a total of 4,708 points or 47 inches,

On the 22nd January ... ... 375 points fell
,, 15th February ... ... 104 ,,
,, 17th February ... ... 131 ,,
,, 26th February ... ... 117 ,,
,, 1st March... ... ... 138 ,,
,, 23rd and 24th April ... 424 ,,
,, 11th, 12th, 13th, 14th Aug. 532 ,,
,, 6th and 7th September ... 214 ,,

In 1881, with a total of 4,109 points, or 41 inches,

On the 11h April ... ... 230 points fell
,, 10th June ... ... 236 ,,
,, 19th October ... ... 425 ,,

In 1882, with a total of 4,228 points or 42¼ inches,

On the 5th and 6th April... ... 946 points fell

On the 10th June ...	... ...	380 points fell.
,, 26th October	... ...	181 ,,
,, 29th October	... ...	424 ,,

In 1885, with a total of 3,991 points or 40 inches,

On the 22nd, 23rd, 24th, 25th June 1250 points fell

In 1886, with a total of 3,943 points, or 39½ inches,

On the 28th January	... ...	195 points fell
,, 14th March	... ...	195 ,,
,, 26th March	... ...	163 ,,
,, 28th May ...	... ...	172 ,,
,, 15th October	... ...	468 ,,

These examples do not exhaust the list of similar storms.

Compare these with 1887 with a fall of 6,016 points or 60 inches. There were only two days in the year when good reservoir-filling rains fell, that is on the 29th and 31st May, when the falls were 283 points and 218 points. On no other day was anything up to two inches recorded.

From these details I think it will be seen that the present catchment area is ample for all purposes. Taking in an additional watershed, with all due respect to Mr. Keele, seems to be unnecessary. It is somewhat on a par with a farmer who in a slovenly manner cultivates 1,000 acres, in comparison with one who scientifically and therefore in a common sense method, works say 200 acres; better returns would be obtained in a majority of years from the smaller area.

The longest period of dry weather that I can find recorded was the nine months, June 1875 to April 1876, during which time no reservoir-filling rain fell, but as there were good rains both before and after that time, there could be no shortage in the water supply. The driest seven years' period in Sydney was from 1901 to 1907 both years inclusive—all years below the average—but the lists herewith will

shew that fine rain storms fell at frequent intervals all through the period, with the exception of the year 1903, this year was the *worst* recorded for water supply. On no day throughout the year was there a fall of two inches, and yet the total 3,861 points or 38½ inches for the year, was not too small a quantity for general purposes.

Sydney Rainfall.

The driest seven consecutive years on record, all below the average.

1901 with a total of *40* inches.

On the 22nd January ...	306 points	
,, 27th April	295 ,,	
,, 28th April	442 ,,	
,, 20th August ...	200 ,,	

1902 with a total of *43* inches.

On the 14th July	173 points	
,, 16th July	181 ,,	
,, 27th July	194 ,,	
,, 13th October ...	637 ,,	

1903 with a total of *38½* inches.

On the 7th May	158 points	Worst year for water conservation
,, 25th and 26th July	270 ,,	
,, 3rd August... ...	157 ,,	
,, 18th September ...	126 ,,	

1904 with a total of *46* inches.

On the 27th, 28th, 29th April	474 points	
,, 26th, 27th, 28th May	400 ,,	
,, 9th July	477 ,,	

1905 with a total of *35* inches.

On the 3rd and 4th March...	397 points	
,, 2nd April...... ...	364 ,,	

1906 with a total of *32* inches.

On the 29th May	335 points	Prospect Reservoir overflowed on the 19th September.
,, 31st August... ...	362 ,,	
,, 14th November ...	187 ,,	

1907 with a total of *31⅓* inches.

On the 16th March... ...	362 points	
,, 15th, 16th, 19th June	504 ,,	

A REVISION OF THE AUSTRALIAN ORECTOLOBIDÆ.

By J. DOUGLAS OGILBY and ALLAN R. McCULLOCH.

[With Plates XLII., XLIII.]

[Communicated by C. HEDLEY.]

[*Read before the Royal Society of N. S. Wales, December 2, 1908.*]

THE *Orectolobidæ* are a family of ground-sharks of primitive characters, popularly known in Australia as Carpet-Sharks or Wobbegongs and Cat-Sharks. Of somewhat sluggish habits and small size, they do not endanger life or limb, nor do they rob the fisherman as do their more active relations. The senior author of this paper has enjoyed control of a large series gathered by the Amateur Fishermen's Association of Queensland, and has also been favoured with opportunities of study in the Queensland State Museum. The junior collaborator has been granted by the Trustees of the Australian Museum permission to incorporate notes on the collection in his official custody. For these advantages they tender grateful acknowledgement.

When our paper was almost ready for press we received Mr. C. Tate Regan's "Revision of the Sharks of the Family Orectolobidæ."[1] We have therefore had to insert the references to his work more hurriedly than we would desire. As will be seen, a study of large series of some species has led us to somewhat different conclusions to those at which he has arrived, and it is principally to these that we have devoted the short time available. Further, as he has taken into consideration all the species of the family, we have curtailed our first intentions, and have confined ourselves to the Australian species only.

[1] *Proc Zool. Soc.*, 1908, p. 347.

Family ORECTOLOBIDÆ.

Form variable; tail not or but little bent upward from the base of the caudal. Body and fins covered with small, smooth or feebly carinated scales. Head with numerous mucous pores, especially on the lower surface of the snout. Nasal cavity with a free cirrus; oro-nasal grooves present; labial folds usually well developed. Eye small, elongate-oval, with rounded pupil; no nictitating membrane. Gill-slits narrow, the two last closer together than the others; three, rarely four, above the pectoral. Two small, subequal, spineless dorsal fins, the first above or behind the ventrals: upper flap of caudal fin vestigial, the lower moderately developed, with a shallow notch near its extremity and no anterior lobe; pectorals and ventrals large. "Rostral cartilages, if present, short and not convergent. Pectoral mesopterygium enlarged and expanded distally, more or less similar to the metapterygium; an oval foramen between the mesopterygium and the metapterygium."[1]

Sharks of small to large size, inhabiting the tropical and temperate zones of the Indian and Western Pacific Oceans; one species—*Ginglymostoma cirratum*[2] from the Western Tropical Atlantic, occasionally straggling to the African coast.[3] Their food consists chiefly of crustaceans and mollusks.

Key to the Australian genera of the Orectolobidæ.

a. Anal fin commencing in advance of the second dorsal; spiracle minute, below the posterior angle of the orbit; teeth lanceolate, sometimes feebly cuspidate; species oviparous. *Parascyllium.*

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[1] Skeletal characters taken from Tate Regan's masterly "Classification of the Selachian Fishes," (*Proc. Zool. Soc.*, 1906, pp. 722 to 758.)

[2] *Squalus cirratus*, Gmelin, *Syst. Nat.*, i, 1789, p. 1492.

[3] Cape Verde, *fide* Capello, *Journ. Sci. Phys. Lisbon*, 1867, p. 167.

aa. Anal fin inserted nearly opposite to the second dorsal; spiracle minute, behind the eye; teeth in three series, of which the outer one only is functional; each tooth with a finely and evenly serrated convex edge; species oviparous? *Nebrius.*

aaa. Anal fin inserted wholly behind the second dorsal.

b. Spiracle large, situated below the level of the eye.

c. Teeth dissimilar, those in front long, slender, and smooth, those on the sides small, tricuspid, and in few series; sides of head with a more or less interrupted series of dermal lobes; species ovoviviparous. *Orectolobus.*

cc. All the teeth similar, small and tricuspid, arranged in many series; head without dermal lobes.

d. Tail short, not more than one third longer than the head and trunk; species ovoviviparous.

e. Head strongly depressed; mouth wholly in advance of the eye; anal fin approximate to the caudal. *Brachælurus.*

ee. Head not depressed; mouth below the front of the eye; anal fin remote from the caudal. *Heteroscyllium.*

dd. Tail long, not less than one half longer than the head and trunk; species oviparous. *Chiloscyllium.*

bb. Spiracle large, behind the eye; teeth inserted on a flat subquadrangular pair of transverse cushions; tail at least twice as long as the head and trunk; species oviparous. *Stegostoma.*

The genus *Nebrius*, Rüppell, considered by Regan to be a synonym of *Ginglymostoma*, M. & H., has not yet been recorded from Australia, but from its extended distribution will very probably be found here later. It is therefore included in this key for future convenience only.

Parascyllium, Gill.

Parascyllium, Gill, *Ann. Lyc. N. York*, 1861, p. 412; Günth., *B.M. Cat. Fish.*, viii, 1870, p. 410; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 349.

Body elongate, somewhat cylindrical, with the tail not elevated above the axial plane. Scales minute, lateral line fairly distinct. Head long and depressed, with a broadly rounded snout. A longitudinal fold below the eye. Nasal valve with an obtuse inner cirrus. Mouth inferior, and nearer to the tip of the snout than to the eye. Lower lip entire. Teeth minute and arranged in many series; similar in both jaws, being triangular and with or without lateral cusps. Spiracle minute, below the posterior angle of the eye. Posterior gill-opening very large; two above the pectoral. Tail about once and two-thirds the length of the head and trunk. First dorsal placed far behind the ventrals. Anal fin in advance of the base of the second dorsal. Caudal fin small. (παρα, beside; σκυλλιον, *Scyllium*).

Small sharks inhabiting the deeper water off the coast of South-eastern Australia and Tasmania.

Anal fin entirely in advance of the second dorsal; brown, with a dark nuchal collar, and with large dark spots. *collare.*

Anal partly below the second dorsal; body clouded with brown and with white spots, a dark nuchal collar closely spotted with white. *variolatum.*

Parascyllium collare, Ramsay and Ogilby.

Parascyllium variolatum, Günth. *B.M. Cat. Fish.*, viii, 1870, p. 410 (non Duméril).

Parascyllium collare, Ramsay and Ogilby, *Proc. Linn. Soc. N.S. W.*, iii, (2), 1889, p. 1310; Waite, *Mem. Aust. Mus.*, iv, 1899, p. 32, pl. ii, f. 2, and *Rec. Austr. Mus.*, vi, 1906, p. 229, pl. xli; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 349.

"Collared Cat-Shark."

Head 6·7 in the total length. Eye large, one half the length of the snout, which is slightly more than one fourth that of the head. Interorbital space very broad and flat, being equal to one third the length of the head. Nasal cirrus very short and thick, and not reaching to the margin of the upper lip. Outer fold of the nostril provided with a small supplementary cirrus-like lobe. Groove behind the lower lip not extending more than one fourth the distance across the mouth. First gill-opening a little nearer the base of the pectoral than to the spiracle; first to fourth subequal in width, the last very large, being $2\frac{1}{2}$ times as wide as the others and very close to the fourth. Tail once and two thirds the length of the head and trunk. First dorsal fin originating a little in advance of the middle of the length, triangular and with the apex rounded. Second dorsal similar in size and shape, its origin placed over the extremity of the anal, which is low with its outer margin rounded and pointed posteriorly. Caudal narrow and somewhat longer than the space between the two dorsals. Pectoral subquadrangular with rounded margins, and originating at a point two fifths of the distance between the tip of the snout and the vent. Ventrals much longer than broad, their outer margins broadly rounded, and the posterior angles acutely pointed.

Colours of a preserved example:—Light brown above with a broad dark brown nuchal collar, which is widest above and covers the space from a point just behind the eyes to between the bases of the pectorals. The tip of the snout and two small areas below the eyes are somewhat darker coloured. The body is ornamented with scattered darker spots, some of which are very large and ill-defined and tend to form cross-bars. The anterior part of the tail is similarly ornamented, but posteriorly the smaller spots are absent and the cross-bands are more distinct. The

vertical fins and the ventrals have also some ill-defined spots, but the pectorals are uniform. (*collare*, collared).

Type in the Australian Museum; total length 765 mm.

The above description is of a full grown male, taken off Broken Head, N. S. Wales, in 28 fathoms, in the Australian Museum. Reg. No. I. 3757.

Deeper waters off the coast of south-eastern Australia and Tasmania.

PARASCYLLIUM VARIOLATUM, Duméril.

Hemiscyllium variolatum, Duméril, *Rev. et Mag. Zool.*, 1853, p. 121, pl. iii, f. 1 and *Hist. Nat. Poiss.*, i, 1865, p. 327.

Parascyllium nuchale, McCoy, *Ann. Mag. N. H.*, xiii, (4) 1874, p. 15, pl. ii.

Parascyllium variolatum, Regan, *Proc. Zool. Soc.*, 1908, p. 349.

Differs from *P. collare* in having the anal fin placed a little farther back, it being partially below the second dorsal, and in lacking the supplementary lobe to the outer labial fold. Body and fins clouded with brown, which on the former tends to form cross-bands. A broad blackish-brown nuchal collar extends from half-way between the eye and the first gill-opening to the base of the pectoral. The back and sides of the body with numerous white spots which are very small and crowded on the dark nuchal collar. (*Variola*, the small pox).

Coasts of Victoria and Tasmania.

The only specimen available to us is a very badly stuffed specimen in the Australian Museum. It is labelled as a co-type of *Parascyllium nuchale*, McCoy from Port Phillip, Victoria, and exhibits the characters above described.

ORECTOLOBUS, Bonaparte.

Orectolobus, Bonaparte, *Faun. Ital.*, *Pesc.*, fasc. 7, 1834 *(barbatus)*; Jordan and Fowler, *Proc. U.S. Nat. Mus.*, xxvi, 1903, p 605; Regan, *Proc. Zool. Soc.*, 1908, p. 354.

Crossorhinus, Müller and Henle, *Arch. f. Nat.*, 1837, i, p. 396 *(lobatus = maculatus)*; *id.*, *Plagiost.*, p. 21, 1841; Günther, *B.M. Cat. Fish.*, viii, 1870, p. 413; McCoy, *Prod. Zool. Vic.*, Dec. v, 1880, p. 15.

Eucrossorhinus, Regan, *Proc. Zool. Soc.*, 1908, p. 357, *(dasypogon)*.

The "Wobbegongs" or "Carpet-Sharks."

Body rather elongate, broad and depressed in front, becoming gradually narrower behind, the tail compressed and tapering, scarcely elevated above the axial plane. Scales minute; lateral line inconspicuous. Head wide and strongly depressed, with very broad rounded snout, the sides with more or less numerous dermal lobes. Mouth nearly anterior, transverse, wide; lips thick and fleshy, fringed within; labial grooves well developed, not continuous across the symphysis of the lower jaw, behind which is a well marked longitudinal groove. Teeth in but few series, the anterior long, subulate, and smooth, the lateral small and tricuspid. Spiracles wide and oblique, below and partly behind the eye. Gill-slits subequal; three above the pectoral. Tail subequal to the head and trunk. First dorsal fin originating above or nearly above the end of the base of the ventral, slightly larger than the second; anal fin small, inserted wholly behind the second dorsal, approximate to and overlapping the caudal; caudal fin short. (ὀρεκτός, stretched out; λοβός, lobe).

Sharks of small or moderate size, inhabiting the coastal waters of Australia and Tasmania, southern and western New Guinea, Austro-Malaysia, China, Japan and the Cape Seas. Species five.

Regan (*loc. cit.*) has erected a new genus, *Eucrossorhinus* for *O. dasypogon*, Bleeker, principally on account of differences in the form of the gill-openings. We have re-examined the two specimens available to us, and also the figure given

by Saville-Kent,[1] and find that they do not differ from those of the other species, the last being the largest, and the last two closer together than the others.

The Wobbegongs or Carpet Sharks[2] are ovoviviparous ground sharks of sluggish habits, frequenting the neighbourhood of the shore, where they lie concealed among the weed covered rocks. Their beautiful colour patterns, harmonious contrasts of varied browns and lilacs, assimilate their surroundings so perfectly as to deceive the small fishes and crustaceans, which with mollusks, form the bulk of their food. The imitation is accentuated by the fringe of dermal lobes which adorn the lips and sides of the head, and which are not found in any other recent selachian.

Four of the five known species are Australian, but of these good specimens of two only, *O. maculatus* and *O. ornatus*, are available to us for examination. There are skins of the others, *O. dasypogon* and *O. tentaculatus* in the Australian Museum, and from these the accompanying observations and figure have been made.

a. Nasal cirrus simple; dorsal surface with numerous papillæ. *tentaculatus.*

aa. Nasal cirrus lobed; dorsal surface without papillæ.

b. Sides of head with a nearly continuous row of branched lobes *dasypogon.*

bb. Sides of head with only a few widely spaced lobes.

c. Body with large light ocelli.

d. Lobe of nasal cirrus simple; supra-labial lobes 2 or 3. *japonicus.*

dd. Lobe of nasal cirrus branched; supra-labial lobes 3 to 6. *maculatus.*

cc. Body marbled with distinct cross-bars; supra-labial lobes 2 to 4. *ornatus.*

[1] "The Great Barrier Reef," 1893, p. 307, pl. xlviii, f. 5.

[2] Occasionally one hears them miscalled "Tiger Sharks," but that name properly applies to *Galeocerdo tigrinus*, which from its strength and ferocity fully merits the title.

ORECTOLOBUS DASYPOGON, Bleeker.

(Plate XLIII, fig. 1.)

Crossorhinus dasypogon, Bleeker, *Arch. Néerl.*, 1867, p. 400, Waigiou; Günther, *B.M. Cat. Fish.*, viii, 1870, p. 414; Ogilby, *Proc Linn. Soc. N.S.W.*, xiv, 1889, p. 184, Torres Straits; Saville Kent, *Great Barrier Reef*, 1893, p. 307, pl. xlviii, fig. 5.

Eucrossorhinus dasypogon, Regan, *Proc. Zool. Soc.*, 1908, ii, p. 357.

"Fringed Wobbegong."

Body robust, the head being rather less than one-fourth of the total length. Snout broadly rounded and flattened above. Nasal cirrus with two or three simple or bifurcated lobes on their outer margins; the space between their bases equal to one-third the width of the mouth, and one-half that of the interorbital space. Upper eyelid with two papillæ. About six more or less branched dermal lobes on the upper lip, the outermost the longest. From behind the angle of the mouth to below the first gill-opening is a row of fourteen or more much branched lobes which are disposd in three groups, those of the first being the longest. Chin with a row of similar lobes of which the median are the longest. Gill-openings decreasing in size backwards to the fourth, the fifth being larger; the first and second are more widely spaced than the others. First dorsal fin originating in front of the posterior base of the ventral, and well behind the middle of the length; its anterior and outer borders gently convex with the angles rounded, and the hinder border straight. Second dorsal similar in shape but rather smaller and originating at a point one-third of the distance between the anterior base of the first dorsal and the end of the tail. Anal fin commencing below the hinder base of the second dorsal; its anterior margin slightly convex and the posterior rounded. Length of the caudal about 5·50 in the total length. Pectoral originating nearer to the tip of the snout than to the base of the ventral; the

anterior margin convex, and the outer nearly straight with the angles rounded. Ventrals similar in shape to the pectorals but much smaller. Skin covered with minute rough tubercular scales, which are smoother on the tail and hinder portion of the body.

Colour light sandy, covered with a network of dark brown rings which are small on the head and larger on the sides and tail. Each ring has a more or less distinct darker centre, which is plainest on the tail. At regular intervals large dark brown blotches break the uniformity of the network. About five inconspicuous darker cross-bands on the body and four more distinct ones on the tail. Fins similar to the body, except that on their posterior portions the network is finer; (δασυς, shaggy; πωγων, beard). Total length 1210 mm.

Type in the South Kensington Museum. Described from two specimens, one skin and one mounted specimen in the Australian Museum from Samarai, New Guinea, and Torres Straits.

Gunther, *loc. cit.*, states that the distance between the two dorsals is equal to the length of the base of the first. In our specimens it is not so long.

ORECTOLOBUS MACULATUS, Bonnaterre.

(Plate XLII., fig. 2.)

Barbu, Broussonet, *Mem. Acad. Sci., Paris*, 1780, p. 657, No. 7: New Holland.

Squalus maculatus, Bonnaterre, *Encycl. Meth. Ichth.*, 1788, p. 8: La mer du Sud.

Squalus barbatus, Gmelin, *Syst. Nat.*, i, 1789, p. 1493; Lacépède, *Hist. Nat. Poiss.*, i, 1798, p. 247; Schneider, *Syst. Ichth.*, 1801, p. 128.

Squalus, Watts' Shark, Phillip, *Voy. Botany Bay*, 1789, p. 285, pl. lii.

Squalus lobatus, Schneider, *ibid.*, p. 138.

Squalus appendiculatus, Shaw, *Nat. Misc.*, xvii, 1806, pl. 727 (after Phillip).

Crossorhinus barbatus, Duméril, *Hist. Nat. Poiss.*, i, 1865, p. 338 (part); Günther, *B. M. Cat. Fish.*, viii, 1870, p. 414 (part); Macleay, *Proc. Linn. Soc. N.S.W.*, vi, 1881, p. 365 (after Günther); Haswell, *Proc. Linn. Soc., N.S.W.*, ix, 1884, p. 92, pl. i, figs. 6 – 8.

Orectolobus barbatus, Regan, *Proc. Zool. Soc.*, 1908, ii, p. 355.

"Ocellated Wobbegong."

Body robust, its depth 8·25 in the total length. Width of head 1·10, depth of head 2·00 in its length, which is 1·55 in the trunk and 4·85 in the total length. Snout broad and rounded, narrowly declivous in front, flattened above. Internasal space 2·10 in the width of the mouth; nasal cirrus with a bifid lobe, its length 1·25 in the internasal space. Width of mouth 1·75, free space between lower labial grooves 4·35 in the length of the head. One or two papillary projections on the upper eyelid; space between eye and tip of snout 1·50 in its distance from the first gill-slit; diameter of eye 8·65 in the length of the head and 1·60 in that of the spiracle. Six simple dermal lobes above the upper lip; four longer lobes behind the angle of the mouth, the first and last longest and bifid, the inner branch of each notched at the tip; two low, wide, crenulated flaps on the side of the head below and behind the spiracle. Interorbital region slightly convex between the supraciliary ridges, its width 4·60 in the length of the head. Branchial region 2·35 times the diameter of the eye; gill-slits of equal width, as wide as the eye. Length of head and trunk rather more than that of the tail. First dorsal fin originating a little in advance of the posterior base of the ventral and slightly in front of the middle of the length; anterior and outer borders of fin gently convex, the intervening angle rounded;

posterior angle obtusely pointed, the hinder border linear, as long as the spiracle, and 2·00 in the basal length, which is equal to the vertical height of the fin; second dorsal similar to and scarcely smaller than the first, its distance from the origin of which is 2·20 in that from the tip of the tail; interdorsal space 1·65 in the base of the first dorsal and 1·10 times the distance between the second and the anal. Height of anal fin 1·75 in its basal length, which is 3·40 in its distance from the ventral. Caudal fin 4·40 in the total length. Pectoral fin tetragonal, originating slightly nearer to the tip of the snout than to the ventral; anterior border convex, posterior concave, outer linear with rounded angles; base of pectoral 1·30 in its greatest width and 1·80 in its length, which is 1·35 in the length of the head and 1·55 in the distance between its origin and the ventral. Origin of ventral fin two-fifths nearer to the first dorsal than to the pectoral, its width 1·35 in its length, which is 1·65 in the head. Skin distinctly rough, the tips of the carinæ forming appreciable spines. Dark sandy, with numerous diversely shaped lilac ocelli and a few inconspicuous darker transverse bands; lower surface cream colour. Fins similar to the adjacent parts of the body, mostly pale edged and with the lilac markings simple. (*maculatus*, spotted).

Length of largest specimen seen by us 1090 mm. Coasts of Tasmania, South-eastern and Eastern Australia. All previous writers having confused this species with the succeeding, it is impossible to fix accurately the exact limits of its range. Described from a female fetus 212 mm. long, in which the yolk-sac was fully absorbed, taken from a specimen captured at Woody Point, Moreton Bay, and presented to the Amateur Fishermen's Association of Queensland by Mr. J. T. Jameson; Cat. No. 388.

We have compared nine examples of *O. maculatus* with seven of the following species, *O. ornatus*, and find that

the most characteristic differences are in the colour markings. Whereas the first is of a simple brown colour ornamented with large lighter ocelli, and with but faint indications of cross-bands, *O. ornatus* is closely marbled with dark brown on a lighter ground, the marbling forming cross-bars at intervals and enclosing imperfect ocelli only. The supralabial lobes of *O. ornatus* are generally fewer in number and more robust than those of *O. maculatus*, being from 2 to 4 as against 3 to 6, and the posterior lobes are generally simple in the young of the first named species. These, however, are very variable, and it may prove that the one species is only a well marked colour variation of the other. Our sixteen specimens, however, are readily divisible into the two species. The specimen recorded from Port Moresby, New Guinea, by Macleay,[1] under the name *Crossorhinus barbatus*, is not this species, but *O. ornatus*.

ORECTOLOBUS ORNATUS, De Vis.

(Plate XLII., fig. 1.)

Crossorhinus ornatus, DeVis, *Proc. Linn. Soc. N.S.W.*, viii, 1883, p. 289; Moreton Bay.

? *Crossorhinus barbatus*, McCoy, *Prod. Zool. Vic.*, Dec. v, 1880, pl. xliii, f. 1 (*nec* Gmelin).

Orectolobus ornatus, Regan, *Proc. Zool. Soc.*, 1908, p. 356, pl. xi, fig. 2.

"Banded Wobbegong."

Body robust, its depth 7·75 in the total length. Length of head 5·10 in the total length. Nasal cirrus with a simple or bifid basal lobe. Width of mouth 1·90, free space between lower labial grooves 4·85 in the length of the head. Papillary projections above the upper eyelid present or absent; space between eye and tip of snout 1·25 in its distance from the first gill-slit; diameter of eye 7·33 in the length of the head and 1·40 in that of the

[1] *Proc. Linn. Soc. N.S.W.*, vii, 1883, p. 597.

spiracle. Two to four simple dermal lobes above the upper lip; several more or less branched lobes behind the angle of the mouth, followed by two posterior lobes which are simple and rounded in the young and branched in the adult. Width of interorbital region 5·00 in the length of the head. Branchial region 2·20 times the diameter of the eye. Length of head and trunk equalling that of the tail. First dorsal fin originating above the end of the base of the ventral and a little behind the middle of the length; anterior border of fin linear; hinder border 2·40 in the basal length, which is more than the vertical height of the fin; space between origins of dorsals 2·00 in that between the second dorsal and the tip of the tail; interdorsal space 1·90 in the base of the first dorsal and equal to the distance between the second dorsal and the anal. Length of caudal fin 5·15 in the total length. Pectoral fin originating one-fourth nearer to the tip of the snout than to the ventral; all the borders convex; its base is 1·50 in its greatest width and 1·65 in its length, which is 1·50 in the length of the head and 1·40 in the distance between its origin and the ventral. Origin of the ventral fin one-half nearer to the first dorsal than to the pectoral, its width 1·15 in its length, which is 1·50 in the head. Pale lilaceous gray, marbled and dotted with sandy-brown; trunk and tail with six broad irregular umber-brown cross-bands, which on the trunk encroach but little on the ventral surface but on the tail form complete or nearly complete annuli; these bands are themselves ornamented with violet spots, which sometimes form ocelli; under surface yellowish white, the abdomen with a median row of violaceous spots and a few scattered spots some of which are faint; a conspicuous spot immediately in front of the vent. Head similar to the trunk, but with three large dusky blotches forming a crescentic band across the occiput and an angular lilac bar across the forehead; two series of dark spots, one of which is much larger than

the rest, on the side of the head; a white spot behind the spiracle; lower lip with dark bars, the outer pair produced inward; symphysial groove and a central spot lilac. All the fins with dark marginal blotches; under surface of paired fins olive; *ornatus*, adorned.

Type in the Queensland State Museum. Total length to 1942 mm. Eastern and South-eastern Australia.

Above description drawn up mainly from a male fetus, 186 mm. long, taken from a specimen captured at Woody Point, Moreton Bay, and presented to the Amateur Fishermen's Association of Queensland, by Mr. J. T. Jameson, Cat. No. 389.

ORECTOLOBUS TENTACULATUS, Peters.

"Sombre Wobbegong."

Crossorhinus tentaculatus, Peters, *Mon. Akad. Berlin*, 1864, p. 123 Port Adelaide, S.A.; Günther, *B. M. Cat. Fish.*, viii, 1870, p. 414, Cape York; Macleay, *Proc. Linn. Soc., N.S.W.*, vi, 1881, p. 365; Ogilby, *Proc. Linn. Soc. N.S.W.*, xiv, 1889, p. 182.

Orectolobus tentaculatus, Regan, *Proc. Zool. Soc.*, 1908, ii, p. 357' pl. xii, fig. 2.

"*Crossorhinus* with simple cutaneous tentacles and the dorsal fins closely approximated; brown with wide inconspicuous cross-bands. All the tentacles are simple and less numerous than in *C. barbatus;* an elongate tentacle on the inner nasal valve and a broader rounded one on the outer; a shorter one at the middle of the upper lip; two similar lobes above and behind the angle of the mouth, and one on the region which corresponds with the distal extremity of the lower jaw. Labial folds and grooves, jaws, number of teeth (21 above, 17 below), and form as in *C. barbatus.* Spiracles crescentic with the convexity above, remote from and twice as wide as the eye, and situated wholly behind them; upper eyelid with two short conical projections

posteriorly. Three last gill-openings above the pectorals, which are rounded-quadrangular, as also are the ventrals; both are proportionally longer than in *C. barbatus.* First dorsal fin inserted almost wholly above the ventrals, the base of the second terminating almost quite in front of the anal; both dorsals about equal in size, with the outer border rounded; interdorsal space about one-fourth of the basal length. Anal fin small, longer than high, low and rounded. Caudal fin commencing almost immediately behind the anal; like *C. barbatus* it has a very small notch on the hinder border and a triangular one on the lower.

"Brown; the young with distinct dusky cross bands; one on the snout; a second on the head; a third between the pectorals; a fourth much broader one from the middle of the back to the ventrals; a fifth which includes the greater part of the first dorsal fin; a sixth which similarly includes the second; and three which follow one another on the base, the middle, and the distal third of the caudal fin. These cross bands become obscure in adult examples, being replaced by scattered black roundish spots. Lower surface yellow, the lips and chin spotted with brown; in young examples the under surface of the tail shows broad bands, in the adult some inconspicuous spots. The scales are small, glossy smooth, quadrangular, rhomboidal, or trapezoidal. Two female examples of different ages show some mucous tubes on the head; on the back also are irregular convex rows of oval or round pitted cutaneous papillæ, which in the larger attain a diameter of five millimeters." (*tentaculatus*, bearing tentacles)—[Peters].

Total length to 900 mm. South Australia (Port Adelaide *fide* Peters); North Australia (Cape York *fide* Gunther).

The only specimen examined by us is a stuffed skin in the Australian Museum, of a female from Port Adelaide, South Australia. It differs from the above description

in having the first dorsal fin originating over the posterior base of the ventral as in other members of the genus, instead of being "inserted almost wholly above the ventrals." If the dermal papillæ on the dorsal surface, which are distinct in our specimen, are normal, they readily distinguish this from all other species.

Dr. Gunther places great reliance on the narrowness of the interdorsal space to differentiate this species from the others, but as pointed out by one of us (Ogilby, *supra loc. cit.)* this is unreliable, specimens of *O. barbatus* in the Australian Museum having that space quite as narrow as that of the *O. tentaculatus* above mentioned.

BRACHÆLURUS, Ogilby.

Brachælurus, Ogilby, *Proc. Roy. Soc*, *Queensl.*, xx, 1906, p. 27 *(Chiloscyllium modestum*, Günth.); Ogilby, *loc. cit.*, xxi, 1907, p. 3 *(B. colcloughi*, Ogil.).

Cirriscyllium, Ogilby, *loc. cit.*, xxi, 1907, p. 4 *(Ch. modestum*, Günth.).

Brachælurus, Regan, *Proc. Zool. Soc.*, 1908, p. 354.

The genus *Brachælurus* was originally proposed without diagnosis to receive *Chiloscyllium modestum*, Günther. Through an unfortunate oversight it was applied later to *B. colcloughi*, Ogilby, and the new name *Cirriscyllium* was proposed for *Ch. modestum*. The fact that *Brachælurus* was definitely associated with *Ch. modestum* prevents its use with *B. colcloughi*, and the new name *Heteroscyllium* has been proposed by Regan[1] to receive the latter species. *Brachælurus* differs from *Heteroscyllium* in the much larger scales and the absence of a lateral line; the head is wider and strongly depressed, and the mouth is placed well in advance of the eye; the ovate spiracles are only partially behind the eye; the anal fin is inserted farther

[1] *Ann. Mag. Nat. Hist.*, ii, (8) 1908, p. 455.

back, being adjacent to and overlapping the base of the lower caudal lobe. (*βραχύς*, short; *αἴλουρος*, a cat).

Small ground sharks from the east coast of Australia. Like *Orectolobus* they are sluggish in their habits, and haunt the vicinity of weed-grown rocks at no great depth, feeding upon mollusks, crustaceans, and small fishes. Monotypic.

BRACHÆLURUS MODESTUS, Günther.

Chiloscyllium modestum, Günther, *Proc. Zool. Soc.*, 1871, p. 654, pl. liv, Coast of Queensland; Macleay, *Proc. Linn. Soc. N.S W.* vi, 1881, p. 363.

Chiloscyllium furvum, Macleay, *ibid.*, p. 364, Port Jackson.

Hemiscyllium modestum, Waite, *Rec. Austr. Mus.*, iv, 1901, p. 28, fig. 9, pl. iv, fig. 1 (fetus).

Brachælurus modestus, Regan, *Proc. Zool. Soc.*, 1908, p. 354.

"Brown Cat Shark," "Blind Shark."

Body robust, its depth 8·00 in the total length. Depth of head 1·40 in its width, which is 1·20 in its length; length of head 1·50 in the trunk and 5·50 in the total length. Snout broadly rounded, depressed anteriorly and rising somewhat abruptly about midway between its extremity and the eye, its preoral length 3·25 in that of the head. Anterior angle of nostril nearer to the tip of the snout than to the mouth; internasal space subequal to the preoral space and 1·10 in the width of the mouth; nasal cirrus as long as the snout, reaching a little beyond the lower labial groove, and 2·35 times the diameter of the eye. Mouth a little nearer to the tip of the snout than to the eye, its width 2·75, that between the outer angles of the labial grooves 2·10 in the length of the head. Eye a little nearer to the first gill-slit than to the tip of the snout, its diameter 8·25 in the length of the head. Interorbital region convex, its width 2·40 in the head. Branchial region 2·80 diameters of the eye; width of first gill-slit equal to

the eye and somewhat narrower than the last slit. Length of head and trunk 1·25 in that of the tail. First dorsal fin originating above the posterior half of the base of the ventral, its distance from the tip of the snout 2·25 in the total length; anterior and outer borders of fin feebly convex, the intervening angle rounded as also is the hinder angle; hinder border feebly emarginate, its length 1·50 times the diameter of the eye and 2·10 in the basal length, which is less than the vertical height of the fin; second dorsal slightly longer but not so high as the first, its distance from the origin of which is 2·65 in that from the tip of the tail. Distance between origin of anal and second dorsal equal to the interval between the dorsals and 3·50 in its distance from the ventrals; its height is 1·75 in its base, which is only separated from the caudal by a notch. Depth of lower caudal lobe 4·60 in its length, which is 3·80 in the total length; extremity of fin rounded and mesially notched, the tip of the vertebral column not reaching the margin. Pectoral fin obovate, originating midway between the ventral fin and the tip of the snout or somewhat nearer to the former, its base 1·60 in its greatest width and 2·25 in its length, which is 1·40 of that of the head. Origin of ventral fin considerably nearer to first dorsal than to pectoral. Back with two to five series of tubercles between the occiput and the first dorsal. Above dark plumbeous, with nine narrow lighter cross bands, the trunk and tail with more or less numerous and distinct round whitish spots; lower surface of head white, of belly dull blue-gray; (*modestus*, without ornamentation).

Type in the Zoological Museum, South Kensington; type of *Ch. furvum*, Macleay, in the Macleay Museum, University of Sydney. Length to 900 mm. Shores of Eastern Australia.

The above description is drawn up from a male fetus 146 mm. long, which has the yolk-sac about half consumed.

It was taken from a female at Woody Point, Moreton Bay, by Mr. J. T. Jameson, and presented to the Amateur Fishermen's Association of Queensland; Cat. No. 390.

HETEROSCYLLIUM, Regan.

Brachœlurus, Ogilby, *Proc. Roy. Soc. Queensl.*, xxi, 1907, p. 3, (*nec Brachœlurus*, Ogilby, *loc. cit.*, xx, 1906, p. 27).

Heteroscyllium, Regan, *Ann. Mag. Nat. Hist.*, ii, (8) 1908, p. 455.

As shown on page 280, the name *Brachœlurus* cannot be used for the following species, and *Heteroscyllium* has therefore been proposed in its stead.

Body short and stout, not depressed, becoming gradually more compressed posteriorly, the distal portion of the tail slightly elevated above the axial plane. Scales extremely small and feebly unicarinate; lateral line conspicuous. Head rather small and narrow, with moderate rounded snout, and without lateral dermal lobes. Nasal valve folded, with a well developed free cirrus. Mouth inferior, transverse, of moderate size, below the anterior portion of the eye; lips not thick nor fringed within; labial grooves well developed, not continuous across the symphysis of the lower jaw, behind which is a conspicuous longitudinal groove. Teeth in both jaws small and tricuspid, arranged in many series. Spiracles large and subcircular, below and wholly behind the eye, surrounded by a prominent rim. Gill-slits moderate, increasing in size from the front; three above the pectoral. Tail a little longer than the head and trunk. First dorsal fin originating above the base of the ventrals and but little larger than the second: anal fin small, originating below the last third of the second dorsal: caudal fin short; (ἕτερος, another; σκυλλιον, *Scyllium*.)

Small ground sharks hitherto only recorded from Moreton Bay. Monotypic.

HETEROSCYLLIUM COLCLOUGHI, Ogilby.

Brachælurus colcloughi, Ogilby, *Proc. Roy. Soc. Queensl.*, xxi, 1907, p. 4.

"Blue-gray Cat Shark."

Body robust, its depth 7·60 in the total length. Width of head subequal to its depth immediately in front of the gill-openings and 1·50 in its length, which is 1·50 in that of the trunk and 5·60 in the total length. Upper profile of head evenly rounded; preoral length 3·00 in the length of the head. Anterior angle of nostril equidistant from the mouth and the tip of the snout; internasal space about equaling the preoral length and 1·15 in the width of the mouth; nasal cirrus 1·40 in the preoral length, not extending to the lower labial groove, and 1·50 times the diameter of the eye. Mouth much nearer to the eye than to the tip of the snout, its width 2·70, that between the outer angles of the labial grooves 2·30 in the length of the head. Eye somewhat nearer to the tip of the snout than to the first gill-slit, its longitudinal diameter 6·40 in the length of the head. Interorbital region mesially concave, its width 2·75 in the head. Spiracle subvertical, situated in a deep ovate rimmed pit, its diameter 1·50 in that of the eye. Branchial region 2·40 times the diameter of the eye; width of first gill-slit 1·50 in the eye and 1·60 in the last slit. Length of head and trunk 1·25 in that of the tail. First dorsal fin originating above the middle of the base of the ventrals, its distance from the tip of the snout 2·25 in the total length; anterior and outer borders of fin sublinear, the intervening angle broadly rounded; posterior angle pointed, the hinder border proximally emarginate, its length 1·50 times the diameter of the eye and rather more than 3·00 in its basal length, which is one-half more than the vertical height of the fin: second dorsal similar to but not quite so large as the first, its distance from the origin of which is 1·75 in that from the tip of the tail. Distance between

origins of anal and second dorsal less than the interval between the dorsals and 4·60 in its distance from the ventrals; its height is 2·80 in its base; free space between anal and caudal 1·85 in the base of the anal. Depth of lower caudal lobe 6·20 in its length, which is 4·35 in the total length, its extremity rounded; tip of vertebral column not nearly reaching the margin of the fin. Pectoral fin obovate, its distance from the ventral fin 1·50 in that from the tip of the snout, its base rather more than 2·00 in its greatest width and rather less than 2·00 in its length, which is 1·85 in the head. Origin of ventral fin a little nearer to the first dorsal than to the pectoral. A slight but distinct vertebral groove between the occiput and the first dorsal; lateral line strongly marked, forming a ridge, connected by a transverse line above the spiracles. Upper surfaces, sides, and tail ashy-gray; lower surface of head, throat, and abdomen white. (Named after Mr. John Colclough, late of Brisbane, and now holding a responsible position in the Aru Islands).

The specimen described above is an immature male measuring 457 millimeters. It was caught at Mud Island, Moreton Bay, on the 8th of June, 1906, by Mr. F. L. Phillips, and presented by him to the A. F. A. Q. Museum, Cat. No. of type 410. A second specimen, also a young male of similar size has been for some years in the Queensland Museum.

CHILOSCYLLIUM, Müller and Henle.

Chiloscyllium, Müller and Henle, *Arch. f. Nat.*, 1837, i, p. 395 and *Plagiost.*, p. 37, 1841 *(plagiosum)*; Cantor, *Journ. As. Soc. Bengal*, xviii, 1849, p. 1374; Jordan and Fowler, *Proc. U.S. Nat. Mus.*, xxvi, 1903, p. 603; Günth., *Cat. Fish.*, viii, 1870, p. 410; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 358.

Hemiscyllium, Müller and Henle, *Arch. f. Nat.*, 1838, i, p. 83 and *Plagiost.*, 1841, p. 16 *(ocellatum)*.

Synchismus, Gill, *Ann. Mus. Nat. Hist. New York*, 1861, p. 408 *(tuberculatus = indicus)*

Body elongate and slender, the distal portion of the tail scarcely elevated above the axial plane. Scales minute and feebly unicarinate; lateral line inconspicuous. Head small, narrow, not depressed, with short and broadly rounded snout. Nasal valve folded, with a short cirrus. Mouth inferior, transverse, small, and much nearer to the tip of the snout than to the eye. Lower lip not divided by a symphysial groove. Teeth similar in both jaws, small and tricuspid, and arranged in many series. Spiracles large, below and partly behind the eye. Posterior gill-slit widest; three above the pectoral. Tail once and a half to twice as long as the head and trunk. First dorsal fin inserted wholly behind the base of the ventrals, subequal in size to the second. Anal fin low, inserted far behind the second dorsal, close to and overlapping the caudal, which is short; (χεῖλος, a lip; σκυλλιον, *scyllium*).

Small oviparous ground sharks inhabiting the Indo-Pacific.

Hemiscyllium, Müller and Henle, is considered by some authors to differ from *Chiloscyllium* in having the lower labial fold continuous across the symphysis of the lower jaw instead of being interrupted, and in having a longer tail. Specimens of both genera examined by us show some variation in the former character, and as we do not think that the length of the tail alone can maintain the genus, we follow Regan in treating it as a synonym of *Chiloscyllium*.

Key to the Australian species.

a. Tail once and a half as long as the head and trunk; no ocellus above the pectoral fin ... *punctatum*.

aa. Tail twice as long as the head and trunk; a large ocellus above the pectoral fin.

b. Body with large scattered dark spots ... *ocellatum*.

bb. Body with numerous small close set dark spots ... *trispeculare*.

Chiloscyllium punctatum, Müller and Henle.

Plate XLIII., fig. 2.

"Brown-banded Cat Shark."

Chiloscyllium punctatum, Müller and Henle, *Plagiost.*, p. 18, pl. iii, 1841, Java; Bleeker, *Verh. Batav. Gen.*, xxiv, 1852, *Plagiost.*, p. 22; Kner, *Reise Novara, Fische*, 1867, p. 413, Java; Günther, *B.M. Cat. Fish.*, viii, 1870, p. 413; Klunzinger, *Sitzb. Akad. Wien.*, lxxx, i, 1880, p. 427, Port Darwin, N.T.; Ogilby, *Proc. Linn. Soc., N.S.W.*, xiv, 1889, p. 181; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 360.

Body slender, its depth 10·65 in the total length. Head moderate, its width 1·40, its depth 1·90 in its length, which is 1·25 in the trunk and 5·85 in the total length. Snout broadly rounded, depressed anteriorly, becoming declivous about midway between its extremity and the eye, its length 3·65 in that of the head. Anterior angle of nostril nearer to the mouth than to the tip of the snout. Internasal space 1·30 in the width of the mouth; nasal cirrus about 1·50 in the diameter of the eye. Mouth much nearer to the tip of the snout than to the eye, its width 3·40, the space between the outer angles of the labial grooves 2·45 in the length of the head. Eye nearer to the first gill-slit than to the tip of the snout, its longitudinal diameter 7·35 in the length of the head. Interorbital region convex, its width 2·75 in the length of the head. Spiracle as large as the eye. Branchial region 2·65 times the diameter of the eye; width of first gill-slit equal to the diameter of the eye and about 1·35 in that of the last slit. Length of head and trunk 1·50 in that of the tail. First dorsal fin originating above the middle of the base of the ventral, its distance from the tip of the snout 2·65 in the total length; anterior border of fin convex, its outer angle broadly rounded; outer and posterior borders feebly emarginate, the intervening angle pointed and slightly exceeding a right angle; length of hinder border

about 1·50 times the diameter of the eye and 2·25 in the basal length, which is rather more than the vertical height of the fin: second dorsal as long as but not so high as the first, its distance from the origin of which is 1·75 in that from the tip of the tail. The distance between the origin of the anal and the second dorsal is 1·65 in the free space between the dorsals and 4·50 in its distance from the ventrals; its height is about 3·00 in its base, which is only separated from the caudal by a notch. Length of caudal fin 5·50 in the total length, its extremity acute, the tip of the vertebral column extending for some distance behind the fin. Pectoral fin obovate, originating somewhat nearer to the ventral fin than to the tip of the snout, its base 1·80 in its greatest width and 3·20 in its length, which is 1·35 in the head. Origin of the ventral fin much nearer to the first dorsal than to the pectoral. Back with a conspicuous ridge between the dorsal fins. Cream colour, tinged along the dorsal edge with buff; tip of snout and upper surface of head between and behind the eyes violaceous-brown, this colour passing forwards below the eyes, which are rimmed with pale blue, to form two broad bands on the sides of the head, the anterior running downwards and forwards to the corner of the mouth, the posterior directly downwards to the lower surface, which is immaculate; branchial region dusky. Body and tail with eight broad brown cross bands, the last five forming perfect rings and having a supplementary bar across the lower surface between each pair of rings; a dusky spot below the end of the pectoral. Dorsals and anal mostly brown; pectorals and ventrals tipped with violaceous-brown, the former with a small round spot about the middle of the anterior margin; (*punctatum*, minutely dotted).

From the Malay Archipelago (Java) eastwards along the coasts of intertropical Australia, and ranging southward on our shores at least as far as Moreton Bay. From the

latter locality no adult specimens have as yet been obtained, though judging from the numerous empty egg-cases washed ashore the species cannot be considered rare. Three fetal specimens have also come to hand, namely, the specimen, 128 millimeters in length, from which the above description was taken, and which was washed ashore in its egg-case at Woody Point, Moreton Bay, and secured by Mr. J. T. Jameson of that place, in whose collection it now is; in this example the yolk-sac is very large, weighing three-fifths of the body or three-eights of the total weight. The second specimen is somewhat larger and has consumed the yolk-sac, only the connecting cord being left unabsorbed; it was presented to the Queensland State Museum by Mr. James A. Hamilton, who obtained it at Amity Point, about twenty-five years ago. The third example, which was also obtained by Mr. Jameson at Woody Point, is much smaller than either of the others; through the kindness of its collector it is in the collection of the A. F. A. Q., Cat. No. 587. The only other Australian record is that of Klunzinger, whose specimen, from Port Darwin was sixteen inches long.

Fig. 1.

Length to 400 millimeters. In all probability the species grows to a considerably larger size.

The egg-cases of this species (fig. 1) differ in a remarkable degree from those of *Scyliorhinus* and its allies. In the latter the case, which is usually golden-brown in

colour, is longitudinally ribbed, and bears at each corner a long filiform process, the function of which is to twine round seaweeds, etc., and so anchor the egg. The chiloscyllian egg-case, on the other hand, is of a shining purplish-black and perfectly smooth; it is also shorter and broader, and lacks the sub-anterior restriction of the typical scyliorhinids, being oval. The embryo, which is curled round the yolk-sac, lies nearest to the posterior extremity of the case, there being between it and the anterior end a closely appressed space. But the most remarkable difference between the two forms is in the means of attachment, for in place of the tendriliform processes of scyliorhinid egg-cases, that of *C. punctatum* has a loop formed of two fibrous extensions, placed on the dorsal edge, at some distance from either end. From a case received from Mr. Jameson it seems certain that the loop is woven round the stem of the support selected as the nursery, by the lips of the parent after deposition of the egg. This specimen was fastened to the stem of a colony of worm-tubes which is so thickened and branched on either side of the point of attachment that it could not possibly have been slipped on either from above or below. Most of the cases examined were collected by Mr. J. T. Jameson at Woody Point, Moreton Bay, but we have also seen some from Dunk Island, where they were taken by Mr. E. J. Banfield, Cat. Nos. 420 and 906. Their average measurements are 97 × 52 mm.

CHILOSCYLLIUM OCELLATUM, Bonnaterre.
"Epaulette Shark."

L' Œillé, Broussonet, *Mém. Acad. Sci., Paris*, 1780, p. 660, No. 10, New Holland.

Squalus ocellatus, Bonnaterre, *Encycl. Meth. Ichthy.*, 1788, p. 8. La mer du Sud.

Squalus ocellatus, Gmelin, *Syst. Nat.*, i, 1789, p. 1494; Schneider, *Syst. Ichth.*, 1801, p. 129; Shaw, *Nat. Misc.*, pl. 161; Griffith, *Anim. Kingd.*, x, 1834, p. 598, pl. 3.

Le Squale oeillé, Lacépède, *Poiss.*, i, 1798, p. 253.

Hemiscyllium ocellatum, Müller and Henle, *Plagiost.*, 1841, p. 16, New Holland; Duméril, *Elasmobr.*, 1870, p. 326.

Scyllium ocellatum, Blyth, *Journ. Asiat. Soc. Bengal*, 1847, p. 726, pl. 25*b*, fig. 2.

Chiloscyllium ocellatum, Günther, *B. M. Catal. Fish.*, viii, 1870, p. 410: Sunday Island, North-west Australia, Cape York, Q.; Macleay, *Proc. Linn. Soc. N.S.W.*, vi, 1881, p. 363, Port Darwin, Torres Straits; *id.*, *ibid.*, vii, 1883, p. 597, Port Moresby, Papua; Ogilby, *Proc. Linn. Soc. N.S.W.*, x, 1885, p. 464, Port Jackson ?; *id.*, *Cat. Fish. N.S.W.*, p. 3, 1886; *id.*, *Proc. Linn. Soc. N.S.W.*, xiv, 1889, p. 181, Port Moresby, Papua; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 358.

Body slender, its depth 11·80 in the total length. Width of head 1·35, depth of head 1·75 in its length, which is 1·70 in the trunk and 8·40 in the total length. Snout rounded, declivous in front, sloping behind, its length 5·20 in that of the head. Anterior angle of nostril nearer to the tip of the snout than to the mouth; internasal space 1·65 in the width of the mouth; nasal cirrus much shorter than the eye. Mouth much nearer to the tip of the snout than to the eye, its width 3·50, the space between the outer angles of the labial grooves 2·35, and that between the lower labial grooves 8·25 in the length of the head. Eye a little nearer to the tip of the snout than to the first gill-slit, its longitudinal diameter 7·35 in the length of the head. Interorbital region flat, its width 2·40 in the length of the head. Spiracle a little smaller than the eye. Branchial region 2·75 times the diameter of the eye; width of first gill-slit rather less than the diameter of the eye and about 2·00 in that of the last. Length of head and trunk 2·15 in that of the tail. First dorsal fin inserted wholly behind the base of the ventral, its distance from the tip of the snout 2·20 in the total length, anterior border of fin sublinear, its

outer angle broadly rounded; outer border linear or feebly convex, posterior border emarginate, the intervening angle bluntly pointed; length of hinder border about twice the diameter of the eye and about half the basal length, which is equal to the vertical height of the fin: second dorsal similar to and scarcely smaller than the first, its distance from the origin of which is 1·75 in that from the tip of the tail. The distance between the origin of the anal and the second dorsal is a little less than the free space between the dorsals and 3·75 in its distance from the ventrals; its height is 3·80 in its base, which is only separated from the caudal by a notch. Length of caudal fin about 6·00 in the total length. Pectoral fin obovate, originating a little nearer to the tip of the snout than to the ventral fin, its base 1·70 in its greatest width and 2·50 in its length, which is 1·25 in the head. Origin of the ventral fin about equidistant from the first dorsal and the pectoral. Back feebly ridged behind the first dorsal. Stone-gray, the upper surface darker, and with numerous scattered darker spots; young with traces of ten brown transverse bands, more conspicuous posteriorly, especially on the caudal fin, where they are permanent as three dark brown or black spots; these bands are continuous below between the ventral and the anal fins in the form of numerous crowded minute brown specks; a large, round or oval, black, white-edged ocellus above the pectoral fin. Upper surface of head with scattered round brown spots. Dorsal fins edged with white and with blackish spots on the anterior border; caudal and anal fins brown spotted; pectorals and ventrals uniform or with one or two faint spots; (*ocellatus*, bearing ocelli: in reference to the humeral spots).

Total length to 900 millimeters. Coasts of Northern and North-eastern Australia; Sunday Island, North-west Australia. Common in lagoons of coral reefs on the

Queensland Coast, living in the crevices of coral blocks, where they have been taken by one of us at Murray Island, Torres Straits, Hope Islands off Cooktown, and at Masthead Island off Port Curtis (McCulloch). It has been recorded from Port Jackson by one of us, but we have reason to believe that this locality is incorrect (Ogilby).

Described from two half-grown specimens (a male of 290 and a female of 325 millimeters) obtained by Mr. E. J. Lyons at Green Island, Cairns, and presented by him to the A.F.A. Q. Museum, Cat. Nos. 195-6.

CHILOSCYLLIUM TRISPECULARE, Richardson.

Hemiscyllium trispeculare, Rich., *Icon. Pisc.*, 1843, p. 5, pl. i, fig. 2, and *Erebus and Terror*, *Fish.*, 1844, p. 43, pl. xxviii.

Chiloscyllium trispeculare, Günth., *Brit. Mus. Cat. Fish.*, viii, 1870 p. 411 ; Regan, *Proc. Zool. Soc.*, 1908, p. 359.

It has been suggested by one of us[1] that this species is probably only a well-marked colour variety of *C. ocellatum*, Gmel. We have examined two fine specimens from Port Darwin in the Australian Museum collection, which agree closely with Richardson's figure, and find that the only differences between them and specimens of *C. ocellatum* are those of colour-marking. In place of the large dark spots scattered over the back, sides, and tail of the latter, the surface is covered with minute brownish dots which are absent only on the under surfaces and between the cross bands on the tail. These dots are not disposed in small groups as shown in the figure, but are evenly spaced throughout. Behind the ocellus are two confluent dark markings which are represented in *C. ocellatum* by two distinct black spots. The differences in the sizes of the fins of the two forms, as mentioned by Regan are not shown in our specimens.

[1] Ogilby, *Proc. Linn. Soc., N.S.W.*, xiv, 1889, p. 181.

STEGOSTOMA, Müller and Henle.

Stegostoma, Müller and Henle, *Arch. f. Nat.*, 1837, i, p. 395, *(fasciatum = tigrinum); id.*, *Plagiost.*, p. 24, 1841 ; Cantor, *Journ. As. Soc.*, *Bengal*, xviii., 1849, p. 1378 ; Günther, *Brit. Mus. Cat. Fish.*, viii, 1870, p. 409 ; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 363.

Body moderately robust, rapidly decreasing posteriorly, the tail very long, slender, and strongly compressed, not elevated distally above the axial plane. Scales minute, tricarinate, the middle carina terminating in a strong, acute point; scales of the mental region much larger, smooth, and ovate; lateral line inconspicuous. Head short, wide, and depressed, with moderate, broadly rounded snout. Nasal valves confluent, folded anteriorly, forming a narrow flap on the angle of the upper lip, and with a short, free, median cirrus. Mouth inferior, transverse, rather small, a little nearer to the tip of the snout than to the eye, with short, deep, labial grooves round the angle. Teeth similar in both jaws, arranged in many series, small and tricuspid, occupying a pair of transverse, subquadrangular cushions. Eyes very small; spiracle large, vertical, close behind the eye. Anterior gill-slits wider than the posterior; four above the pectoral. Tail more than twice as long as the head and trunk. First dorsal fin inserted for the most part opposite to the ventrals, larger than the second; anal fin inserted wholly behind the second dorsal, rather low, close to and overlapping the caudal, which is exceedingly long; (στέγος, a roof or covering; στόμα, mouth; in allusion to the wide overhanging upper lip, which conceals the mouth).

Ground sharks of large size from the Indian and Western Pacific Oceans, not entering rivers. Monotypic.

STEGOSTOMA TYGRINUM, Bonnaterre.[1]

Seba, Thesauri, iii, p. 105, pl. xxxiv, fig. 1, prior to 1765.

Squalus sp., Gronovius, *Mus. Ichth.*, i, p. 62, 1754; *id.*, Zoophyl, p. 31, No. 147, 1763.

Squalus tygrinus, Bonnaterre, *Encyl. Meth. Ichthy.*, 1788, p. 8, pl. viii., fig. 23.

Squalus tigrinus, Gmelin., *Syst. Nat.*, i, p. 1493, 1789, Indian Ocean; Forster, *Zool. Ind.*, (2) p. 24, pl. xiii, fig. 2, 1795; Lacépède, *Poiss.*, i, p. 249, 1798.

Squalus longicaudus, Gmelin, *ibid.*, p. 1496.

Squalus fasciatus, Bloch, *Ausl. Fisch.*, pl. cxiii, 1795.

Poolleemakum, Russell, *Fish. Vizagapatam*, i, p. 11, pl. xviii, 1803, Coromandel Coast.

Scyllium heptagonum, Rüppell, *Neue Wirbelth. Abyss. Fisch.*, p. 61, pl. xvii, fig. 1, 1837, Massoua.

Stegostoma fasciatum, Müller and Henle, *Plagiost.*, p. 24, pl. vii (lower surface of head), 1841; Cantor, *Journ. As. Soc. Bengal*, xviii, 1849, p. 1378, Sea of Pinang; Gray, *Cat. Chondropt.*, p. 38, 1851, Madras; Jerdon, *Madras Journ. Lit. and Sci.*, 1851, p. 148; Bleeker, *Verh. Batav. Gen.* xxiv, 1852, *Plagiost.* p. 23; *id.*, *ibid.*, xxv, 1853, Bengal en Hind., p. 80; Blyth, *Journ. As. Soc. Bengal*, xxix, 1860, p. 35; Duméril, *Elasmobr.* p. 336, 1865; Günther, *Fish. Zanzibar*, p. 140, 1866; Klunzinger, *Verh. zool.-bot. Ges. Wien.*, 1871, p. 672, Red Sea.

Stegostoma carinatum, Blyth. *ibid.*, xvi, 1847, p. 725, pl. xxv, fig. 1.

Squalus cirrosus, Gray, *Cat. Fish. Gronov.*, p. 6, 1854.

Stegostoma tigrinum, Günther, *B.M. Cat. Fish.* viii, p. 409, 1870, Zanzibar, Ceylon, India, Formosa; Day, *Fish. India*, p. 725, pl. clxxxvii, fig. 4, 1878, Malay Archipelago; Ogilby, *Catal.*

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[1] We use Bonnaterre's name because the want of books prevents us from tracing the literary history of this shark further back. Those more fortunately situated, to whom we leave the final revision, may trace it to earlier authors.

Palæichth. Fish. Austr. Mus., p. 7, 1888, Cape York, Q.; Waite, *Rec. Austr. Mus.*, iii, p. 133, 1899; Regan, *Proc. Zool. Soc.*, 1908, ii, p. 364.

"Zebra Shark."

Body moderately robust, its depth 7·85 in the total length. Head much wider than deep, its width 1·10, its depth 1·40 in its length, which is 1·75 in the trunk and 8·15 in the total length. Snout feebly declivous in front, linear and scarcely oblique behind, its length 1·55 in that of the head. Anterior angle of nostril one-third nearer to the mouth than to the middle of the snout; internasal space one-fifth wider than the mouth. Free nasal cirrus about as long as the diameter of the eye. Mouth one-fifth nearer to the tip of the snout than to the eye, its width 2·80, that between the outer angles of the labial grooves 2·00, the free space across the chin 4·15 in the length of the head. Space between eye and first gill-slit one-half of its distance from the tip of the snout, its longitudinal diameter 8·90 in the head. Interocular region convex, 1·20 in the head. Spiracle forming a suboval slit, nearly as wide as the eye. Branchial region 3·35 times the diameter of the eye; width of first gill-slit three-fifths more than the eye and one-fifth more than the last slit. Length of head and trunk 2·15 in that of the tail. First dorsal fin originating somewhat in advance of the ventral and not reaching quite so far back basally, its distance from the tip of the snout 3·90 in the total length; anterior border of fin sublinear; outer border and its angles forming an even and continuous convexity; hinder border emarginate, its length three-fourths more than the diameter of the eye and 2·80 in the base of the fin, which is seven-tenths more than its vertical height: second dorsal similar to but much smaller than the first, its distance from the origin of which is 4·35 in that from the tip of the caudal fin. Distance between origin of anal

and second dorsal 1·25 in the free space between the dorsals and 2·00 in its distance from the ventral; its height is 2·55 in its base, which is contiguous to the caudal. Length of caudal fin 1·90 in the total length. Pectoral fin obovate, originating midway between the tip of the snout and the ventral fin, its base 1·30 in its greatest width and 1·90 in its length, which is one-tenth more than that of the head. Origin of ventral fin three-fourths nearer to the first dorsal than to the pectoral. Dorsal surface with a strong median ridge, clothed with enlarged scales, from between the eyes to the first dorsal; on each side above, a similar but less conspicuous ridge, commencing a little in advance of the branchial region and disappearing below the second dorsal. Rich chestnut-brown above, the head and trunk with four narrow golden transverse bars; the first crescentic, between the second pair of gill-openings, and curving forward upon the interorbital region; the second between but not nearly reaching to the base of the pectorals, its lower extremities expanded and claviform, and sometimes extended for some distance backward and downward; midway between these bands is a small golden bar crossing the dorsal ridge; the third behind the base of the pectoral and the fourth below the first dorsal, both extending downward to the level of the pectoral; between each of the two last pairs is a median golden bar similar to that between the first pair, below which is a long narrow vertical spot, sometimes forked inferiorly, which may be absent between the middle pair or broken up into several spots between either pair; lower portion of the sides of the trunk lighter brown with some scattered darker spots; under surface of head and trunk yellowish; a short, curved, golden bar across the snout and an oval spot in front of the gill-opening present or absent: upper half of tail with twenty-one continuous alternate bars of chestnut and gold, the former much the broader; below paler brown, with a correspond-

ing number of large round saffron spots. Pectoral fins with a pair of basal golden spots and sometimes a similar central spot, and with numerous rather obscure round brown spots; ventrals also dark-spotted; (*tigrinus*, resembling a tiger, in allusion to its striped body).

Total length to 360 centimeters; said to attain 450. From the Red Sea and the East Coast of Africa, through all the Indian Seas northward to Formosa, and eastward through Malaysia to New Guinea and Eastern Australia, large examples occasionally straggling southward even so far as the Port Jackson District.

The Zebra Shark is a peculiarly handsome species, which, notwithstanding the large size to which it grows, is quite harmless to man; its food consists almost wholly of crustaceans and mollusks, and it is therefore possible that the adult fishes may be capable of doing considerable damage on the pearl-oyster beds in places where they are plentiful; they are, however, too scarce in Queensland waters to cause any apprehension on this account. The young sharks frequent shallow bays and inlets, but as they increase in size they gradually retire into deeper water.

Described from a specimen 500 millimeters long, captured off the Little Mulgrave River, and presented to the State Museum by Mr. Archibald Meston, Reg. No. D. 7057. The only other Australian examples recorded are the two from the Port Jackson district, and the young Cape York specimen, all of which are in the Australian Museum, Sydney, and a fetal example from Normanton, presented to the A.F.A.Q. Museum, by Mr. W. Hamilton.

A fine egg-case of this species with the contained embryo has recently been received by the Trustees of the Australian Museum from Mr. J. Ross Smith who obtained it from some natives at Dobbo, Aroo Islands. The case, which measures 110 mm. in length by 65 mm. in breadth, is oblong

and without apparent means of attachment. It is of a deep purplish-black colour, and the surface is marked with distinct though not prominent longitudinal striæ. The embryo is 150 mm. in length, the tail portion being 96 mm. long, and the large spherical yolk-sac is 46 mm. across. After preservation in formalin, the embryo is white in colour, with twenty-six grey cross-bars over the back and tail, those anterior to the second dorsal fin being disposed in pairs. Sun-dried cases have also been forwarded by Mr. E. J. Banfield, from Dunk Island.

SOME GEOLOGICAL NOTES ON COUNTRY BEHIND JERVIS BAY.

By H. I. Jensen, D. Sc.

[*Read before the Royal Society of N. S. Wales, December 2, 1908.*]

In January last I spent a few weeks in the district lying between Nowra, Nerriga and Nelligen. Since then I have had an opportunity confirming several of the observations made by a second visit.

Physiography.—From the Currockbilly Range[1] at Sassafras the country slopes gently to the east, the altitude falling gradually from about 2,200 feet on the range to near sea-level at Jervis Bay and Nowra. The inclined plane so formed is dissected by numerous cañons which pursue a north and south direction, *e.g.*, the cañons of the Ettrema, Danjera (Tianjara Creek or Fall Creek) and Yalwal Creek which flow north into the Shoalhaven, and the gorge of the Clyde River which runs south emptying into the sea at

[1] Pigeon House Range of Tourist Bureau Map.

Bateman's Bay. The entire area encompassed by the headwaters of these streams is very poor, sandy and stony country, useless for agricultural and pastoral purposes, with the exception of a few basaltic ridges of small extent. In spring an abundance of wild flowers lends a more inviting appearance to the landscape. Here and there occur large swampy tracts either destitute of arboreal vegetation or supporting a variety of shrubs—teatrees and other myrtaceous plants. Here and there occurs a huge floor of bare rock, swept clean of all traces of soil by wind and rain. Often these bare tracts show a rude columnar jointing which, however, only penetrates an upper layer of rock a foot or two in thickness. Whether this structure is due to the action of weathering and the heat of the summer sun, or to the removal of a former basalt sheet I am not prepared to say, but I am inclined to the latter supposition. The country rock is sandstone of Upper Marine age. Similar barren country extends all the way from Sassafras to the coastal fringe of alluvium.

The Sassafras tableland in which the Clyde River, the Ettrema Creek and the Danjera Creek take their rise, has an average height of over 2,000 feet, and is on the Nowra-Nerriga Road, 5 or 6 miles wide. On the eastern side it falls sharply about 300 feet, and on the western side it falls even more abruptly about 500 to 600 feet. Both slopes present a somewhat facetted appearance, especially the western one. The gorges cut through the surface covering of Upper Marine sandstone and deeply dissect the underlying folded strata.

Further south, between Nelligen and Braidwood, the ascent to the dividing range from the coastal side is also gradual, and the fall on the western side to the plains sudden. Here the Upper Marine sandstones have been removed by denudation, but the processes which formed

the range (Currockbilly Range) appear to have been the same as at Sassafras. The rocks exposed between Ulladulla and Nelligen in a strip about 10 miles wide (where not capped by sand-dunes) are of Silurian or Ordovician age. To the west of this strip most of the rocks are Devonian. It is evident that the Sassafras tableland and the great dissected inclined plane between the Currockbilly Range and the sea constitute an uplifted plain of marine sediments, whose uplift has been slowly and gradually effected in the long period intervening between the Permo-Carboniferous and the present. Sedimentation might have continued uninterruptedly into the Triassic or later Mesozoic periods, but all traces of such deposits have been removed by denudation. The whole area therefore forms a raised plain of marine accumulation and not a raised peneplain.

Geology.—The geology of the Permo-Carboniferous rocks which cover a great part of this area has been accurately described by Jaquet, Harper, and Card;[1] excellent maps and sections accompany their paper. The writer has described the occurrence of copper in basalt and the remarkable quartz veins in the Nelligen district.[2] Dr. W. G. Woolnough and Mr. T. G. Taylor have contributed an important paper[3] on the physiography and geology of the district lying immediately to the north of the one under discussion here.

The Permo-Carboniferous rocks which form the surface formation between the Currockbilly Range and Jervis Bay belong to the Upper Marine Series. A thickness of between three and four thousand feet has been assigned to them by Jaquet. I do not believe that they attain quite this thick-

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[1] *Records Geol. Surv. N.S.W.*, 1905, Vol. VIII, pt. ii, pp. 67 – 94.

[2] This Journal, June 3, 1908, p. 56.

[3] "A striking example of River Capture in the Coastal District of New South Wales," *Proc. Linn. Soc. N.S.W.*, 1906, pt. iii.

ness anywhere to the south of the Shoalhaven River. At Sassafras and everywhere on the Currockbilly Range near Sassafras they attain a thickness of from four hundred to about six hundred feet, and overlie folded rocks of Devonian age. They were deposited on a peneplain undergoing slow subsidence. This is shown by the fact that the base of the Upper Marine in all the gorges is an almost even plane, parallel with the bedding plane of the coal measures. Occasionally but not often a slight bulge may be observed in the surface of this plane.

The Upper Marine strata have a slight dip to the N.E. (at between 2° and 5°), their tilt being almost the same as the general slope of the country. At Sassafras Hill the dip becomes very much accentuated: for a short distance it attains an angle of 20°. This local increase in dip on the eastern fall of the tableland, as well as its facetted appearance, suggest that here we have a sharp monoclinal fold accompanied by a fault. The country to the east of it has probably been down-thrown a couple of hundred feet. The faulting was accompanied by those basaltic extrusions which cap the tableland in many places.

On the western flank of the Sassafras tableland the evidence of faulting is much more marked. The tableland is bordered by a line of cliffs beautifully facetted by cañons of the tributaries of the Endrick River (or Bulee). On descending by road to Nerriga one leaves the Upper Marine and enters the Siluro-Ordovician formations a couple of hundred feet above the point where the road crosses the Endrick. Following the road for four or five miles one meets with Siluro-Ordovician slates, intrusive quartz-diorite, quartz reefs and basalt all the way. A couple of miles beyond Nerriga, sandstone cappings were again noticed actually occupying the same or a lower level than the base of the sandstones in the tableland, but still preserving

almost the same dip. As the base of the sandstone should here be several hundred feet higher than five miles further east, we have clear evidence that a great fault must have taken place and that the western side has been downthrown at least five hundred, and possibly a thousand feet or more.

It appears therefore that the Sassafras tableland is a '*horst*' having a great fault on its western side. From the direction of the facetted cliffs it was seen that these faults have a due north and south trend. As the Currockbilly Range has a similar structure all the way from the Shoalhaven River to Milo Mountain,[1] I am of the opinion that the whole belt lying between the Clyde and the facetted western cliffs of the range forms part of a narrow horst elongated in a north and south direction. The Endrick River, the Clyde, and Ettrema Creek rise in the heart of the horst. The Endrick runs in a spiral, first south, then west, and finally north. It has carved a huge gash in the western cliffs of the range, and owes its size to the existence of a basaltic neck in its valley a few miles from its source and a downthrow of a portion of the plateau around the focus of volcanic action (Kesselbrücke). The Ettrema having no such natural weak spots to work upon runs in a narrow and awful gorge.

The basaltic neck in the Endrick valley and the basaltic dykes and flows around Nerriga are probably of the same age as the faults, perhaps a trifle later. From the clear facetted nature of the cliffs facing Nerriga I should think that the formation of the Sassafras horst and the extrusion of the basalts cannot be older than Pliocene.

In the auriferous country between Nerriga and the Shoalhaven, deep leads of a payable nature may be found under the basalt flows.

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[1] Sugarloaf Mountain of the Tourist Bureau Map.

In the eastern branch of the Ettrema one may see a line of sandstone cliffs, three hundred feet in thickness, flanking the cañon. Under this formation we have a series of highly folded and fractured rocks consisting of cherts, quartzites, slate, and limestone. This series contains typical Devonian fossils (*Spirifer disjuncta* and *Rhynconella pleurodon*). Some beds of limestone are rich in crinoid stems. On the Nelligen to Braidwood road one encounters calcareous shales and sandstones containing the same fossils in a better preserved condition. Evidently the Devonian rocks have undergone much more alteration at the Ettrema than thirty miles further south at Milo mountain. Yet, even here, they have been greatly folded for in Budawong mountain one may see the whole series folded into a gigantic anticline over 1,500 feet in amplitude.

The Upper Marine series at Sassafras commence at the base with conglomerates. This is particularly well seen on the western fall of the tableland. Both in conglomerates and in the overlying beds of coarse and fine sandstone there frequently occur boulders of great dimensions, some reaching three feet in diameter. Some of them are rounded and some angular, and they consist of various rocks, granite, quartz porphyry, slate, basalt, quartzite, etc., some of which are not known to occur *in situ* within a radius of fifty miles. Although a few of these boulders exhibit scratches there are no striations which can with certainty be identified as glacial; yet, from their mode of occurrence, I believe that they belong to the glacial horizon of the Upper Marine (Branxton horizon). Several beds of very fine grained white and very fissile sandstone occur above this horizon. They cleave into thin plates, whose surfaces are studded with carbonaceous vegetable imprints, too poorly preserved for identification. Still higher occur sandstones which contain *Martiniopsis subradiata*, *Spirifer*

duodecimacostata, and other fossils typical of the Upper Marine. As the dip of the strata agrees very closely with the general slope of the country from Sassafras to Nowra, the beds of sandstone of the latter locality are probably not much higher up in the series than those of Sassafras. The Nowra sandstones contain *Productus brachythœrus*, *Martiniopsis subradiata*, *Spirifer duodecimacostata*, crinoid stems, *Conularia* and *Chœnomya*.

In the Clyde gorge, Mr. Jaquet found that lower members of the Upper Marine and also the Greta coal measures occur. This is to be expected, as the dip is N.E. In the sandstones above the coal he found *Martiniopsis subradiata* and *Productus brachythœrus*. Near Conjola he also found *Mœonia carinata*. The supposed glacial horizon mentioned above is probably identical with the one found by Mr. E. O. Thiele at Crookhaven Heads.[1]

Ore Deposits.—The south coast to the south of Nowra is so poor and barren that unless the burrawang (*Macrozamia spiralis*), grasstree (*Xanthorrœa*) and other indigenous plants can be made of commercial use the district will have to rely on its mineral resources for its future prosperity. Yalwal, Nerriga, Braidwood, Nelligen, Moruya, and Araluen are important and well known goldfields. Most of the old mines and alluvials are worked out and now these fields are almost deserted. There remains, nevertheless, a hope that with more thorough prospecting, reefs of greater permanency may be found. Metals other than gold have been hardly looked for. Yet in many of the wild gorges which empty themselves into the Shoalhaven and Clyde great mineral wealth lies unexplored and untouched.

The axes of folding and the lines of faulting of the older rocks of the Currockbilly Range are almost due north and south. It will be seen that the galena-zincblende-mispickel

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[1] *Proc. Roy. Soc., Vict.*, 1903. xvi., pt. i, pp. 57 – 59.

deposits of Moruya, Ettrema, Talwong and Burragorang lie on a narrow belt preserving the same N.S. direction. West of this belt lies the copper-gold-mispickel belt which includes Araluen and Braidwood.

The ore deposits of Moruya, Ettrema and Talwong are all of a highly complex and refractory character, containing much zinc and arsenic. Fortunately antimony is absent. The similarity of the ores and the main structural line leads one to expect that many other similar deposits are hidden under the sandstone capping. These may be discovered and tapped in time to come. Because of the sandstone covering, the mineral lodes occur in almost inaccessible gorges (excepting at Moruya) and are exposed only where the bed of a creek has dissected them.

The only ore deposit in this area which I have examined is that of the Ettrema cañon near Sassafras. It is highly instructive, casting light upon the geological history of the district and its own origin. This ore deposit was discovered by John McKane and Sons of Oallen, near Tarago, and Mr. John R. Chaffey. It occurs in the bed of the western branch of Ettrema Creek (called Rolfe's Creek). This creek follows for a distance of half a mile or more above and below the ore deposit an old fault running N.N.W. to S.S.E. and antedating the deposition of the Permo-Carboniferous strata. The fault dips W.S.W. at 60°, and the eastern side is the downthrow side. East of it the strata dip gently towards the west and pitch towards the north. West of it they are thrown into an overfold, overthrust from west to east. The fold is partly shown in section by denudation, and its western limit is faulted and downthrown some distance. Both the principal fault and the secondary fault have acted as channels for the ascent of metallic solutions from below. The strata east of the principal fault consist mainly of Devonian quartzites and

cherts; the folded and contorted strata to the west consist of similar cherts and quartzites above and limestone below. The limestone was determined by an exposure in the main branch of the Ettrema to have a thickness of about 500 feet or more.

The main fissure (thrust plane?) cuts the creek in several places and seems to contain the best ore and the ore body has a maximum width where exposed of from 6 – 8 feet. It consists of argentiferous galena, zinc-blende, chalcopyrite and mispickel. The secondary fissure which cuts the anticline runs almost due north and south, dips (underlies) to the east at an almost vertical angle, and the lode is of great size, having a width in the bed of the creek of over 20 feet. The eastern half of the lode contains galena, but the western half is almost pure zinc blende. Both these fissure lodes appear to thin out and bifurcate upwards and to thicken downwards. From their direction and dip it is clear that they will meet at a depth.

In addition to these two fissure lodes there are numerous bedded veins varying from 6 inches to 3 feet in thickness, forming huge floors of ore. These occur in great abundance in the folded strata west of the creek and may extend for hundreds of yards into the adjacent mountain. The bedded veins contain a more complex grade of ore than the fissure lodes, being very rich in arsenical pyrites. They constitute replacement deposits in limestone.

All the rocks on both sides of the creek are of Devonian age and pitch to the north. They were probably folded in the Carboniferous period. The intensity of the folding movements led to fracturing, and metallic solutions rose along the fissures and precipitated their contents on the walls. On reaching the limestone they filtered along the bedding planes and dissolved out carbonate of lime leaving metallic sulphides instead. The source of the minerals

and perhaps also the cause of the dislocations may be a great laccolite of quartz diorite intruded at a great depth. In the Endrick River I have seen quartz-diorite traversed by veinlets of mispickel and blende. The cooling of a huge mass of such rock might well have given rise to large ore deposits in overlying strata into which hot solutions rose from the shrinking mass. Certain it is that the Ettrema deposits are not contact deposits, nor are they segregation veins, for no rocks occur anywhere in the vicinity which contain their mineral contents. The only igneous rocks which I have seen cutting the Devonian rocks in the Ettrema gorge are a thin dyke of decomposed (chloritic) andesite, less than a foot wide, and a couple of diorite dykes.

The solutions which brought the minerals to the surface must have consisted of alkaline sulphides, sulphuretted hydrogen, silicic acid solutions, for they strongly interacted with the limestone with the result that great thicknesses of what was originally limestone has been turned partially or wholly into chert.

The entire geological surroundings indicate that the two fissure lodes will widen and meet at depth, their joint pipe still widening until the base of the limestone is reached, inasmuch as in the limestone solution and replacement have taken place on the walls. The base of the limestone will be about 600 feet below the bed of the creek at the mine. After that in the subjacent slaty and schistose rocks the lode will become somewhat narrower and probably richer in the more valuable metals (Ag., Au., Cu. and Pb.) and arsenic until the source is reached. Whether an ore deposit of such a complex character and situated in so awkward a place will pay to work in our time is a question which must be left to time and to mining engineers to solve.

Results:—1. It has been shown that the country between the upper Shoalhaven and the sea is a raised plain of marine sediments and probably not a raised peneplain.

2. The Sassafras tableland and the Currockbilly Range form a dissected '*horst*' or 'block mountain.'

3. Faulting movements of Tertiary age probably account for the north and south trend of the creeks rising near Sassafras. The Ettrema approximately follows a palæozoic fault line along which small movements may have taken place in Tertiary time. A line of weakness and severe jointing so formed has rendered the affected parts subject to easy attack by subærial erosion. As soon as the underlying palæozoic rocks were reached the N. and S. direction would become accentuated, the palæozoic structure lines having that trend. In the Ettrema the creek at the mine has after cutting through the sandstone, followed a palæozoic fault which has been impregnated with ore bodies. No doubt river captures, such as that described by Dr. W. G. Woolnough near Marulan have aided to bring about the peculiar direction and disposition of the streams.

4. The occurrence of a glacial horizon in the Upper Marines of Ettrema Creek is suspected.

5. Late Tertiary basalt eruptions are shown to have followed upon the formation of the Sassafras horst and to have been accompanied by local subsidences (as in the Endrick).

6. The fault formation throughout the area belongs to two periods—the Carboniferous and the late Tertiary. In both cases the fissures run approximately north and south.

7. The Devonian rocks occupy a basin lying between two strips of Silurian or Ordovician age, the one extending from Milton to Nelligen, the other from Nerriga to Braidwood. This Devonian trough was folded and elevated in the Carboniferous.

8. The Devonian and late Permo-Carboniferous were periods of sedimentation. The Carboniferous witnessed

folding, uplift and dissection; the early Permo-Carboniferous peneplanation; and the Meozoic and Tertiary periods plateau uplift, dissection and erosion.

9. One mineral deposit characteristic of the area has been briefly described and its probable origin outlined.

Further work in the area will be taken up when time permits. The present paper is necessarily of a highly generalised nature and based upon scattered observations rather than detailed work, except at the Ettrema Cañon, where more than a week was spent on field work.

It is interesting also to note that at Sassafras and in all the gorges heading in this tableland, the caves in the sandstone cliffs contain an efflorescence of alum. It is possible that the production of this mineral may be partly due to the slow evolution of sulphuretted hydrogen by the sulphide minerals in the underlying formations, and the upward passage of the gas into the sandstones in solution in spring water. On approaching the surface oxidation to sulphuric acid by the aid of iron oxides in the sandstone and the reaction of the acid with felspar might easily give rise to alum. It may also be due to organic matter in the sedimentary rocks.

On the divide between the Endrick and Ettrema headwaters some dry basins, amphitheatre-like in shape, occur. Here the sandstone seems to cave in and drainage appears to be subterranean. If appearances be true these basins probably overlie cavernous limestone. The matter requires further investigation.

THE DISCONTINUITY OF POTENTIAL AT THE SURFACE OF GLOWING CARBON.

By Professor J. A. POLLOCK, A. B. B. RANCLAUD, and E. P. NORMAN.

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[*Read before the Royal Society of N. S. Wales, December 2, 1908.*]

OWING to the projection of ions by hot substances a discontinuity of potential will occur at the surfaces of the electrodes in any circuit in which these latter are formed of heated materials. The value of this potential discontinuity has been calculated by Professor Richardson[1] from considerations connected with the gas theory of metallic conduction, and has been found in the case of carbon by Mr. Duddell,[2] who observed at the surface of the cathode of the ordinary carbon arc a forward electromotive force of 6·1 volts, and a back electromotive force of 16·7 volts at the surface of the anode.

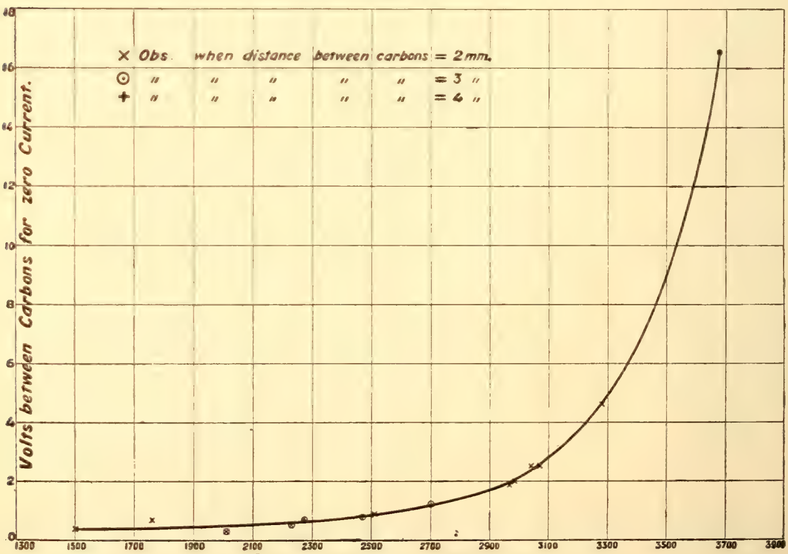
In a circuit with one heated electrode in air at ordinary pressure, the projection of ions from the hot surface necessitates the establishment of a potential difference between the electrodes if the current in the circuit is to be zero. If electrons alone were projected, a layer of gas close to the hot surface would become negative to the solid and the potential difference between the electrodes for zero current might be taken as a measure of the surface discontinuity of potential. When positive ions are emitted as well as electrons, owing to the difference in the distances from the electrode at which the two classes of ions are stopped by collision with the gas molecules, the electric force may

[1] *Phil. Trans.*, A 201, p. 497, 1903. [2] *Phil. Trans.*, A. 203, p. 305, 1904.

change sign in the near neighbourhood of the heated surface. In this case the potential difference between the electrodes for zero current, with appropriate sign, must be less than the value of the surface discontinuity of potential which would be due to the projection, alone, of that class of ions which conditions the sign of the potential difference.

With the apparatus described in a previous paper[1] the potential difference for zero current has been found in the case of glowing carbon at various temperatures. The experiments were a continuation of the work already described, and in the paper just mentioned will be found full details of the method of investigation. The observations, which fulfil the condition that the values should be independent of the distance separating the electrodes, are shown in figure 1. For zero current the hot carbon was positive to the cooler electrode in all cases.

Fig. 1.



Potential differences for zero current.

[1] Pollock and Ranclaud, this Journal p. 201.

The heated electrodes were cored carbon rods, 0·5 centimetres in diameter, supplied by Messrs. Siemens Brothers for use with their Lilliput arc lamps, with the exception of the one employed for the observation at 3040° absolute which was a squared rod, 0·5 centimetres on the side, of solid Conradty carbon marke C. As the measure with this material agrees well with the other results, it may be concluded that values of the potential difference for zero current with hot electrodes of different makes of carbon do not seriously differ.

At 3120° absolute, with 50 volts between the electrodes, the ratio of the flow of negative electricity from the hot carbon to the flow of positive, when the sign of the potential difference was reversed, was as 20 to 1.

On the assumption that at high temperatures the potential difference for zero current measures the surface discontinuity of potential, as the number of electrons then projected per second far exceeds that of positive ions, the curve in figure 1 has been continued to the value, 16·7 volts, found by Mr. Duddell, (*loc. cit.*), for the back electromotive force at the anode of an arc between solid Conradty Noris carbons. This measure has been plotted for the temperature of the crater, 3690° absolute, determined by Messrs. Waidner and Burgess[1] from observations with a Holborn-Kurlbaum optical pyrometer, a similar instrument to that with which we have estimated the other temperatures. Mr. Duddell gives 6·1 volts as the measure of the forward electromotive force at the arc cathode; this value corresponds, on the curve of potential differences for zero current, to a temperature of 3375° absolute, which, if the assumption already stated is legitimate, may be taken as an estimate of the temperature of the cathode of the carbon arc.

[1] *Phys. Rev.*, 19, p. 255, 1904.

With a heated iron wire in the place of the hot carbon of the previous experiments, the potential difference for zero current was 0·85 volts at 1410° absolute and 0·25 volts at 1570°, the hot wire being in both cases, negative to the cooler electrode. The potential difference with a platinum wire, not specially treated, at 1580° absolute was 0·40 volts, the hot wire being again negative. With a Nernst filament, designed for 0·25 ampère at 90 volts and used under those conditions, the potential difference for zero current was 0·25 volts. In this case the filament was positive to the cooler electrode, and with a potential difference between the electrodes of 45 volts, the ratio of the flow of negative electricity from the hot filament to the flow of positive, when the sign of the potential difference was reversed, was as 33 to 1.

Professor Richardson, (*loc.cit.*), gives, for the number of corpuscles shot off from unit area of a hot conductor per second, the expression $A\theta^{1/2}\epsilon^{-b/\theta}$, in which A depends on the number of corpuscles per unit volume of the conductor, and b on the work done by a corpuscle in passing through the surface layer, θ being the absolute temperature. The formula, considering A and b as constants, very well represents the observations of its author and others on the saturation currents from hot bodies through the range of temperature for which it has been employed; from such observations the values of b for certain substances have been determined. In the theory by which the expression is deduced, b is equal to ϕ/R, where ϕ is the work done by a corpuscle in passing through the surface layer and R a gas constant, equal to $p/N\theta$, p being the pressure and N the number of molecules per cubic centimetre. The discontinuity of potential is thus represented by bR/e, where e is the ionic charge.

The following are the values of the discontinuity of potential as calculated by Professor Richardson:—

	Temperature absolute.		Discontinuity of potential.
Sodium ...	490° – 700°	...	2·46 volts.
Platinum ...	1378 – 1571	...	4·1 ,,
Carbon ...	1520 – 1770	...	6·1 ,,

These results which are not appreciably altered by recalculation with the new value of the ionic charge determined by Professor Rutherford and Dr. Geiger,[1] seem singularly high. If bR/e really represents the discontinuity of potential, the fact that the discontinuity varies somewhat rapidly with temperature for higher values shows that b cannot be considered altogether constant.

In a recent paper Professor Richardson and Mr. Brown[2] originate the theory of a method for finding the kinetic energy of the electrons projected from heated materials, and they have experimentally determined the component, perpendicular to the hot surface, of the velocity with which electrons are projected from glowing platinum, the result for a temperature of 1650° absolute being $1{\cdot}5 \times 10^7$ centimetres per second. This velocity of projection, in the case of glowing carbon, may, on certain assumptions, be estimated from the results already given in the present paper. As suggested by one of us[3] a point of view is possible from which the work done in connection with the passage of the electrons through the surface layer may be considered as represented by their translational energy when they emerge into the gas. In such a case the surface discontinuity of potential, V, may be expressed by the equation,

$$V = \tfrac{1}{2}\frac{m}{e}v^2,$$

where m is the mass of the electron, e the ionic charge, and v the component, in the direction of the field, of the

[1] *Proc. R.S.*, A. 81, p. 162, 1908.

[2] *Phil. Mag.*, 16, p. 353, Sept. 1908.

[3] Pollock, *Proc. Elect. Assoc. N.S.W.*, 1908-9.

velocity with which the electrons are projected from the hot surface. If this equation holds, on the assumption previously stated, we may deduce from the curve in figure 1, that the velocity with which electrons are projected from glowing carbon varies from $1 \cdot 5 \times 10^8$ centimetres per second at 3375° absolute to $2 \cdot 5 \times 10^8$ centimetres per second at 3690° absolute. In a similar way, from the result previously given, a lower limit to the velocity with which electrons are projected from the Nernst filament may be calculated as 3×10^7 centimetres per second.

THE SEDIMENTARY ROCKS OF THE LOWER SHOALHAVEN RIVER.

By Charles F. Laseron.

(Communicated by R. T. Baker, F.L.S.)

[*Read before the Royal Society of N. S. Wales, December 2, 1908.*]

Introduction.—The following paper comprises the main features of geological interest noted in the course of several excursions made to the district within the last four years. As the river for some distance above Nowra is very difficult of access, considerable labour was experienced in exploiting it. But owing to the kindness of one of the local residents, Mr. Robert Condie, who has assisted me on every occasion, I have been able to examine its course nearly to its junction with its tributary, the Kangaroo River. Two camping expeditions were undertaken to this part, the boat with outfit and provisions being hauled up the rapids, which above Burrier are very common. The results of the previous expeditions were briefly reviewed in the *Australian*

Naturalist,[1] but much additional data having been obtained, further conclusions arrived at are here placed on record. My indebtedness is due to Messrs. Youll, Blackmore, and Martin, who accompanied me at various times. To Mr. Blackmore, my thanks are particularly due for the trouble he took in obtaining photographs, and to Mr. Youll for his indefatigable assistance in the field.

The Devonian fossils before collected, were very kindly named by Mr. W. S. Dun, Palæontologist to the Mines Department.

Previous Literature.—Literature on the district is very limited and chiefly confined to the comparatively small area covered by the Yalwal Gold Field. The Rev. W. B. Clarke[2] in the sixties, touched on the main features of the district. Mr. E. C. Andrews, Geological Surveyor, did considerable work in the district, though his observations were more confined to the gold field at Yalwal.[3] The Upper Marine Series, south of Nowra, were studied in 1890 by Professor David,[4] and Messrs. Jaquet and Harper reported on the geology of Conjola in 1904.[5] Practically no work has been done however in the study of the conditions under which the Upper Marine Series were deposited, of the relations of the various sub-divisions, one to the other, and of their fossil contents.

Physiography.—The Shoalhaven River lies just beyond the edge and flows parallel to the plateau, which marks the southern limit of the great coal basin formed by the Upper or Newcastle coal measures, overlain by the Hawkesbury-

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[1] Vol. I, pt. 3, 1906. [2] Southern Goldfields.

[3] Report on the Yalwal Gold Field, Geological Survey of N. S. Wales, Mineral Resources, No. 9.

[4] Annual Report Department of Mines of N. S. Wales, 1890, Progress Report.

[5] Records of Geological Survey of N. S. Wales, 1904.

Wianamatta series. This plateau terminates on its southern boundary in high escarpments and deep gorges, which the tributaries of the Shoalhaven have in the course of ages cut out to a depth of 2,000 feet and more. The most familar of these is the valley of the Kangaroo River, which can be well studied from Bundanoon. This river has eroded its channel right through the Triassic, the Upper Coal Measures, and well into the Upper Marine Series. From its southern edge the plateau follows the northern dip of all these strata and slopes gradually until it reaches sea level at Sydney.

The Shoalhaven itself has in its lower courses practically reached base level, but the country being broken and irregular, it does not cut the deep regular gorges that its tributaries do, while the country it drains is exceptionally rough. Rich alluvial flats occur on the inside bends of the river as far as it was examined, some of considerable area, and for some distance above Nowra they are farmed successfully. These and the numerous patches of river gravel prove that the river has now practically ceased the erosion of its bed, and is now depositing material instead. River terraces are not uncommon, though they do not present the beautiful regularity seen on some rivers.

Geology.—The items of geological interest of this part of the country, and more particularly those which are here discussed may be tabulated as follows:—

(1) Several new and interesting localities for the collection of fossils.

(2) The occurrence at Yalwal Creek of freshwater beds containing *Glossopteris*.

(3) Theoretical reasons for the supposition of an inlier of Devonian rocks between Grassy Gully and Yalwal Creek.

(4) Beautiful examples of unconformity between the Permo-Carboniferous and Devonian formations.

(5) A very interesting example of extreme folding on Yalwal Creek.

(6) The relations of the various subdivisions of the Upper Marine strata, with a glimpse at the local geography in old Palæozoic times.

(7) The nature of the habitat of many of the Permo-Carboniferous molluscs.

For reasons dealt with later, the following division of the sedimentary rocks has been adopted :—

DEVONIAN—Quartzites and Rhyolites.

PERMO-CARBONIFEROUS—*Upper Marine Series.*

(1) Conjola Beds
- (*a*) Freshwater beds with *Glossopteris* } contemporaneous.
- (*b*) Conglomerates }

(2) Wandrawandian Series
- (*a*) Mudstones at Burrier }
- (*b*) Sandstones of Grassy Gully } contemporaneous
- (*c*) Grits with Edmondia }

(3) Nowra Grits

RECENT—River Gravels and Alluvium.

Devonian—This is the age consigned by Mr. Dun to the fossils collected from the large series of quartzites and other rocks, underlying the Permo-Carboniferous. They first make their appearance at Grassy Gully, where they consist of hard silicious rhyolites, showing beautiful flow structure. These have been described by Mr. E. C. Andrews.[1] Further west they outcrop at intervals, all along the river banks, as far as it was explored, that is nearly to the junction of the Kangaroo River. In the neighbourhood of Yalwal Creek beautiful sections of unconformity occur, the folded Devonian standing out in marked relief to the Upper Marine sandstone above.

[1] Report on Yalwal Goldfield. p. 22. Geol. Surv. N.S. Wales, Mineral Resources, No. 9.

At Yalwal Creek the Devonian consist nearly wholly of quartzite, and dip to the north-west. As no marine fossils had ever been found in these beds, considerable search was made, but for a long time without success. Boulders containing Devonian fossils were found at last in Yalwal Creek, and eventually *in situ* at the junction of Yalwal and Ettrema Creeks. At this spot the folding is very symmetrical, regular anticlines and synclines being formed. The strike is invariably N.E. and S.W. The rocks consist of quartzites, sandstones and grits containing several fossiliferous horizons, which consist of bands of sandstone up to 3 feet in thickness, practically made up of the remains of pelechypods.

Mr. Dun identified the following genera—*Allorisma? Sphenotus*, *Leptodomus*, *Pterinea*, and *Goniophora*? No other fossils at all occur with the exception of several specimens of *Lepidodendron*. The shells are unfortunately very badly preserved, and no specimens perfect enough to describe were obtained. The internal casts of the specimens were often encrusted with minute doubly terminated quartz crystals, of which there was usually a cluster of somewhat larger ones on the beak. There is an absence of pebbles of any sort among these strata.

Following the course of Yalwal Creek above its junction with Ettrema Creek for about a mile, a very interesting section occurs. A high cliff runs back at right angles to the creek, sectioning the hillside. The strata at its base are quite vertical and even inverted, while about half way up the face they are sharply bent to the right, until they are past the horizontal. In the face of the cliff, on closer examination, it is seen that the various layers have stood the enormous strain unevenly. Some of the bands have yielded, producing a number of miniature thrust faults. The appearance of the fold suggests that it was just on the

point of yielding when the folding force ceased. This force seems to have come from the south-east.

Another series of fossiliferous strata of Devonian age were found on the Shoalhaven River, about three miles west of Yalwal Creek. They consist of quartzites dipping to the S.W. at an angle of 60°. As in the Ettrema beds, there are a number of fossiliferous horizons, the maximum being about three feet in thickness. They are completely composed of the remains of shells, which however are wretchedly preserved. The rock consists of a quartzose limestone, which is very hard and tough so that it breaks completely across any fossils it may contain. Fossils can only be obtained in the completely weathered material, and these are very poor. They are remarkable for the prevalence of gasteropods, *Bellerophon*, *Euomphalus? Naticopsis?* and *Mourlonia?* were the genera found. Of the pelecypods *Goniophora?* and *Ctenodonta?* were the only ones found. *Spirifer disjuncta* and *Rhynconella pleurodon* were here found *in situ*.

Devonian Inlier near Grassy Gully.—Though not seen *in situ*, there seems reasonable evidence that an inlier of Devonian rocks should exist somewhere between Grassy Gully and Yalwal Creek. On one of the previous excursions a boulder was found lying in a gully on the northern side of Grassy Gully. This was found *above* the junction of the Devonian rhyolite and the Upper Marine sandstone, and contained numerous specimens of *Spirifer disjuncta* and *Rhynconella pleurodon*. This seemed to suggest an outcrop of Devonian higher up. The gully was subsequently explored further up and the face of the mountain partially examined. Numerous hard quartzite boulders up to two feet in diameter were found, but no actual outcrop was seen. But as the country is very rough and the outcrops largely hidden by talus slopes, such an outcrop might easily

escape observation. The large boulders however seem to point to Devonian rocks at a high altitude in the locality.

On ascending the mountain from the Yalwal Creek side, more large boulders of quartzite with veins of quartz were found in abundance, almost on the top of the range. They were of all sizes and littered the whole hillside. Again no outcrop was seen. The largest boulder was quite four feet across and must have weighed over half a ton or more. One or two were found near here embedded in Upper Marine sandstone. The majority were waterworn. Assuming these boulders to be embedded in a Permo-Carboniferous sandstone, the only force that could have brought them from any distance is floating ice. Water power certainly could not have moved them far. Several of the boulders were extracted, and the unweathered portion examined, but no ice striations could be detected. However, it does not necessarily follow that the absence of ice-striations excludes the possibility of the agency of ice, but the boulders being of the same character as the local quartzites and the presence in them of Devonian fossils, seems evidence that they have come from an actual outcrop in the near neighbourhood.

The Upper Marine sandstones on top of the range were noticed for some distance to be dipping to the west, at an angle of 20°. For beds so high up in the series, this is remarkable, unless this inlier occurs immediately to the east, on the sloping sides of which the later beds were deposited. The rhyolites at Grassy Gully reach quite a high altitude, their junction with the sandstone being quite 300 feet above river level. This means that *high land existed here* when the Permo-Carboniferous sea started to encroach, even if the inlier of Devonian sedimentary rocks does not exist.

Permo-Carboniferous.—With the exception of a certain small series of sediments at Yalwal Creek, which are fresh-

water in origin, and can therefore hardly be said to belong to the Upper Marine Series, the Permo-Carboniferous rocks of the district are confined entirely to that formation. From Nowra to Yalwal Creek they fall naturally into a threefold subdivision. Further to the south a similar division occurs.[1] To avoid duplication of names it is here proposed to retain the local names applied to the various formations further south, for the several series discussed. It is probable that the mudstones at Burrier, the sandstones of Grassy Gully, and the grits of Yalwal Creek, are connected with the Wandrawandian sandstones, and are only their western or north-western extension. The topmost members of the Upper Marine Series are the Crinoidal Beds, which are well developed on Cambewarra mountain. For purposes of convenience I have also made a horizontal division in two of the series, owing to the different characters and fossil contents of the same formation in different localities. This will be best seen on studying the section. The names however are of a purely local nature, and it is not intended that this nomenclature should hold good elsewhere.

Sub-Division I—*The Conjola Beds.*

These beds are probably of the same age as the extensive series at Conjola, though formed under different conditions. However it is the nature of these conditions which makes me incline to the view that the freshwater beds, though containing *Glossopteris*, are yet of later age than, and therefore were formed when the Clyde Coal Measures further south had already been submerged.

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[1] Professor T. W. E. David, Progress Report, Annual Report Department of Mines of N.S.W., 1890. The following subdivisions of the Upper Marine Series are made south of Nowra:—(1) Nowra Grits, (2) Wandrawandian Sandstones, (3) Conjola Beds. The second formation is described as consisting of dark grey mudstones with abundant fossils, which have the original shell matter preserved, and with a thickness of 550 feet. The Conjola Beds consist of sandstones and conglomerates with a thickness of 1,400 feet, and contain a strongly carinated *Mœonia* in abundance.

(*a*) *Freshwater Series.*—A good section of these is exposed in the mountain side near the junction of Yalwal Creek and the Shoalhaven. It consists of three or four terraces outcropping in a small dry gully. The thickness of the series which consist of finely laminated, micaceous shales and sandstones, is here about 30 feet. They rest immediately on the Devonian, and their position is generally indicated by talus slopes. Nearly all the laminæ yield fragments of plants, and about midway in the series several specimens of *Glossopteris* and *Phyllotheca* were obtained. Their southern extent can be traced along Yalwal Creek for about half a mile, but they narrow down considerably, until at last we find the Upper Marine Series resting upon the Devonian.

Near this spot a narrow bed of shale was found about eight inches thick interstratified between two thick beds of very coarse conglomerate. This also contained fragmentary plant remains. The most western outcrop was seen on the Shoalhaven River about three-quarters of a mile beyond Yalwal Creek. To the east of the first outcrop the shales were not found, except immediately on the opposite side of Yalwal Creek. The talus slope is there however, but the sandstone gradually encroaching at last rests directly on Devonian rhyolites, about a mile from Yalwal Creek.

On the eastern side of Yalwal Creek immediately above the Devonian, the freshwater beds are mostly hidden by talus slopes, which are very steep and are covered by coarse grits and conglomerates. In the conglomerate, however, at several different horizons, thin beds of shale occur. Some of the layers are very carbonaceous and contain numerous fine impressions of *Glossopteris*, *Gangamopteris*, *Nœggerathiopsis* and *Phyllotheca*. These thin seams are lenticular and can be traced until no thicker than a sheet of paper.

In one spot no less than four were found, one above the other. The lower two were each about one foot in thickness and ten feet apart, and the topmost two were only two or three inches thick and two feet six inches apart.

Mr. E. C. Andrews[1] mentions strata with plant remains from Yalwal goldfield, further to the south, but does not give many particulars of their occurrence.

(b) *The Conglomerates.*—These are best studied about three miles west of Yalwal Creek. The Devonian here reach a height of about 100 or 150 feet. Immediately above lies the conglomerate, occupying the same relative position in regard to the Devonian and the Edmondia sandstone that the Freshwater Series do further to the east. The height of the hills on either side of the river rises as we go westward, and strange to say the conglomerate also thickens, though the height of the Devonian remains stationary and the sandstone cap still occurs above. At this spot there is a thickness of about 300 feet of conglomerate. It is remarkably homogeneous in character, the pebbles being usually from two to six inches in diameter, set in a sandy and somewhat argillaceous groundmass. One huge waterworn boulder however was over three feet in diameter.

The topmost beds of the conglomerate here form a prominent escarpment below the sandstone capping. Owing to the soft nature of the binding material the rock is easily disintegrated; consequently numerous deep rock shelters have been formed, some with very narrow openings. In these, deposits of alunogen are very common. In one place through this wearing or fretting on unexposed surfaces, a perfect natural arch has been formed. The peculiar appearance of the conglomerate, of which great masses

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[1] Report on Yalwal Goldfield, p. 17, Geol. Surv. N. S. Wales, Mineral Resources, No. 9.

strew the mountain side, the caves, the natural archway, all covered with dense vegetation, combine to make a scene of great rugged grandeur.

Origin of the Conglomerates and Freshwater Beds.—There can be no doubt that the conglomerates were formed by the erosion of the underlying Devonian beds, when first buried beneath the sea, and also that the material of which they are composed has not travelled any distance. The pebbles are almost entirely composed of a quartzite, the one or two exceptions noticed being of quartz. These quartzites are lithologically identical with the Devonian quartzites of the neighbourhood. If the pebbles had travelled far, there would have been a more or less mixed variety of them, as to the south there are granites, to the west slates and granites, and to the east rhyolites and dolerites. The present river gravels show just such a variety.

The peculiar conditions under which the two series were laid down, can best be understood by remembering the presence of high land in the neighbourhood of Grassy Gully. At this time, the Lower Coal Measures were just being submerged beneath the Permo-Carboniferous sea, which was gradually encroaching from the north and east. The hollows were first submerged, and in them settled the detrital material, which the ever advancing breakers tore from the neighbouring land, and from the higher ground which now existed as islands. One of these islands existed somewhere near Grassy Gully, as stated before. On its western side was a plain of narrow extent, probably not more than three or four miles across. To the west deep water existed ; in this the conglomerates were laid down, being formed as they are of quite local rocks. As the land sank and the conglomerate accumulated, it was piled back against the edge of this ancient plain by the surf, and

formed beaches of coarse shingle. These would naturally dam back the surface drainage from the island or perhaps peninsula lying to the east. Thus lagoons were formed, in which ferns and horse-tails became embedded and preserved. Similar lagoons to these may be seen in many places on our own coast at the present time. At times the sea would break through these barriers and a layer of sandstone would result. As the land sank these inundations became more frequent, until at last the plain became entirely submerged with marine sediments deposited above. But before the final inundation took place, slight changes of level allowed the old conditions to be resumed for short intervals. Thin lenticular beds of shale were then formed near the landward boundary of the old plain, but at last these too were finally submerged beneath the Permo-Carboniferous sea. But by this time the coastline had retreated away to the south and west, and naturally finer sediments began to be deposited ; these were the Edmondia sandstones and grits, the Grassy Gully sandstones and the Burrier mudstones, which will now be considered in detail.

Sub-Division II—*The Wandrawandian Series.*[1]

(*a*) *Grits with Edmondia.*—This formation is characterised by the abundance of the shell *Edmondia nobilissima*, de Kon., in some horizons. Many good outcrops are to be found in the neighbourhood of Yalwal Creek, where they form the lofty escarpments which cap the mountains bordering both Yalwal Creek and the Shoalhaven. They consist of sandstones, grits and conglomerates, and dip slightly to the east. At Yalwal Creek they cap the fresh-water beds, but further to the west they lie directly on the conglomerates, from which they are in some places

[1] Professor David calls these the Wandrawandian Sandstones. As the series evidently embrace other rocks besides sandstone, the word series is here substituted.

separated by lenticular beds of a fine grained sandstone. At this spot they exhibit some remarkable examples of weathering. In several rock shelters numerous sheets of sandstone a foot across were flaking off, across the stratification, and were frequently not more than one-eight of an inch in thickness. In other places regular jointed beds had had their cracks filled with iron oxide. Subsequent decomposition of the sandstone had left a peculiar boxlike arrangement of limonite, sometimes standing out as a framework two or three feet from the wall. The well known honeycomb weathering familiar in the Hawkesbury sandstone was very common.

It is worthy of note that these beds, though much finer than the conglomerates beneath, are still very coarse. It is evident that only the strongest shells would stand a chance of preservation. In the conglomerates on the other hand it is doubtful if any organism would remain intact. Thus we find two tough shells in the forms of *Edmondia nobilissima* and *Mœonia elongata* in the Edmondia sandstones, and with the exception of one or two *Spirifers* and a little bivalve found in abundance in a ferruginous sandstone overlying the Edmondia horizon, these were the sole fossils. This fossil bivalve is important, as it occurs right throughout the Wandrawandian Series being found about the same horizon on the western and north-eastern sides of Sugarloaf, at Grassy Gully and in the Burrier mudstones. As exemplyfying the turbulent conditions prevailing when the Edmondia beds were deposited, I might mention that we were for some time puzzled as to the nature of certain fragments of shell with a fibrous structure; these were very common, but never more than one inch across. At Grassy Gully, however, we found large specimens of *Aphanaia gigantea* with the shell complete, which corresponded with the fragments found; evidently this mollusc

was not stout enough to resist fracture, and immediately on death the shell became broken. As in the conglomerates, deposits of alunogen are found in the rock shelters, also stalactites both of limonite and calcite and some earthy oxide of manganese.

(b) *The Sandstones of Grassy Gully.*—These are really an eastern extension of the previous formation, but on account of their nature and their fossil contents, they are here considered separately. They are found resting directly on the Devonian rhyolites on both sides of Grassy Gully. Both the freshwater beds and conglomerates are absent. From this it is evident that the sea here abutted directly against the high shores of the island, and no plain existed as on the other side. The beds themselves consist of sandstones and grits, but very little conglomerate. In the lower beds pebbles of rhyolite are not uncommon, and of a similar nature to the local rhyolites. The remarkable feature of the beds, however, is the abundance of fossils in some horizons; whole masses of rock are entirely composed of their remains. Sometimes they are remarkably well preserved with the original shell matter intact. It is noteworthy that the fossils found consisted almost entirely of brachiopods, of which several species of *Spirifers*, two species of *Martiniopsis*, *Dielasma*, *Productus*, and *Stropholosia*, were very common. Of the Pelecypods the *Pectens* were commonest, and the other species were those mostly allied to *Mytilus*, such as *Aphanaia* and others. The same little pelecypod found at Yalwal Creek is abundant, also *Platyschisma* and *Mourlonia;* several good specimens of *Conularia* were also found.

Fossils were also collected on the western side of Sugarloaf about the same horizon, and also on its northern side. They were similar in character but with *Edmondia* and *Mœonia elongata*. *Goniatites* was found on the Shoal-

haven River near Grassy Gully (E on map), and with it some peculiar structures which only seem attributable to worm burrows. These cross the stratification at all angles, are circular in section and about one-quarter of an inch in diameter. At Grassy Gully it was noted that while *Dielasma* and *Productus* were common in a perfect state with both valves joined, yet the *Spirifers* and *Martiniopsis* usually consisted of one valve only, and were frequently fragmentary. Further to the east, where the Devonian rhyolites first outcrop on the Shoalhaven, they rise very quickly and the sandstones abut against them rather than overlie them. Thus it is evident there was a sudden deepening of the old sea at this spot.

(c) *Mudstones at Burrier.*—The sandstones of Grassy Gully as they extend eastwards insensibly pass into a series of a much finer texture which contain a different fossil fauna. They are well exposed in the neighbourhood of Burrier and outcrop on the banks of the river from there to Longreach, where they disappear beneath beds of a later age. They consist largely of micaceous shales intercalated with beds of a fine grained grey or red sandstone. The latter is very hard and tough and in parts tuffaceous. A high cliff just above Burrier shows a splendid section of these beds, and in the centre is a small fault with a displacement of a couple of feet. All these beds dip a little to the north of east; the angle is very uniform and varies between $2\frac{1}{4}°$ and $2\frac{1}{2}°$. Fragmentary pieces of fossil wood are common in the shales, and evidently have drifted into their present position. Impressions of a doubtful nature are very common, and are I think referable to worm-tracks. One noticed was over one foot long, lying upon the bedding plane in the shape of a horse shoe. In diameter, it was about an inch, but of no great thickness.

Burrier proved to be a magnificent collecting ground for fossils. In the hard sandstone they were admirably pre-

served, and though somewhat difficult to extract, yet amply repaid the labour involved. Unfortunately owing to rain, I did not have time to thoroughly prospect these beds, but nevertheless many good specimens were obtained. It is at once noticeable that pelecypods predominate. They are in remarkable abundance and variety. Slab after slab of sandstone contained nothing else. For the most part they were found with both valves complete and with the original shell matter preserved. *Martiniopsis*, so common at Grassy Gully, is entirely absent here, while *Spirifers* and other brachiopods were not at all common. Several specimens of *Zaphrentis* were found in one locality near Longreach, and near this a band of mudstone with *Astartila*, *Platyschisma* and other fossils.

Origin of Wandrawandian Series.—When the Wandrawandian Series as a whole began to be deposited, the conglomerates and freshwater beds at Yalwal had just disappeared beneath the sea. As mentioned before, the shore had by this time retreated away to the south and west, and so the beds consisted of finer material which had travelled farther. But the sea bottom was not by any means stable, and slight elevations continued at various times to bring shallower portions above sea level, and expose them to the action of the breakers. Thus material was obtained, which was consolidated into beds of conglomerate, and these we find interstratified with the Edmondia grits. As we go farther to the eastward, we recede from this old shore and the sediments get finer and finer, forming the sandstones at Grassy Gully and the mudstones at Burrier. The sea was not necessarily deep at this stage, but seaward currents must have existed to have brought the fossil wood at Burrier so far from land.

Sub-Division III—*The Nowra Grits.*

"*Nowra Grits*" is the name proposed by Professor David for the series of sandstones and grits which underlie

Nowra. They occur as low cliffs, flanking the river from Nowra to the head of Longreach, and further to the west, capping Sugarloaf Mountain, and also the high range which lies to the north of the river above Yalwal Creek. At the latter locality they overlie the Edmondia sandstone, and consist of sandstones and grits showing current bedding. The only fossil found was a spirifer. *Spirifer vespertilio* was also found in this series on the summit of Sugarloaf. Above Nowra, current bedding is well exhibited, but the series here is chiefly remarkable for the uniformity of its jointing. Two series of joints are generally developed, their directions on the surface being north and south, and east and west respectively. But whereas the east and west joints are perfectly perpendicular, the north and south ones invariably incline to the east at an angle of about 60°. This is noticeable even in the small cracks. The remarkable constancy of this angle is astonishing, and produces some very peculiar results in rock sculpture.

Some distance back from the river the dipping of the joint planes has the effect of tipping enormous masses of sandstone into all sorts of queer positions. Lofty pinnacles of sandstone are separated by deep narrow cracks, and great isolated blocks lean one against the other, producing deep fissures and caves. The country is covered with a dense brush vegetation, while orchids and creepers cover the rocks and trees, and combine to make a scene of the wildest confusion and magnificence. The current bedding of this series dips only in the one direction, that is to the east. The angle of dip of the false stratification is much lower than that of the joint planes, but the unvarying direction of the two would seem to have some connection. These characters persist from Nowra to Longreach, and evidently denote a shallow sea with a perpetual strong current from the west or south-west. The series as a

whole are very barren of fossils. In one or two horizons, however, internal casts consisting entirely of brachiopods were fairly common. At the Grotto near Nowra, good internal casts of *Spirifer* are common, and on the range between Burrier and Longreach, sandstone made up of masses of *Productus* was found.

River Gravels and Alluvium.—These are comparatively of recent age, and are found on the inside bends of the river as far as it was explored. The river gravels consist of a great variety of rocks and get coarser the higher we ascend. Gold occurs in cracks almost anywhere in the river bed, but only in small quantities.

Habitats of the Palæozoic Fauna.—This is a very fascinating but difficult subject, and one hardly as yet touched upon. The clearness of local conditions under which the Wandrawandian Series were formed may however throw some light on the subject. In the storm tossed waters near the old shore, only very strong shelled molluscs could survive. Here we find *Edmondia* and *Mœonia* flourishing. The Grassy Gully beds contain brachiopods, with a few pelecypods of a peculiar littoral nature, such as *Aphanaia;* these shells probably lived under the lea of the neighbouring island, and evidently preferred quiet water with a sandy bottom. They are very similar in appearance to the common mussels (*Mytilus*) and probably had the same habitat. Here too, occasional pteropods drifted in from the open ocean and their delicate shells had a chance to be preserved.

In the Wandrawandian period we see a shallow sea with a muddy bottom in which countless pelecypods such as *Pachydomus*, *Mœonia*, *Pleurophorus*, *Chœnomya*, *Merismoptera* abounded. The gasteropods *Mourlonia* and *Platyschisma*, together with the *Spirifers* seem to have been ubiquitous and to have lived anywhere. Goniatites probably was like the pteropods and floated on the open

ocean, for we find its remains scattered almost anywhere in marine rocks. No crinoids were found in the district; it is evident that they required much clearer seas, far distant from land. The very shallow seas with strong currents in which the Nowra Grits were deposited, could only support a brachiopod fauna, which evidently stood a greater variety of conditions than the pelecypods. I have but touched on this most fascinating subject, which seems to me of considerable geological value. Further data however are required, which can only be gained by careful and systematic collecting.

Conclusion.—While thoroughly conscious of many shortcomings in the preceding notes, I nevertheless think, that they give a fairly complete picture of the conditions which prevailed at the close of the period which marked the deposition of the Lower Coal Measures, and at the beginning of the formation of the Upper Marine Series. Though these observations were purely local, it seems to me that they will probably apply to other localities on the border of the old Permo-Carboniferous sea. This class of geological work is particularly interesting, dealing as it does with an ancient geography which existed millions of years ago, and which was superficially different and yet had essentially the same features as that which prevails now. And consequently, if I have added in these pages but one particle to our knowledge of this ancient earth of ours, I shall be quite satisfied.

Explanation of Lettered Localities on Map.

A. Shales containing *Astartila polita* etc.

B. Shales containing *Zaphrentis.*

C. Sandstone with abundant *Productus.*

D. Mudstones and sandstones with abundant and well preserved fossils chiefly pelecypods.

E. Sandstone with Goniatites and worm burrows?

F. Sandstone with abundant fossils: *Productus*, *Aviculopecten*, *Aphanaia*, *Conularia*, etc.

G. Loose boulder with *Spirifer disjuncta* and *Rhynconella pleurodon*

H. Large blocks of hard quartzite.

I. and J. Fossiliferous sandstone.

K. Devonian fossils (gasteropods chiefly).

L. Lenticular bands of shale, containing well preserved specimens of *Glossopteris* and other plants.

M. Shale with *Glossopteris.*

N. Coarse sandstone and conglomerate containing *Edmondia.*

O. High cliff showing section of overfold.

P. Devonian fossils.

Q. Sandstone with internal casts of brachiopods.

R. Outcrop of Devonian inlier (theoretical).

S. Sandstone (Nowra Grit) with *Spirifera.*

VOCABULARY OF THE NGARRUGU TRIBE N.S.W.

By R. H. Mathews, L.S.

[*Read before the Royal Society of N. S. Wales, December 2, 1908.*]

I wish to place on record a vocabulary obtained by me from the remnant of the Ngarrugu tribe, which formerly occupied the country from Queanbeyan, via Cooma and Bombala, to Delegate. Adjoining the Ngarrugu on the north from Queanbeyan to Yass, Booroowa and Goulburn, was the Ngunawal tribe. In 1904 I published a short grammar and vocabulary of the Ngunawal language,[1] a sister tongue of the Ngarrugu. The grammatical structure of these languages is closely similar, and several words of their

[1] *Journn. Anthrop. Inst.*, vol. 34, pp. 294 - 305.

vocabularies are almost identical. Adjoining the Ngarrugu on part of the west was the Walgalu, and westerly again of the latter was the Dhudhuroa, a grammar and vocabulary of whose language I shall publish later on. On part of the south, the Ngarrugu was bounded by the Birdhawal tribe, whose language and initiation ceremonies have been reported by me.[1] West of the Birdhawal and south-west of the Ngarrugu the Kurnai language was spoken, a grammar and vocabulary of which I published in 1902.[2] It should be mentioned that between the Ngarrugu and the sea coast are a number of tribes, whose initiation ceremonies and dialects have been dealt with by me in various Journals.

The tribal name, Dhudhuroa has been erroneously reported as "Theddora" by some writers. Walgalu as "Wolgal," and Birdhawal as "Biduelli."

Ngarrugu Vocabulary.

This vocabulary contains about 260 words collected personally among the remnant of the Ngarrugu natives in the Monaro district, New South Wales. Instead of arranging the words alphabetically they are placed together under separate headings. As the equivalents of English terms will most frequently be required they are put first.

Family Terms.

Mankind,	murriñ	Father's father,	ngatyen
A man,	baual	Father's mother,	kubbing
Husband,	manggala	A woman,	bullan
Old man,	muyulung	Old woman,	goan'ditch
Clever man,	guragalang	Wife,	manggala
Sorcerer,	murlimuluntra	Girl,	mullangan
Boy,	burubal	Elder sister,	ngummang

[1] *Mitteil. d. Anthrop. Gesellsch. in* Wien, Band 38, pp. 17 – 24, and *Proc. Amer. Philos. Soc.*, vol. 46, pp. 346, 347.

[2] This Journal, vol. 36, pp. 92 – 106, and *Proc. Amer. Philos. Soc.*, vol. 46, pp. 357 – 359.

Initiate,	kuringal	Younger sister,	kallan
Elder brother,	dyiddyang	Mother,	ngaddyang
Younger brother,	kugang	Mother's mother,	ngañ
Father,	bubang	Mother's father,	ngagun
Master,	beang'go	Infant,	wengu and mūmū

Parts of the Body.

Head,	kuttagang	Knee,	bummat
Forehead,	ngulange	Foot,	dyinnang
Hair of head,	yerrange	Heart,	yugurang
Beard,	yerrañ	Liver,	dhubbut
Eye,	gundthul	Blood,	guruba
Nose,	kūng	Fat,	bē-wan
Back of neck,	binggal	Bone,	gundal
Throat,	dhulet	Penis,	dyubbadyang
Ear,	dyanyange	Scrotum,	gurra
Mouth,	mundhange	Pubic hair,	burrāre
Teeth,	ērange	Copulation,	dyumbullañ
Mammæ,	munyuknge	Masturbation,	wattugañ
Navel,	nyuri-nyuriñ	Semen,	burranya
Belly,	būllinguringu	Vulva,	willing
Arm,	kungathalungi	Anus,	gunung
Elbow,	kungalngurunge	Urine,	dyūng-ur
Shoulder,	bundagangi	Excrement,	gunnunggu
Hand,	murrungga	Venereal,	dhauadhawathara
Thigh,	dhurra		

Inanimate Nature.

Sun,	mummatch	Fire,	wattha
Moon,	yeddhi	Smoke,	dhūnbūk
Stars,	dyuang	Flesh, food,	ngulla
Pleiades,	bralung	Ashes,	birriñ
Thunder,	mirrabi	Charcoal,	dhallang
Lightning,	mullup	Firewood,	kulgagal
Rain,	wallung	Live coal,	kunnamarang
Rainbow,	gurangurang	Day-light,	mummatch
Dew,	dying-e-ang	Night,	dhai-a-go

Fog,	kanggat	Hill,	bunggal
Frost,	dhān	Grass,	nalluk
Hail and snow,	gunama	Leaves of trees,	gundigang
Water,	ngadyung	Wild honey,	gwanggal
Ground,	dhau-ur	Grub in Wattle,	gunung-gurañ
Stone,	gurubang	Grub in Gum-tree,	gubbadyuk
Sand,	memburrang	Bloom on trees,	gubbura
Cold,	kurritgo	Pathway,	be-al′
Camp,	bandya	Shadow,	mambarang′i
Pipeclay,	kabbatch	Tail of animal,	kumeang
Red ochre,	ngai-ur	Summer,	wirrin

Mammals.

Native bear,	dandeal	Brush wallaby,	dhurragang
Dog,	mirrigang	Wombat,	bungadhung
Opossum,	gungurang	Porcupine,	kau-an
Kangaroo-rat,	dyimmang	Kangaroo,	burru
Native cat,	bindyellang	Platypus,	dyam-a′-lung
Bandicoot, long nose,	dhurwañ	Ringtail opossum,	balgai
Bandicoot, short nose,	manyuk	Bat, small,	ngud′yan-ngudyan
Water rat,	batpu	Bat, large,	berkun
Tiger cat,	gūndarang	Flying squirrel, large,	ngallawa
Rock wallaby,	wai-at	Flying squirrel, small,	watchgang

Birds.

Birds, collectively,	būdyan	Rosella parrot,	dŭñ
Crow,	yukumbrak	Swift,	birging
Laughing Jackass,	kumburang	Peewee,	dhirra-dhirri
Curlew,	wŭrbil	Chock,	dyarrandyak
Plain turkey,	karūk	Leather-head,	birrigigik
Swan,	kunyuk	Thrush,	dūngang
Eaglehawk,	mirrung	Plover,	bindhawindherri
Emu,	gun-gwan	Lyrebird,	bullit-bullit
Magpie,	gurambugang	Small owl,	dyūnūtch
Black Jay,	i-buk	Black cockatoo,	yerriak
Mopoke,	go-gok	Little owl,	i-bing
Bronzewing pigeon,	wawaka		

Fishes, Reptiles, Invertebrates.

Eel,	kalgun	Locust,	galang-galang
Blackfish,	mundya	Blowfly,	ngago
Frog, large,	gumbillang	Louse,	kadyi
Frog, small	dyirrigorat	Nit of louse,	dhandiko
Tree iguana,	buddha'luk	Leech,	dyirrang
Turtle	ngūllukbang	Bulldog ant,	dyubburu
Sleepy lizard,	dyirri-dyirritch	Maggot,	ngagomiñ
Small lizard,	dyirrimala'ka	House fly,	gunagungun
Small black lizard,	gurgurwúrak	Spider,	marar
Carpet snake,	dyiddyugang	Scorpion,	dhūrt
Wood lizard,	ngullum'ba	Mussel,	bindugañ

Trees, Plants, etc.

Tea-tree,	dyelládru	White gum,	balluk
Wattle,	mātrŭk	Ribbon gum,	dyua
Pine,	būmbur	Currant bush,	maranggang
Red gum,	dhūmba	Swamp gum,	murrigal
White box,	gunumba	Black sally,	buguger'ak
Yellow box,	dhukkai	Snow gum,	warrugang
Honeysuckle,	gillarung	Yam,	mēwañ

Weapons, Ornaments, etc.

Tomahawk,	ngumbugang	Woman's bag,	badyung
Koolamin,	dyinburing	Man's belt,	dhūrunggal
Yamstick,	kuggang	Man's apron,	barrañ
Spear, wood	dyerrumba	Woman's apron,	dyabañ
Spear, reed	kamai	Man's brow-band,	dyabbatch
Spear lever,	berami	Canoe,	dyinburu
Spear shield,	birkumba	Paddle,	kagang
Waddy shield,	ngummal	Arm-band,	nurabutbut
Fighting club,	gudyurung	Bullroarer,	mooroonga
Boomerang,	ngullamur		

Adjectives.

Alive,	kubbukudyan	Quick,	gurung-gurung
Dead,	dhirrakumba	Afraid,	dyau-atbunya
Large	yeppungbilli	Right,	mandhang

Small,	kubiangai	Wrong, foolish,	wang-ang
Good,	yellagañ	Tired,	yalawunya
Bad,	muruba	Cold,	karattha
Thirsty,	wunya	Greedy,	mura-nhuna
Hungry,	mirritya	Sick,	kokumbalinya
White,	kurbit	Stinking,	ngulukumban
Red,	ngaiernger	Pregnant,	bullindherra
Black,	dhaguk		

Verbs.

Die,	birrakumbañ	Sing,	yangabilliñ
Eat,	dhambilli	Weep,	kumbaliñ
Drink,	ngukai	Steal,	kiandyuluk
Sleep,	kubbukai	Climb,	gulligimbilli
Stand,	dyubingalai	Jump,	bibburai
Sit,	ngullagai	Laugh,	yindiai
Talk,	baiallanga	Scratch,	bingga'dya
Tell,	bemmaramban	Pick up,	mamutch
Walk,	yerrabalinga	Throw down,	burramai
Rung,	munningale	Swim,	bulmai
Bring,	bundingalai	Throw,	yerre
Break,	kuragungambi	Whistle,	winde-ai
Beat or strike,	wapma	Vomit,	dhura dhurat
Arise,	nguyuka	Go,	yerrabadya
Fall down,	bukkáli	Come,	yerrabingalai
See,	nhamai	Bite,	nyukkangi
Listen,	ngattai	Kill,	birrak-ngambi
Give,	yunganyilla		

Numerals.

One, bur or burē ; two, bulala ; a pair, wadyala.

APPENDIX.

EXPLANATION *re* "NOTES ON THE ARRANDA TRIBE."

In an article published in this Journal, Vol. XLI., p. 151, I gave the marriage and offspring of a certain woman named

Nakara. As I possess the pedigree of this woman backward to her grandfather, and forward to her grandchild, Dr. W. H. R. Rivers, an eminent English anthropologist, has asked me to publish it. I therefore submit the following table, in which the names of men are given in capital letters those of women in lower-case type, and the names of the men are always to the left of those of their wives. The section to which each person belongs is entered in italics directly under his or her proper name. The letter *m* stands for "married."

TABLE.

JUKARA *m.* Mokurkna
Kamara *Paltara*

First Son.		Second Son.	
ARKARA *m.* Tjupuntara *Purula* *Pananka*		TJIRTJALKUKA *m.* Relkua *Purula* *Pananka*	
TPITARINJA *m.* Laramanaka *Kamara* *Paltara*		MAKANA *m.* Nakara *Bangata* *Kamara*	
JUKUTA *m.* Ruth *Purula* *Pananka*		JAKOBUS *m.* Lydia *Pananka* *Ngala*	
USTAV *Kamara*	unmarried.	Frieda *Bangata*	unmarried.

In the left hand side of the above table, all the marriages and the descent of the offspring are in accordance with Table I, p. 68 of volume XLI of this Journal, and with Table C, *American Anthropologist*, Vol. X, N.S., pp. 89–90. In the right hand side of the above table, Nakara is married to an alternative or No. 2 husband, and her child Jakobus, takes the section name of his mother's mother and of his father's father. Jakobus marries an alternative or No. 2 wife and the child, Frieda, takes the section name of her mother's mother and father's father, in accordance with Table B, p. 151 of volume XLI of this Journal. The man Jakobus is about 37 years old at the present time. He

was born about 1872, before any Mission Station was established at Hermannsburg, and his pedigree is consequently free from any European influence.

CORRECTION.

In my table of the intermarrying divisions of the Warramonga tribe, reported at p. 73 of Vol. XXXII of this Journal, 1898, some clerical errors occurred. In a few instances the "alternative" or No. 2 wife was given instead of the "normal" or No. 1. In 1901 I published a correct table at p. 74 of Vol. XVI, *Queensland Geographical Journal*, to which the reader is referred.

Diagram 1.

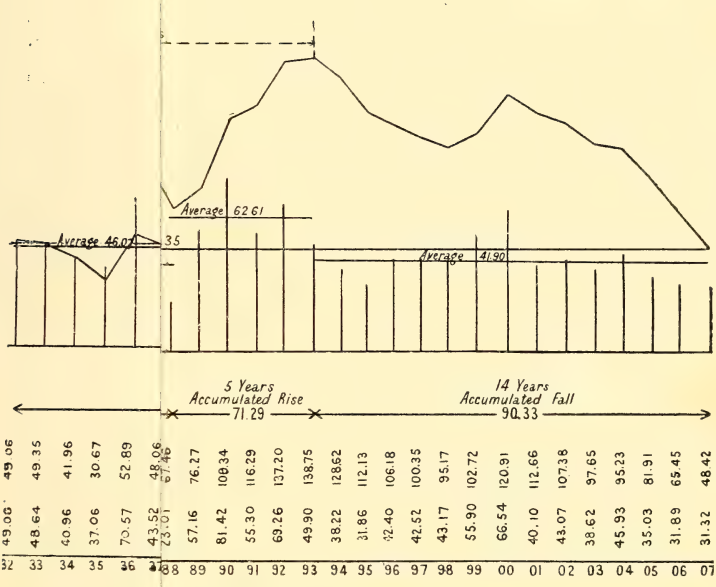

Average 46.07
Average 62.61
Average 41.90
35
5 Years
Accumulated Rise
71.29
14 Years
Accumulated Fall
90.33
49.06 49.35 41.96 30.67 52.89 48.06 67.46 76.27 108.34 116.29 137.20 138.75 128.62 112.13 106.18 100.35 95.17 102.72 120.91 112.66 107.38 97.65 95.23 81.91 65.45 48.42
49.06 48.64 40.96 37.06 70.57 43.52 23.01 57.16 81.42 55.30 69.26 49.90 38.22 31.86 32.40 42.52 43.17 55.90 66.54 40.10 43.07 38.62 45.93 35.03 31.89 31.32
32 33 34 35 36 37 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07

Diagram 1.

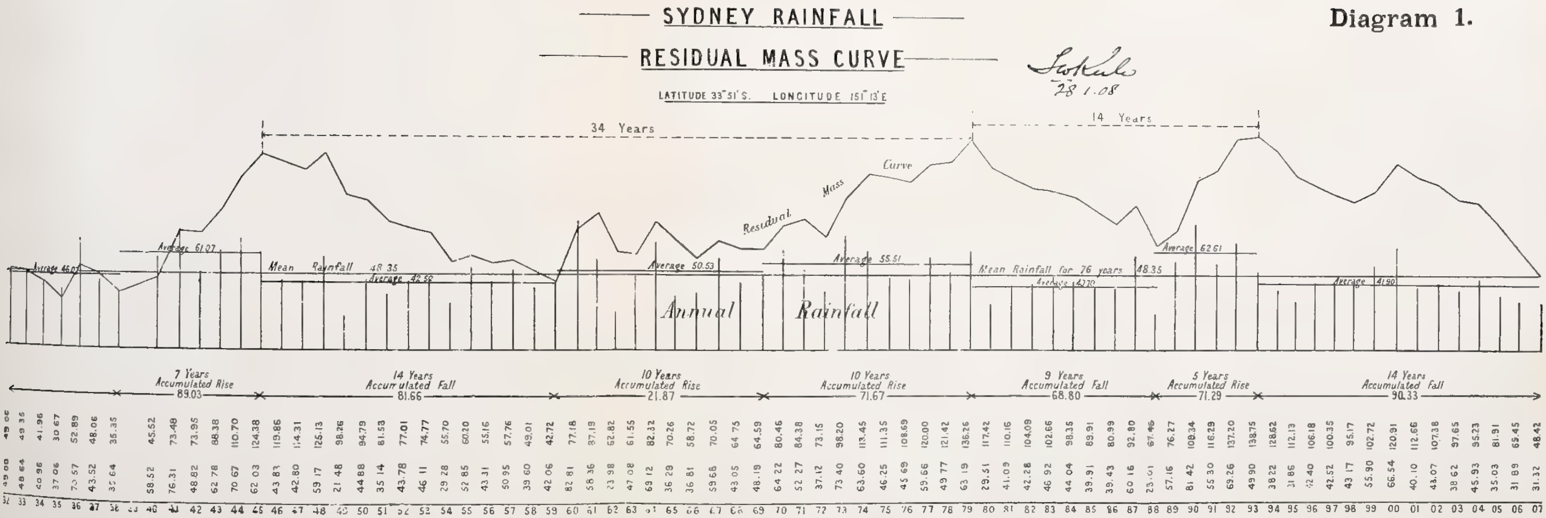

SYDNEY RAINFALL
RESIDUAL MASS CURVE
LATITUDE 33° 51' S. LONGITUDE 151° 13' E
34 Years
14 Years
Residual Mass Curve
Average 46.07
Average 61.07
Mean Rainfall 48.35
Average 42.58
Average 50.53
Average 55.51
Mean Rainfall for 76 years 48.35
Average 42.70
Average 62.61
Average 41.90
Annual Rainfall
7 Years Accumulated Rise 89.03
14 Years Accumulated Fall 81.66
10 Years Accumulated Rise 21.87
10 Years Accumulated Rise 71.67
9 Years Accumulated Fall 68.80
5 Years Accumulated Rise 71.29
14 Years Accumulated Fall 90.33

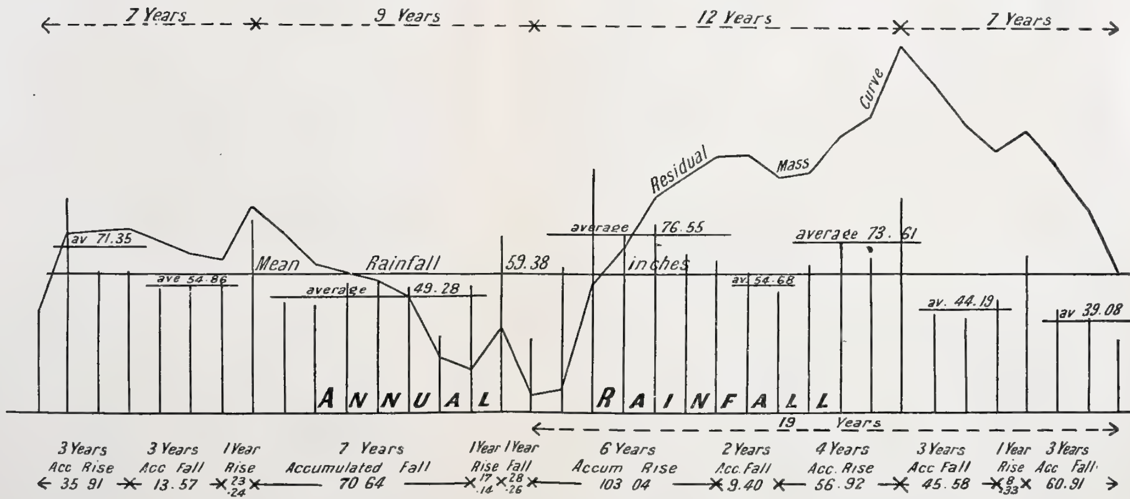
Diagram 2.

CORDEAUX RIVER RAINFALL

RESIDUAL MASS CURVE

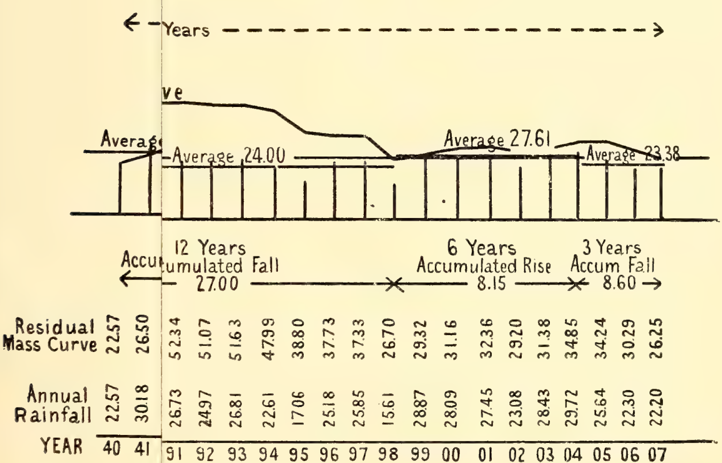
Latitude 34° 19' S Longitude 150° 44' E

12.3.08



Year	Residual Mass Curve	Annual Rainfall
72	43.15	43.15
73	76.68	92.91
74	77.58	50.28
75	79.06	60.86
76	73.20	53.52
77	67.90	54.08
78	65.49	56.97
79	88.73	82.62
80	77.09	47.74
81	63.70	45.99
82	59.97	55.65
83	56.55	55.96
84	49.42	52.25
85	23.05	33.01
86	18.09	54.42
87	35.23	76.52
88	6.97	31.12
89	9.84	62.25
90	54.63	104.17
91	71.01	75.76
92	92.30	80.67
93	101.77	68.85
94	110.01	67.62
95	109.93	59.30
96	100.61	50.06
97	103.62	62.39
98	118.36	74.12
99	125.59	66.61
00	157.53	91.32
01	141.08	42.93
02	123.07	41.37
03	111.95	48.26
04	120.28	67.71
05	105.10	44.20
06	87.10	41.38
07	59.37	31.65

Diagram 3.

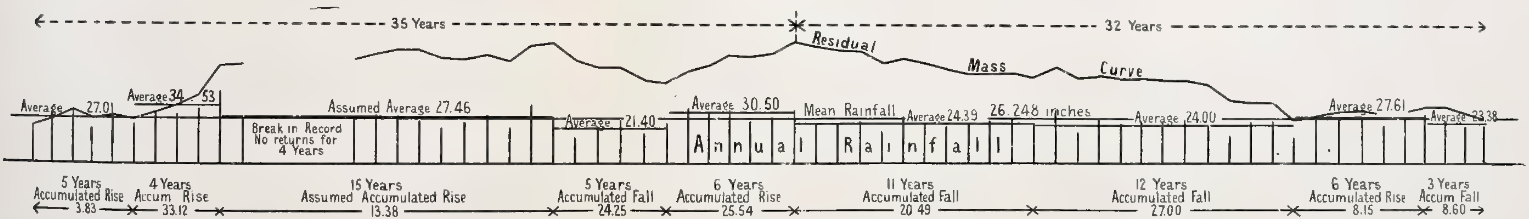

Years
ve
Averag
Average 24.00
Average 27.61
Average 23.38
12 Years
Accumulated Fall
27.00
6 Years
Accumulated Rise
8.15
3 Years
Accum Fall
8.60
Residual Mass Curve 22.57 26.50 52.34 51.07 51.63 47.99 38.80 37.73 37.33 26.70 29.32 31.16 32.36 29.20 31.38 34.85 34.24 30.29 26.25
Annual Rainfall 22.57 30.18 26.73 24.97 26.81 22.61 17.06 25.18 25.85 15.61 28.87 28.09 27.45 23.08 28.43 29.72 25.64 22.30 22.20
YEAR 40 41 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07

MELBOURNE RAINFALL
RESIDUAL MASS CURVE

LATITUDE 37°50'S LONGITUDE 144°59'E

Diagram 3.

12.2.08



YEAR	Residual Mass Curve	Annual Rainfall
40	22.57	22.57
41	26.50	30.18
42	31.41	31.16
43	26.70	21.54
44	28.72	28.26
45	26.40	23.93
46	30.68	30.53
47	34.61	30.18
48	41.52	33.15
49	59.52	44.25
50	60.25	26.98
51		
52		
53		
54		
55	62.21	28.21
56	65.71	29.75
57	68.37	28.90
58	68.13	26.01
59	63.70	21.82
60	62.83	25.38
61	65.74	29.16
62	61.57	22.08
63	71.75	36.42
64	72.90	27.40
65	62.59	15.94
66	58.75	22.41
67	58.30	25.79
68	50.32	18.27
69	48.65	24.58
70	56.17	33.77
71	60.09	30.17
72	66.37	32.52
73	65.72	25.60
74	67.57	28.10
75	74.19	32.87
76	71.98	24.04
77	69.84	24.10
78	68.95	25.36
79	61.98	19.28
80	64.21	28.48
81	62.04	24.08
82	58.20	22.40
83	55.66	23.71
84	55.26	25.85
85	55.95	26.94
86	53.70	24.00
87	59.85	32.39
88	53.02	19.42
89	53.91	27.14
90	51.86	24.20
91	52.34	26.73
92	51.07	24.97
93	51.63	26.81
94	47.99	22.61
95	38.80	17.06
96	37.73	25.18
97	37.33	25.85
98	26.70	15.61
99	29.32	28.87
00	31.16	28.09
01	32.36	27.45
02	29.20	23.08
03	31.38	28.43
04	34.85	29.72
05	34.24	25.64
06	30.29	22.30
07	26.25	22.20

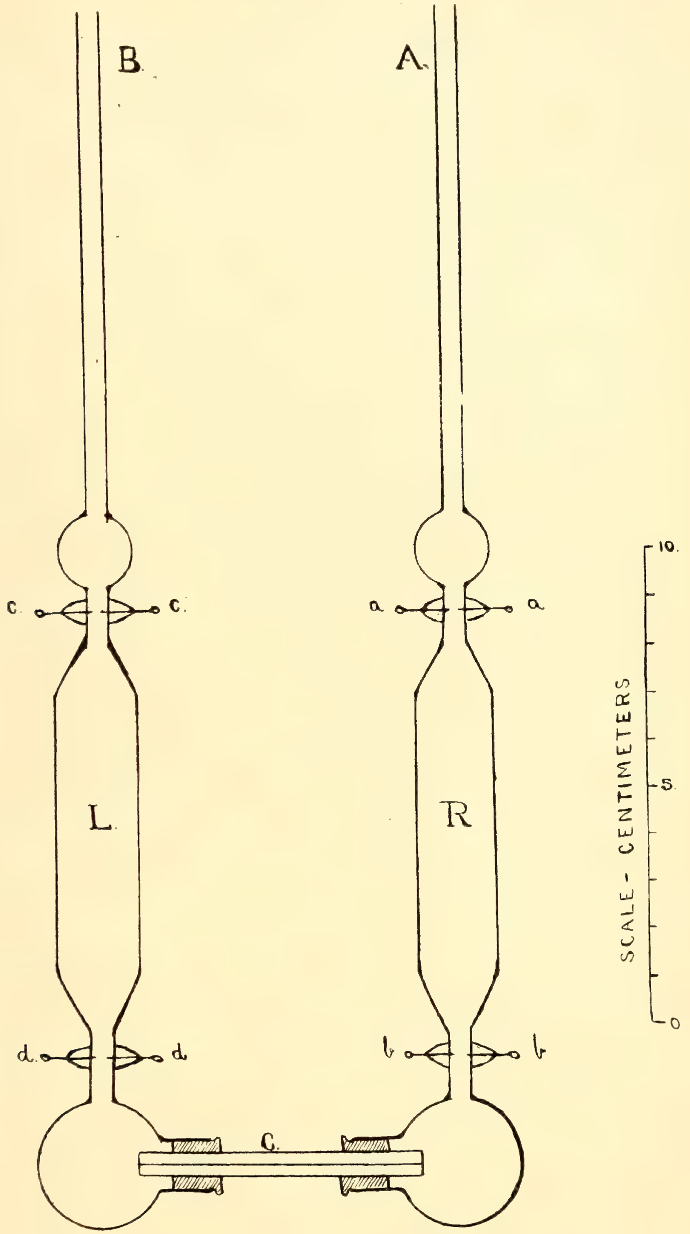


Fig I. Glischrometer.

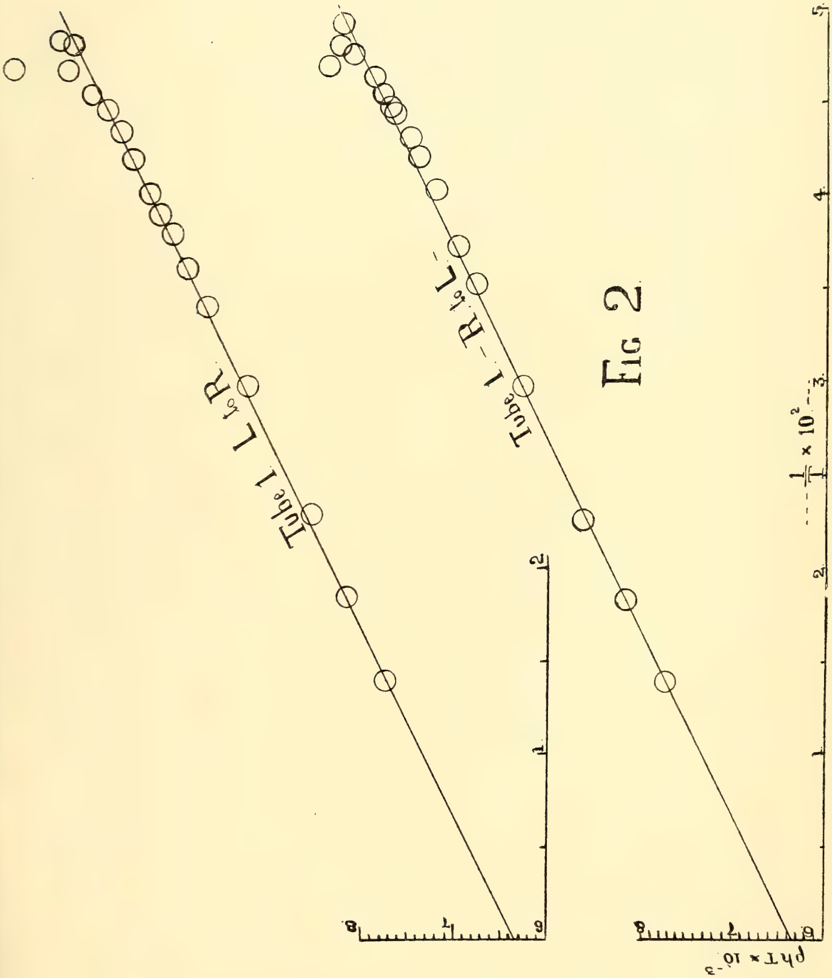


FIG 2

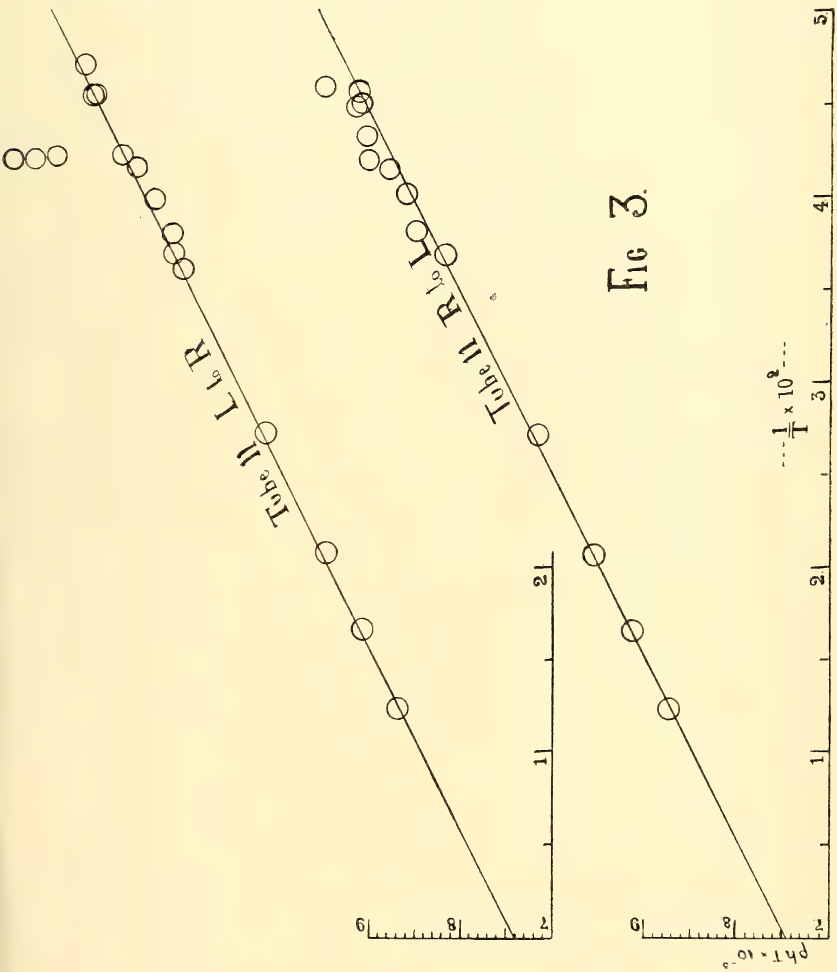


FIG 3.

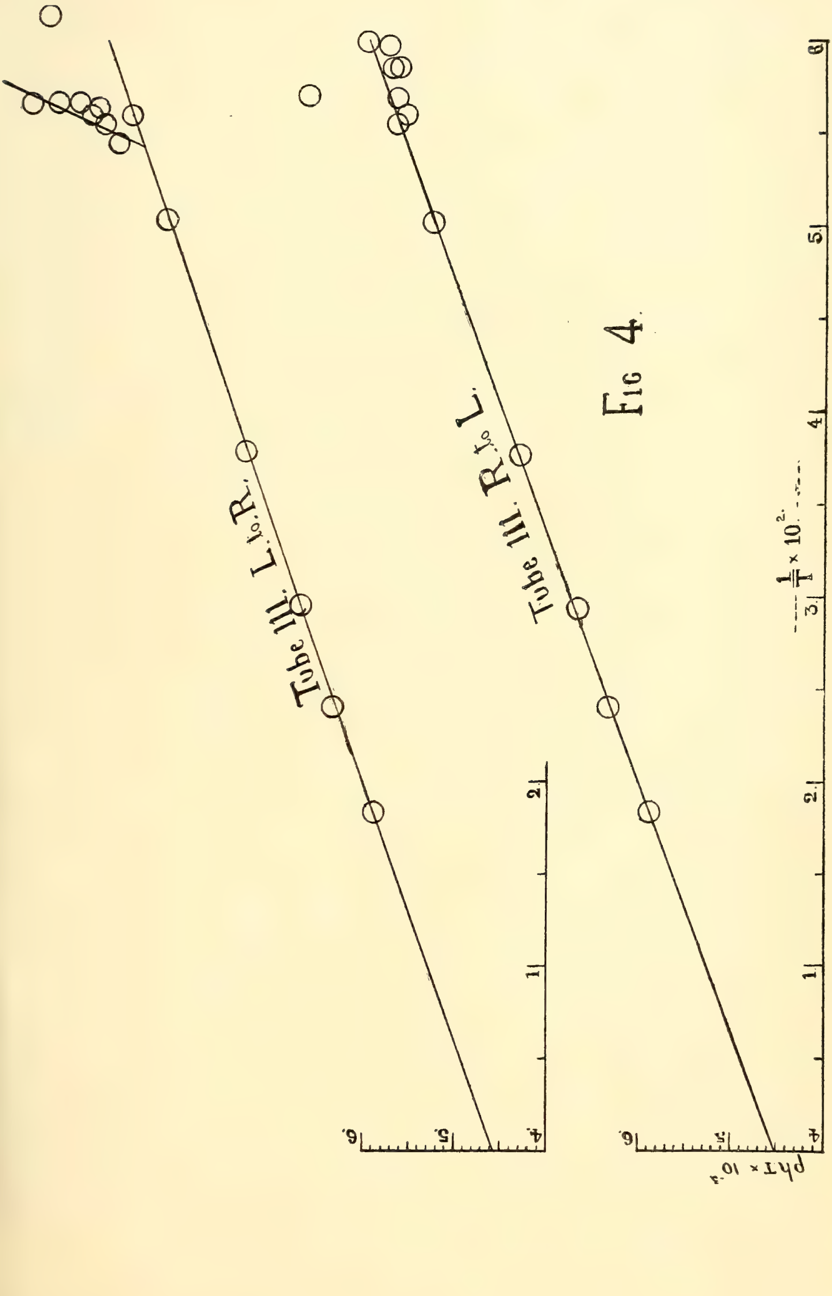


Fig 4.
Tube III. L. to R.
Tube III. R. to L.
1/T × 10²
phT × 10⁴
.4
.5
.6
1
2
3
4
5
6

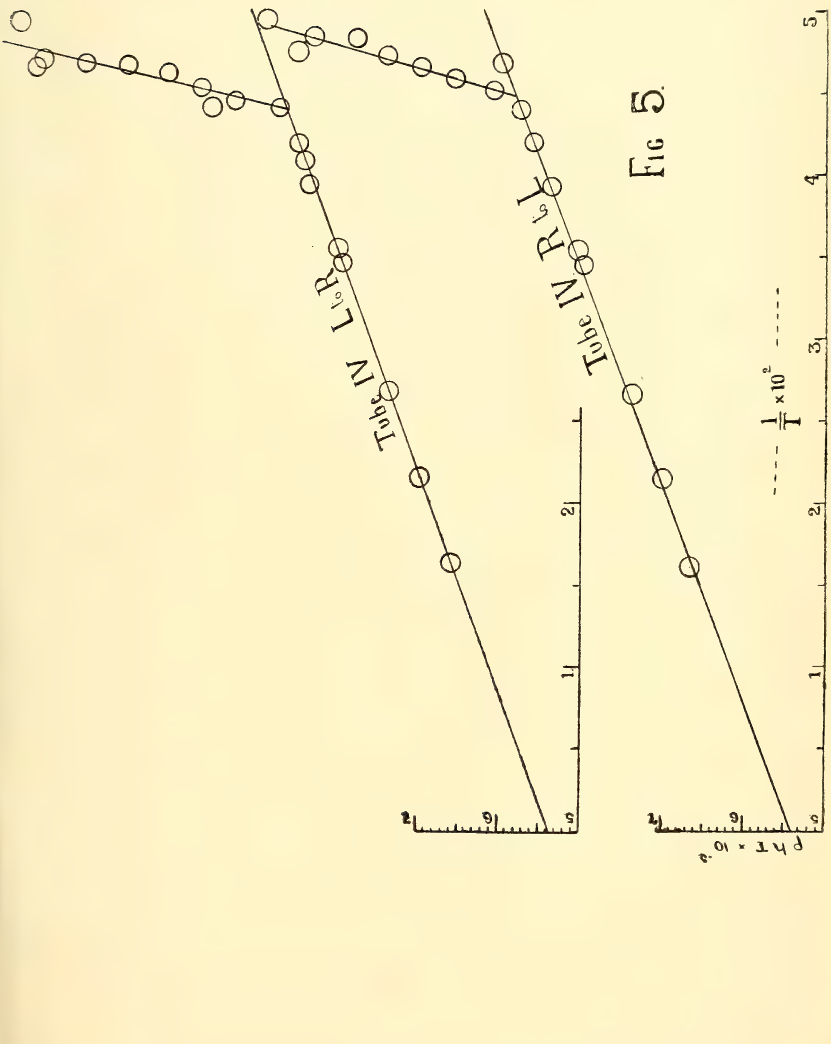
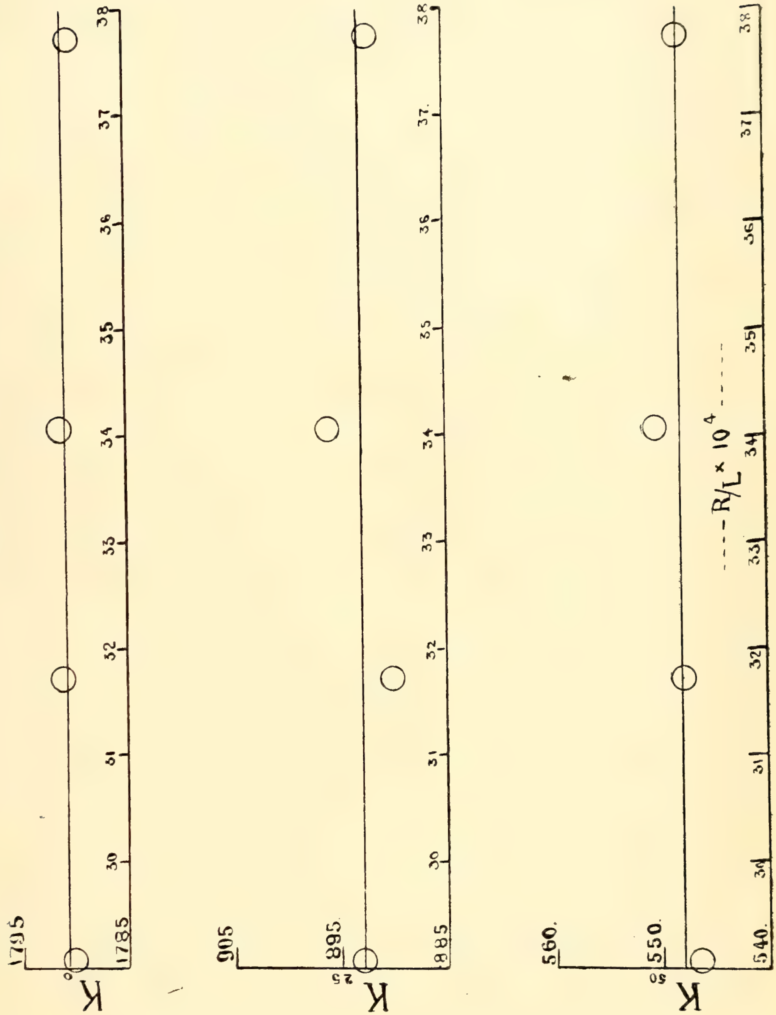


Fig 5.

Fig 6.

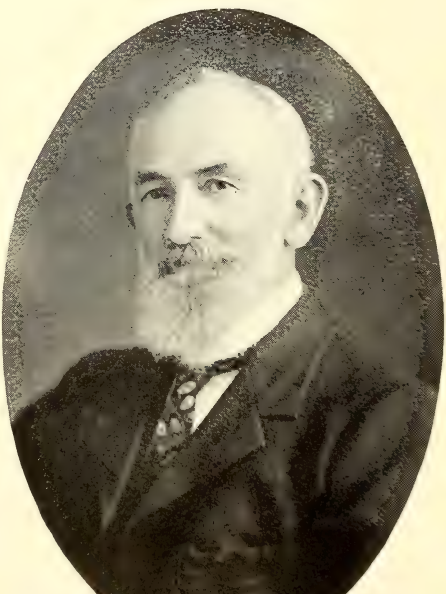

K0
1795
1785
K25
905
895
885
K50
560
550
540
30
31
32
33
34
35
36
37
38
R/L × 10^4

GEORGE BENTHAM,
(1800 - 1884).

EDWIN HAVILAND,
(1823 - 1908).

Rev. ROBT. COLLIE,
(1839 - 1892).

WILLIAM VERNON,
(1811 - 1890).

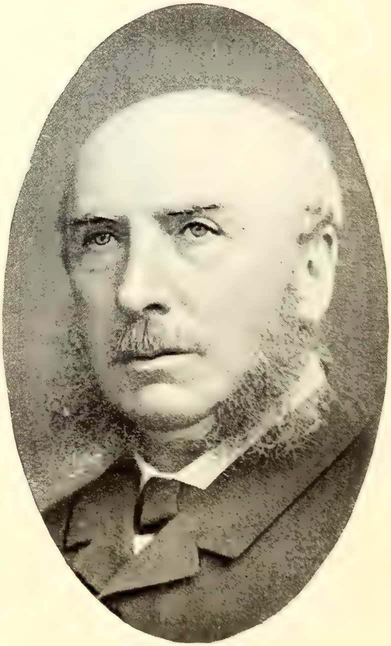


A. RUDDER,
(1828 - 1904).

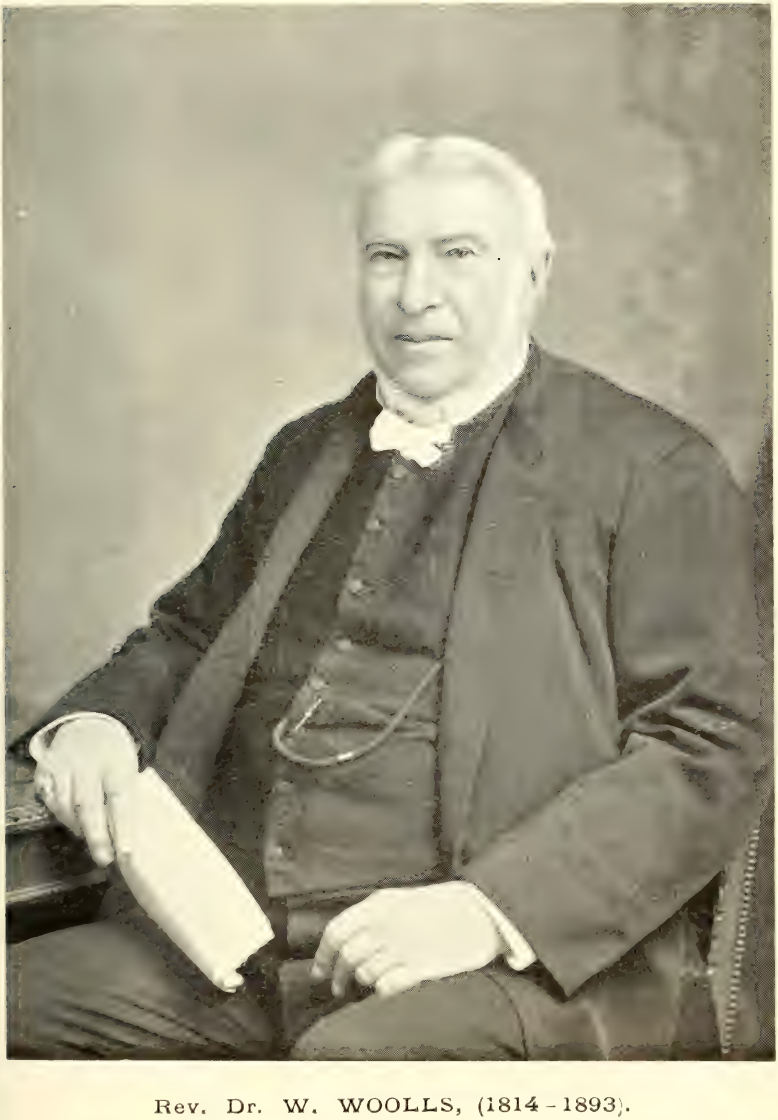
WILLIAM CARRON,
(1823 - 1876).

JAMES KIDD,
(1801 - 1867).

FREDERICK STRANGE,
(1826 ? - 1854).



R. D. FITZGERALD,
(1830 - 1892).



Rev. Dr. W. WOOLLS, (1814-1893).

CAROLINE LOUISA WARING CALVERT (née ATKINSON,)
(1834 - 1872).

Fig. 1. × 80

Fig. 2. × 80

White or Cypress Pine, *Callitris glauca*, R.Br.

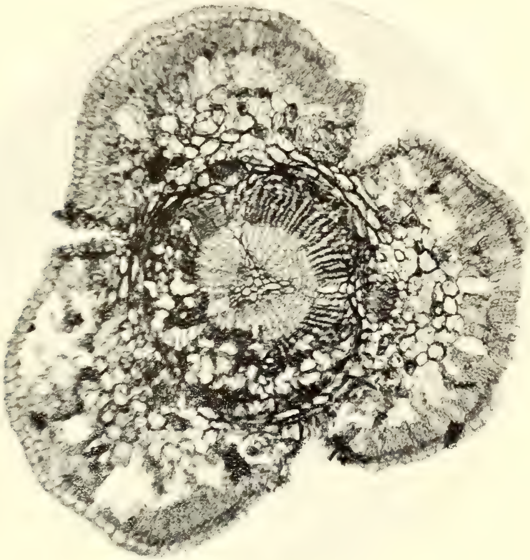


Fig. 3. ×80

Fig. 4. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

Fig. 5. ×80

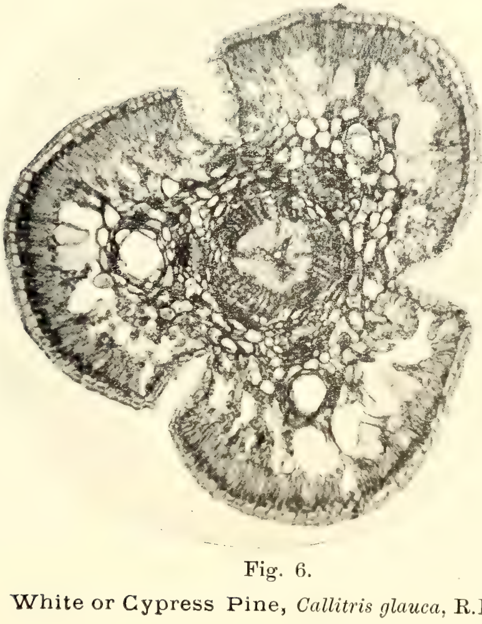


Fig. 6. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

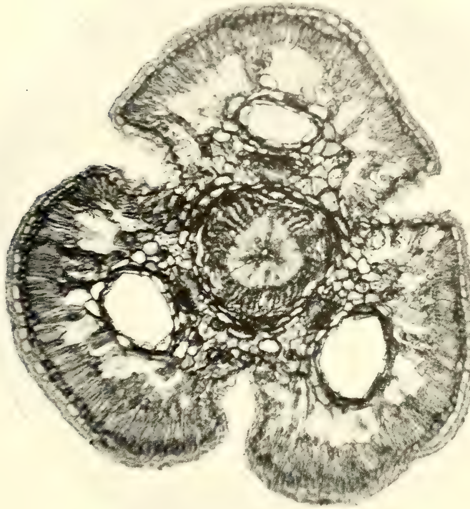


Fig. 7. ×80

Fig. 8. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

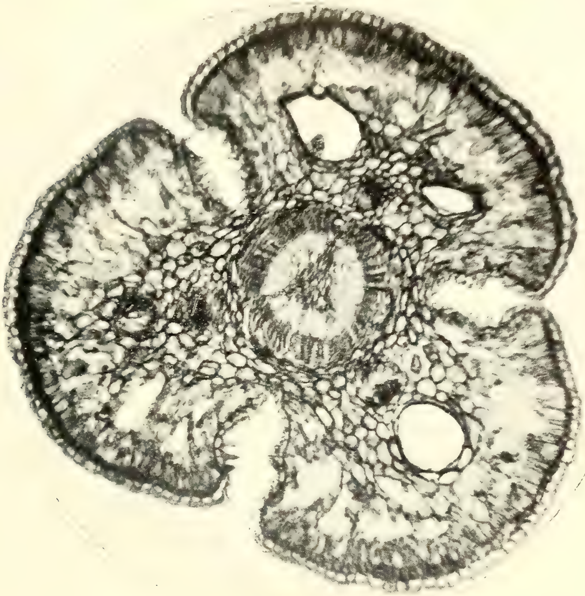


Fig. 9. ×80

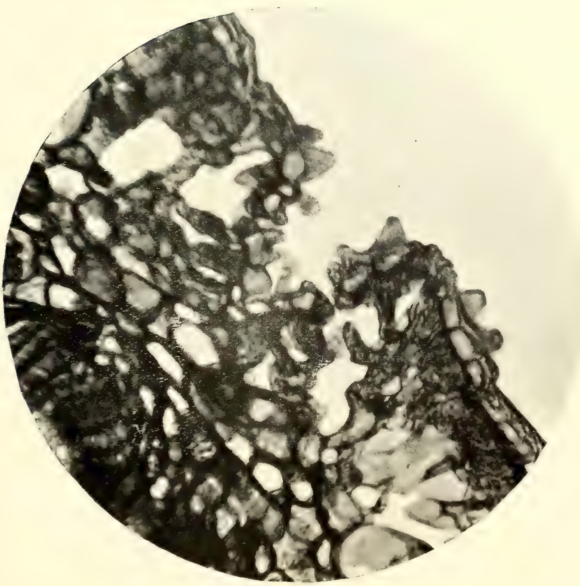


Fig. 10. ×160

White or Cypress Pine, *Callitris glauca*, R.Br.

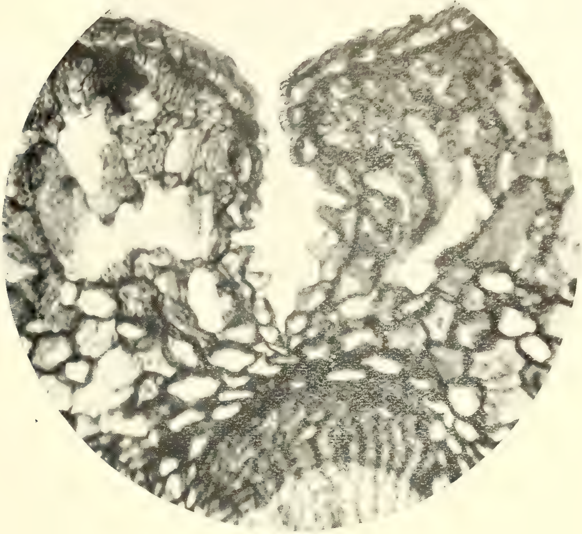


Fig. 11. ×160

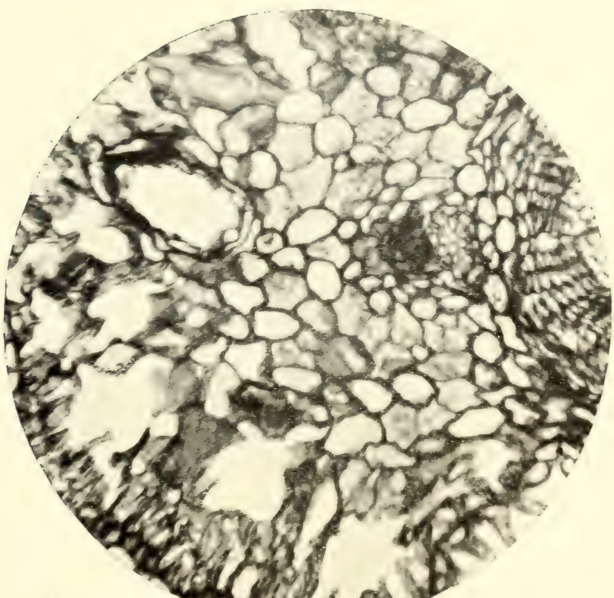


Fig. 12. ×160

White or Cypress Pine, *Callitris glauca*, R.Br.

Fig. 13. ×160

Fig. 14. ×55

White or Cypress Pine, *Callitris glauca*, R.Br.

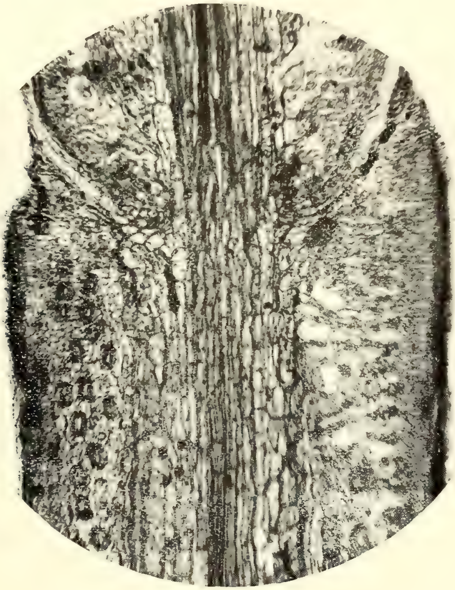


Fig. 15. ×50

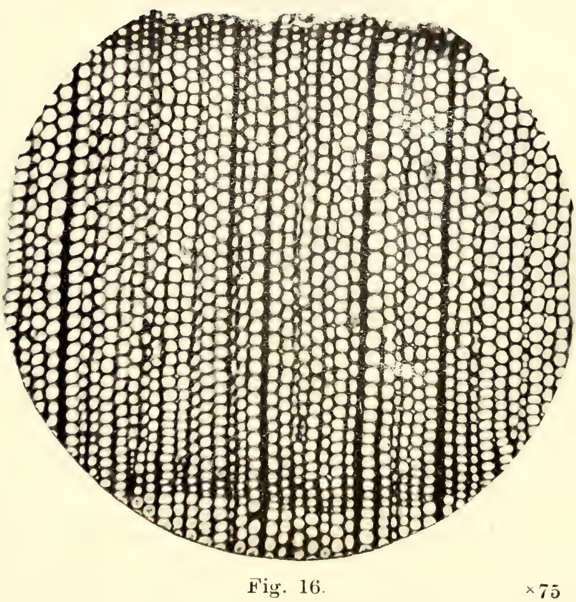


Fig. 16. ×75

White or Cypress Pine, *Callitris glauca*, R Br.

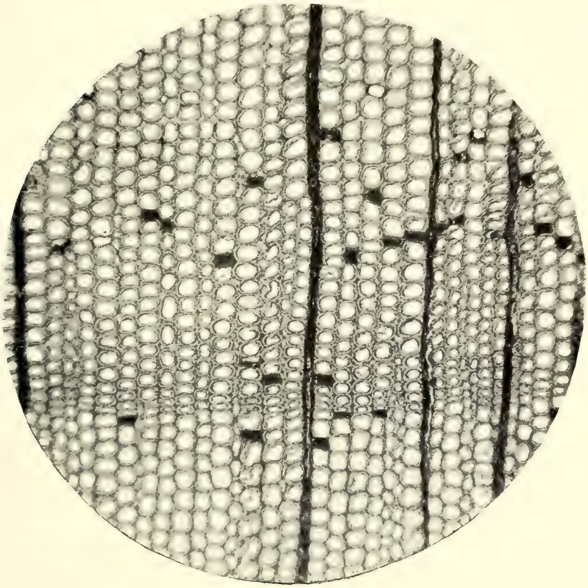


Fig. 17. ×80

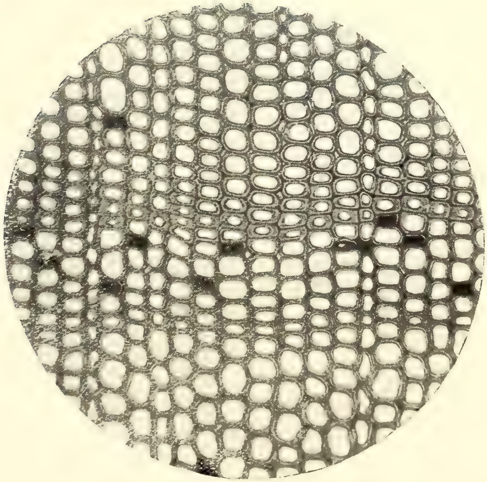


Fig. 18. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

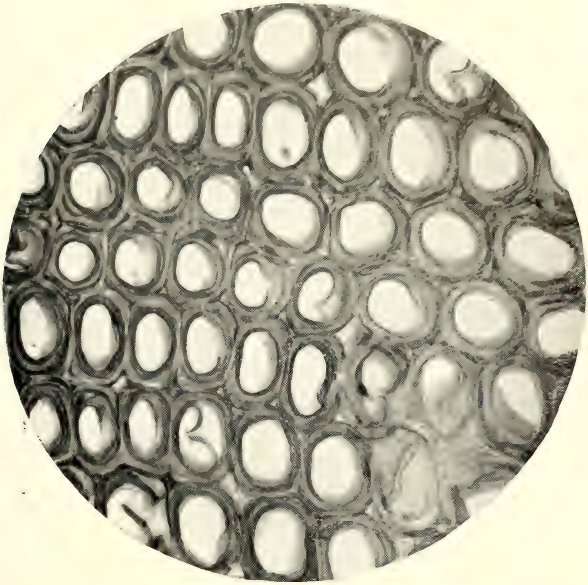


Fig. 19. ×210

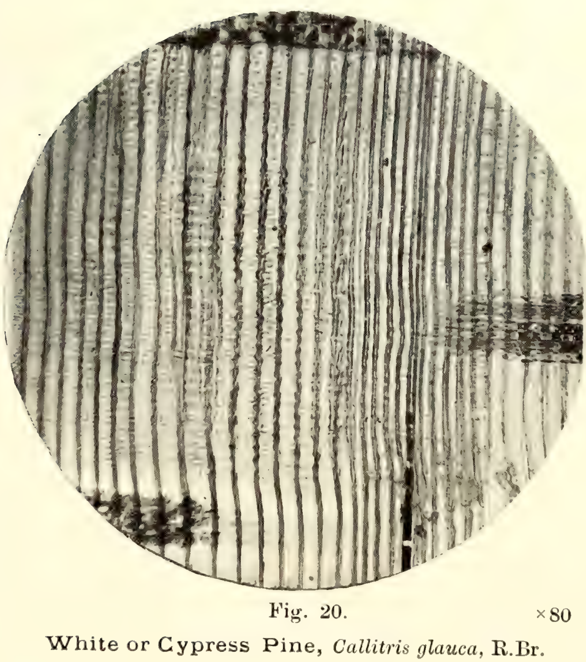


Fig. 20. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

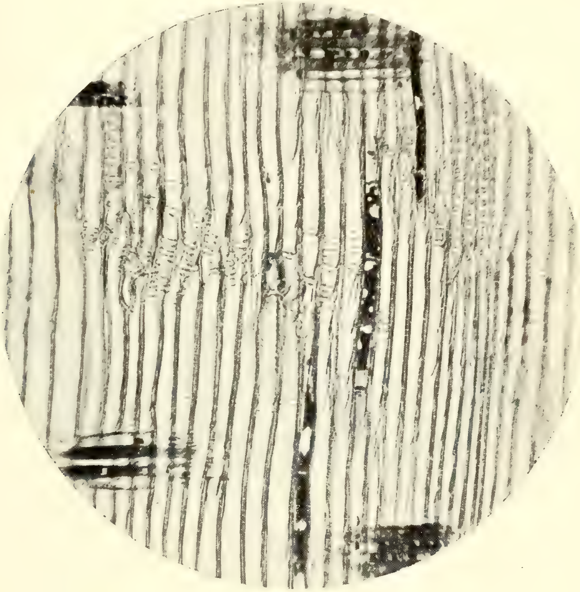


Fig. 21. × 80

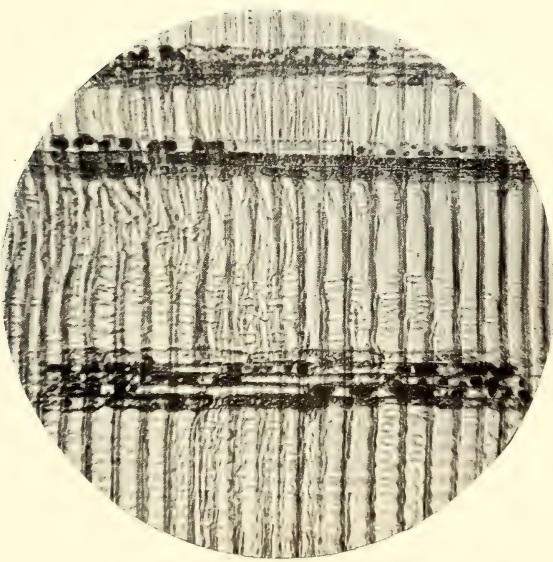


Fig. 22. × 80

White or Cypress Pine, *Callitris glauca*, R.Br.

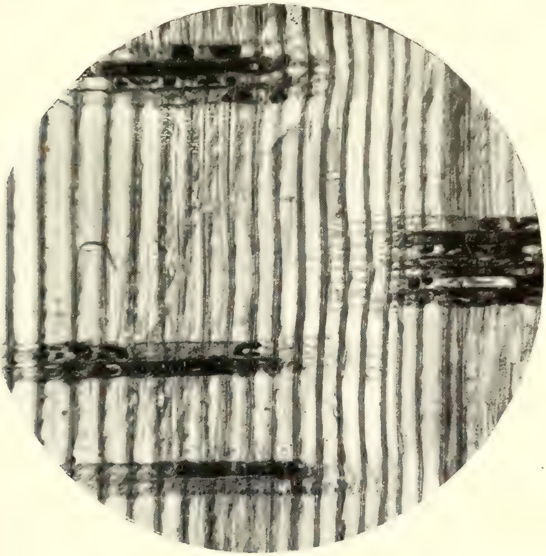


Fig. 23. ×80

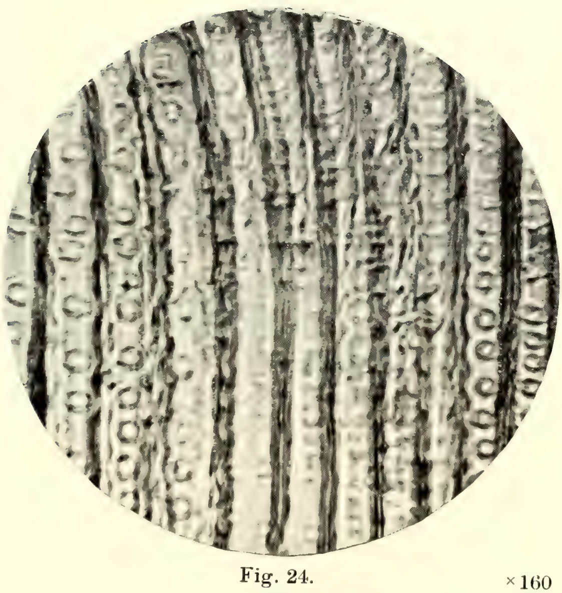


Fig. 24. ×160

White or Cypress Pine, *Callitris glauca*, R.Br.

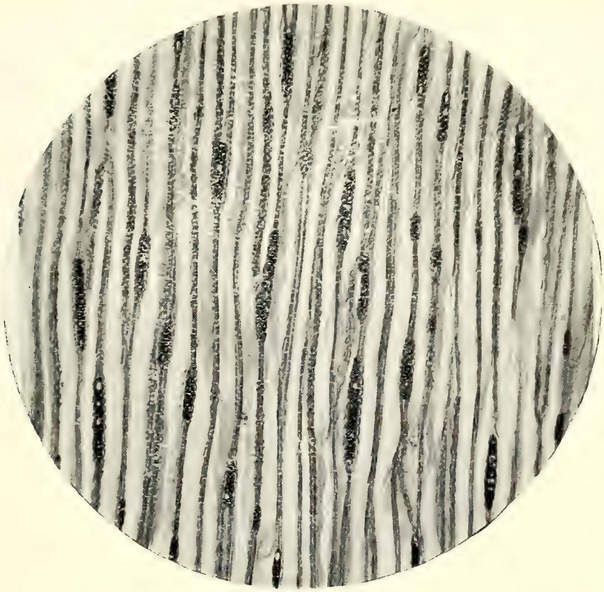


Fig. 25. ×80

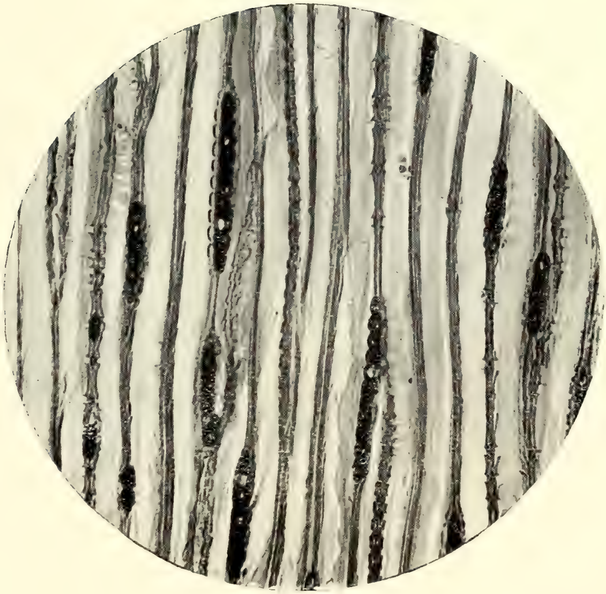


Fig. 26. ×160

White or Cypress Pine, *Callitris glauca*, R.Br.

Fig. 27. ×43

Fig. 28. ×43

White or Cypress Pine, *Callitris glauca*, R.Br.

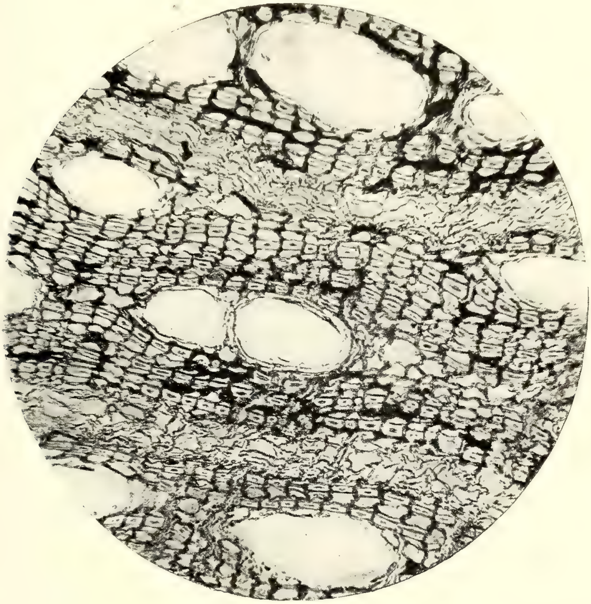


Fig. 29. ×80

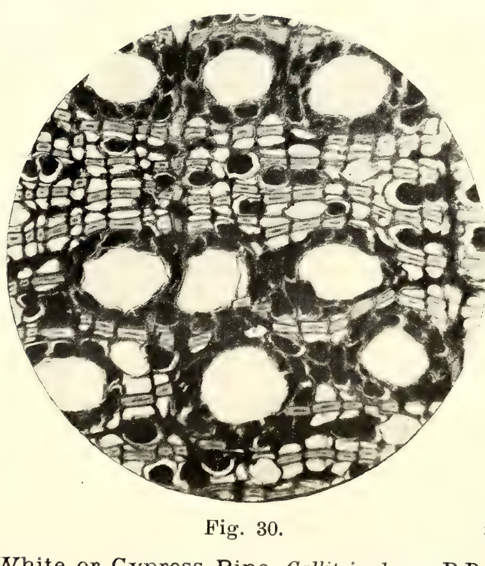
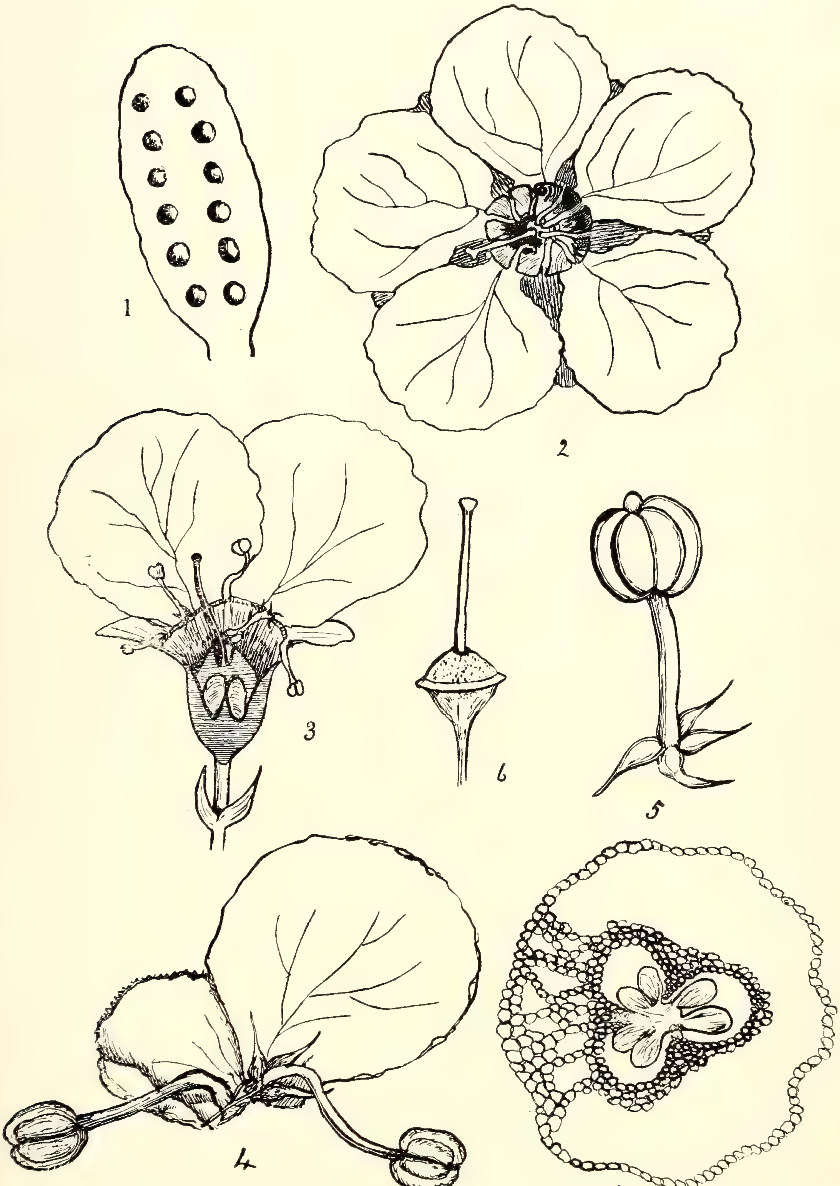
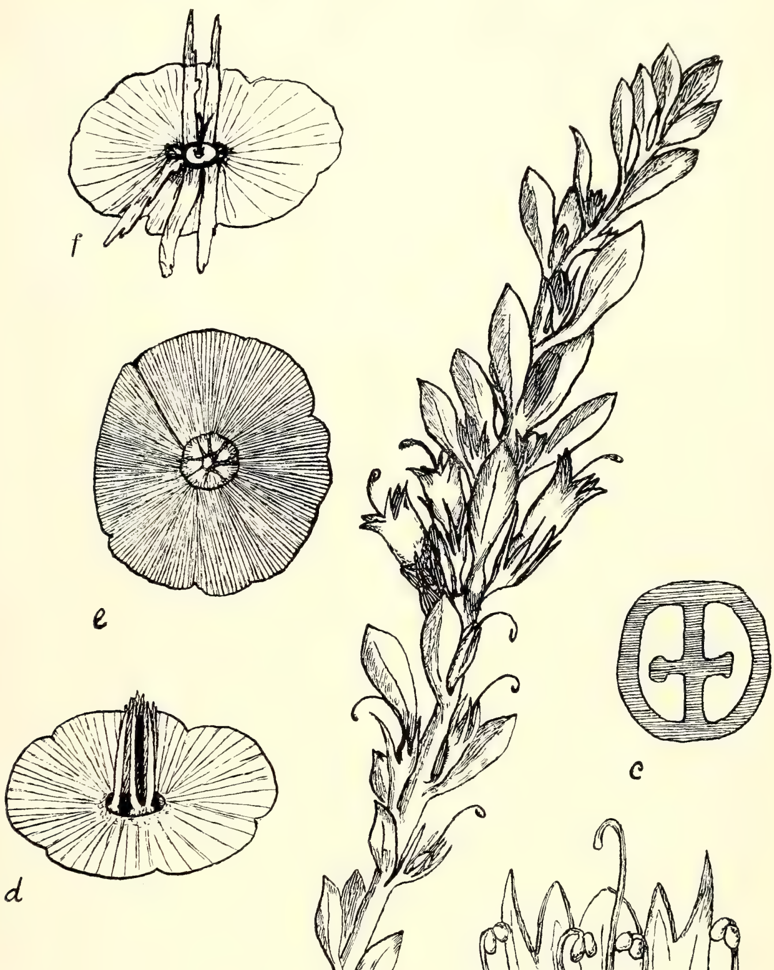


Fig. 30. ×80

White or Cypress Pine, *Callitris glauca*, R.Br.

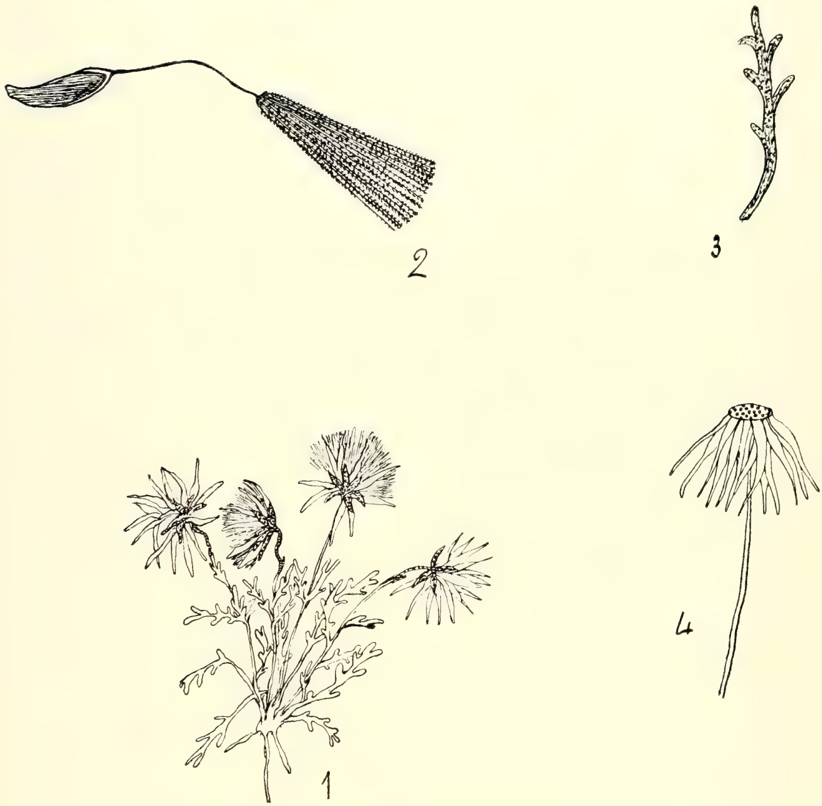


Baeckea Maideni, *Ewart and White.*

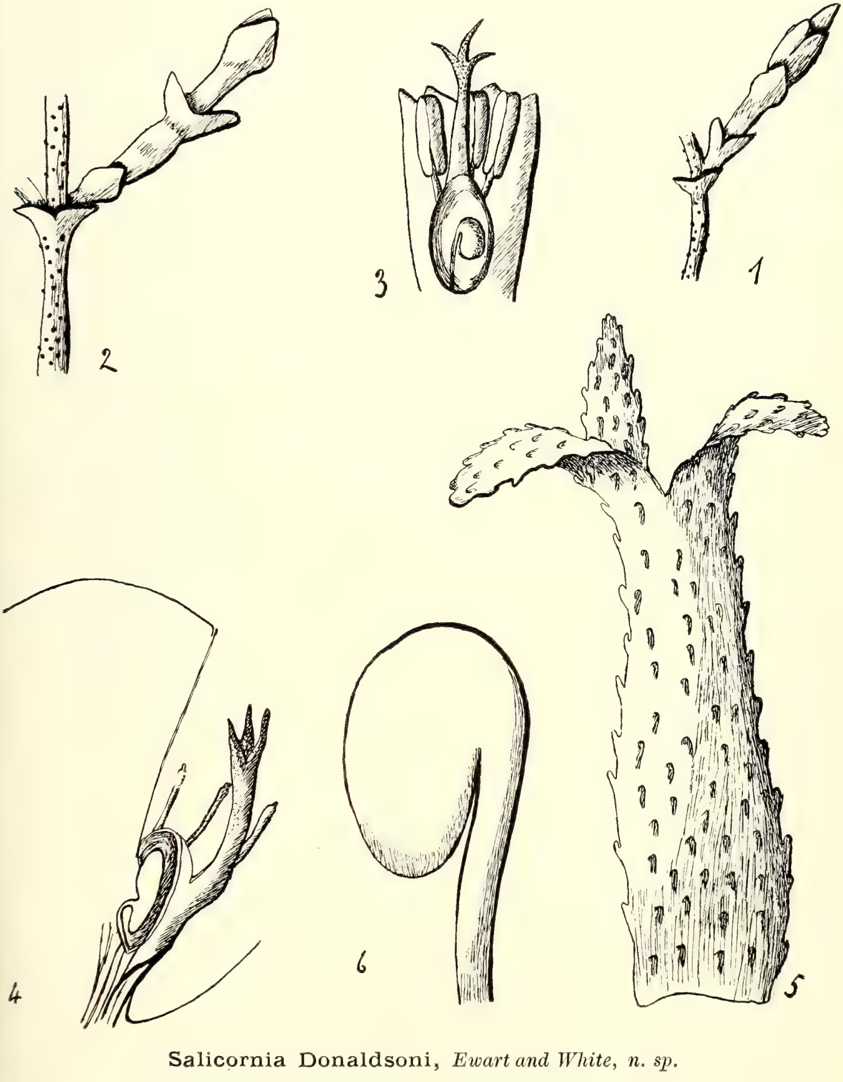


Eremophila Kochi, *n. sp* (Figs. *a, b, c,*)

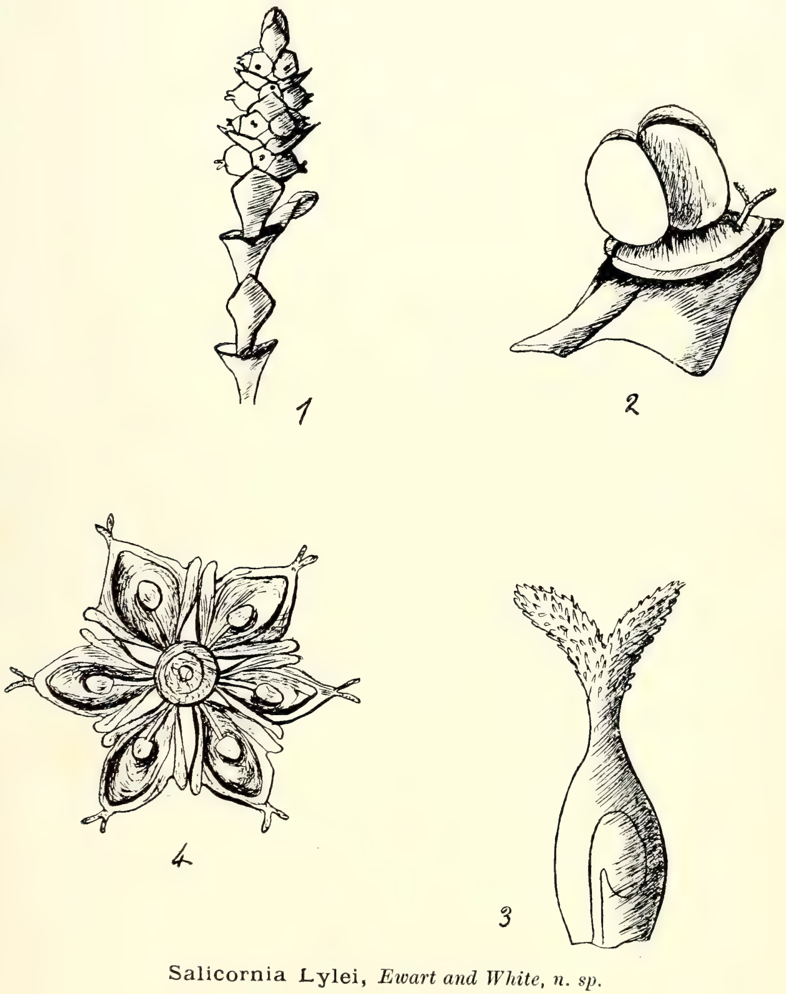
Kochia Atkinsiana, *W.V.F.*, (Figs. *d. e. f.*)



Podocoma nana, *Ewart and White, n. sp.*

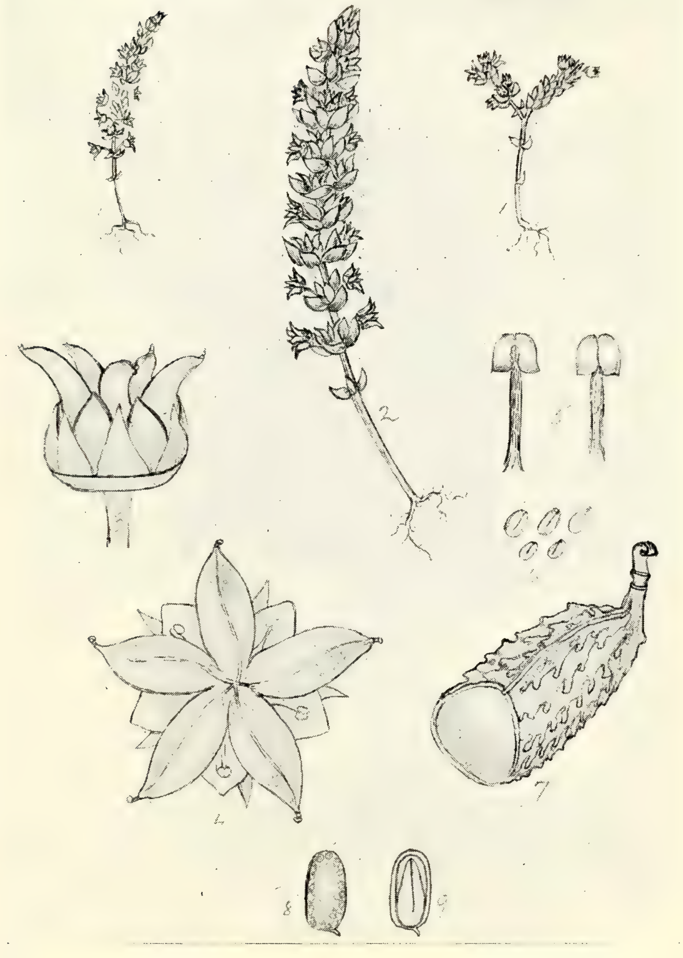


Salicornia Donaldsoni, *Ewart and White, n. sp.*

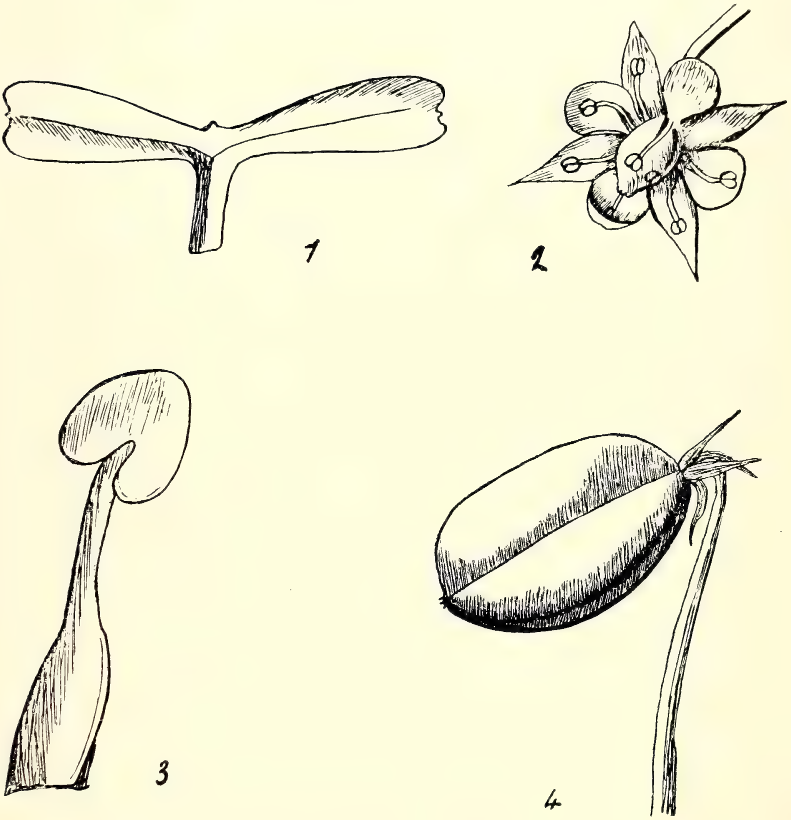


1 2 4 3

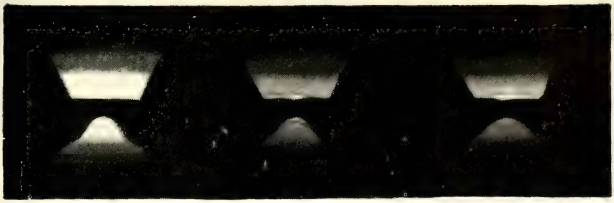
Salicornia Lylei, *Ewart and White, n. sp.*



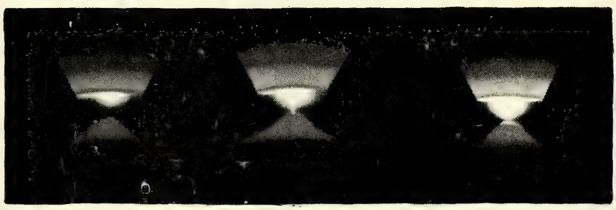
Tillaea exserta, *Reader.*



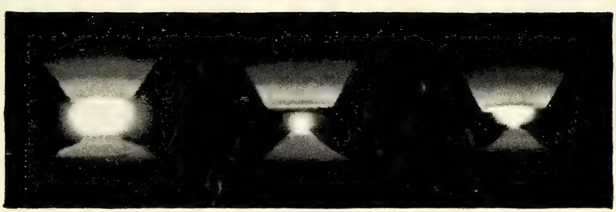
Zygophyllum ovatum, *Ewart and White.*



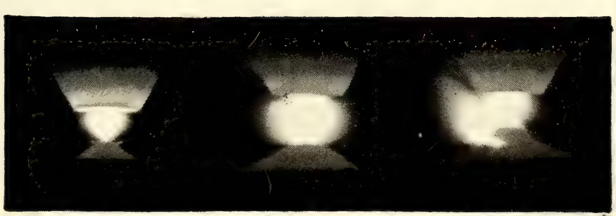
1 2 3



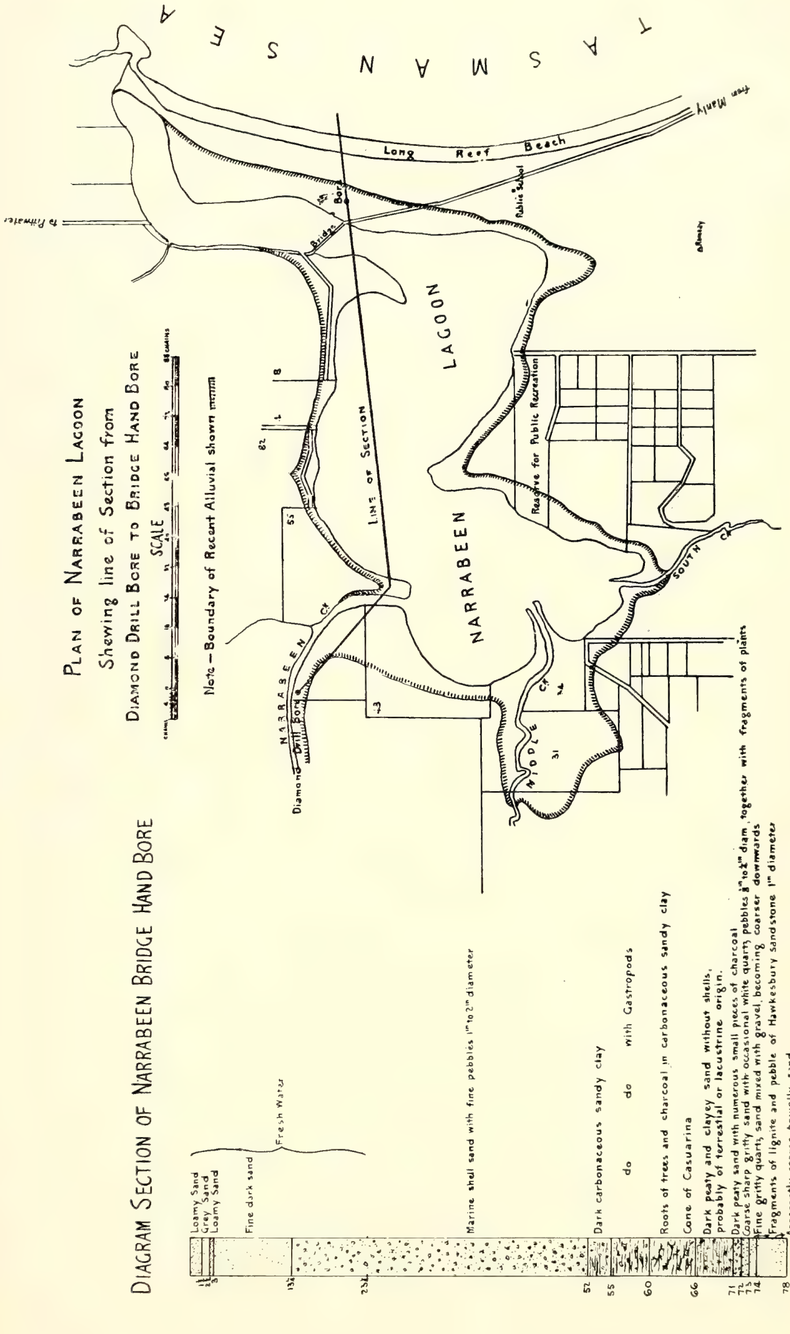
4 5 6



7 8 9



10 11 12


Plan of Narrabeen Lagoon
Shewing line of Section from
Diamond Drill Bore to Bridge Hand Bore
SCALE
Note — Boundary of Recent Alluvial shewn
TASMAN SEA
Long Reef Beach
from Manly
to Pittwater
Bridge
Bore
Public School
NARRABEEN LAGOON
Line of Section
Reserve for Public Recreation
South Ck
Middle Ck
Narrabeen Ck
Diamond Drill Bore
Diagram Section of Narrabeen Bridge Hand Bore
Loamy Sand
Grey Sand
Loamy Sand
Fine dark sand
Fresh Water
Marine shell sand with fine pebbles 1" to 2" diameter
Dark carbonaceous sandy clay
do do with Gastropods
Roots of trees and charcoal in carbonaceous sandy clay
Cone of Casuarina
Dark peaty and clayey sand without shells, probably of terrestial or lacustrine origin.
Dark peaty sand with numerous small pieces of charcoal
Coarse sharp gritty sand with occasional white quartz pebbles

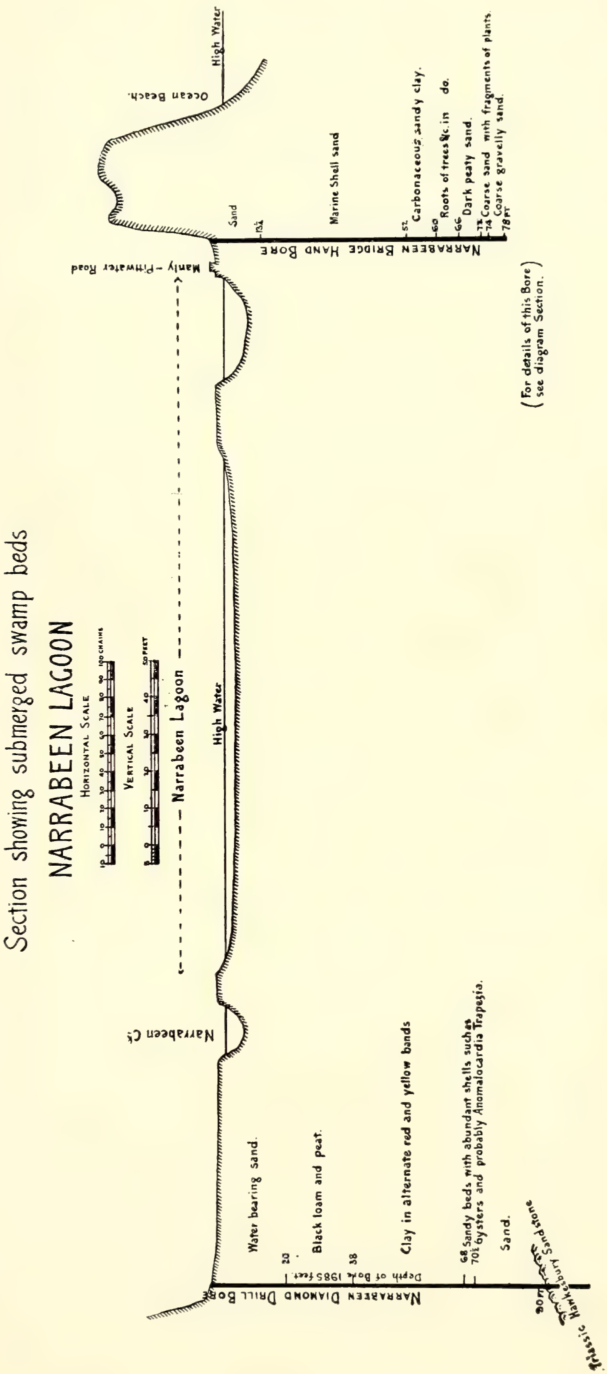
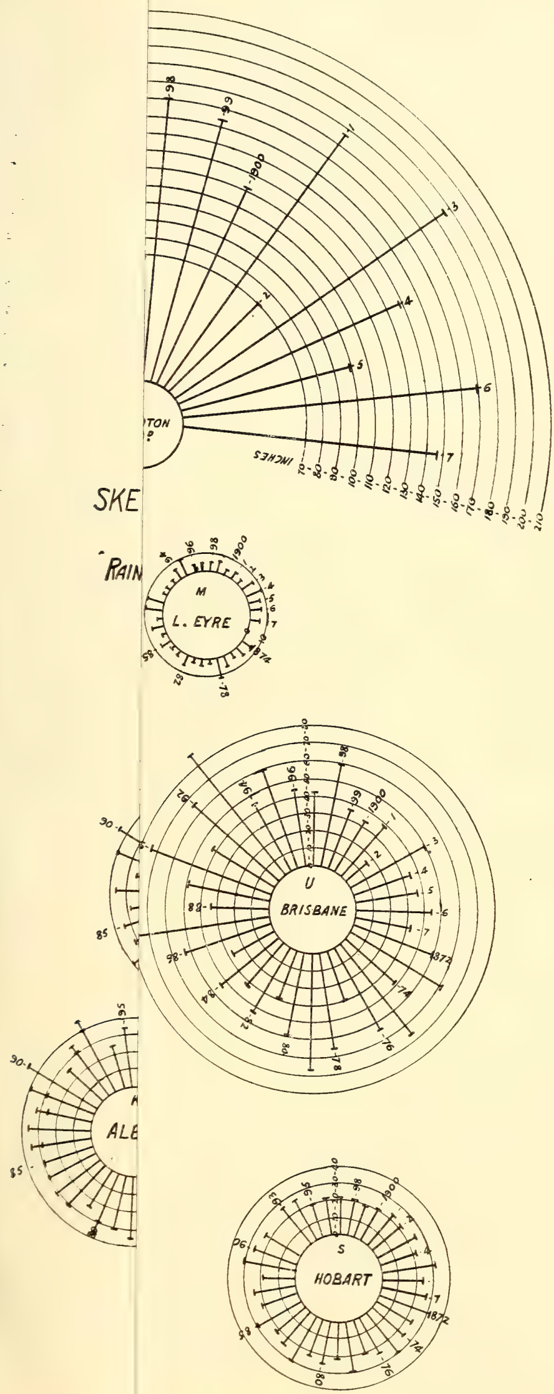

Section showing submerged swamp beds
NARRABEEN LAGOON
Horizontal Scale
100 chains
Vertical Scale
50 feet
Narrabeen Lagoon
High Water
Ocean Beach.
High Water
Sand
Marine Shell sand
Carbonaceous sandy clay.
Roots of trees &c. in do.
Dark peaty sand.
Coarse sand with fragments of plants.
Coarse gravelly sand.
78 ft
Narrabeen Bridge Hand Bore
Manly - Pittwater Road
(For details of this Bore see diagram Section.)
Narrabeen Ck
Water bearing sand.
Black loam and peat.
Clay in alternate red and yellow bands
Sandy beds with abundant shells such as oysters and probably Anomalocardia Trapezia.
Sand.
Triassic Hawkesbury Sandstone
Depth of Bore 1985 feet.
Narrabeen Diamond Drill Bore

Plate XL.



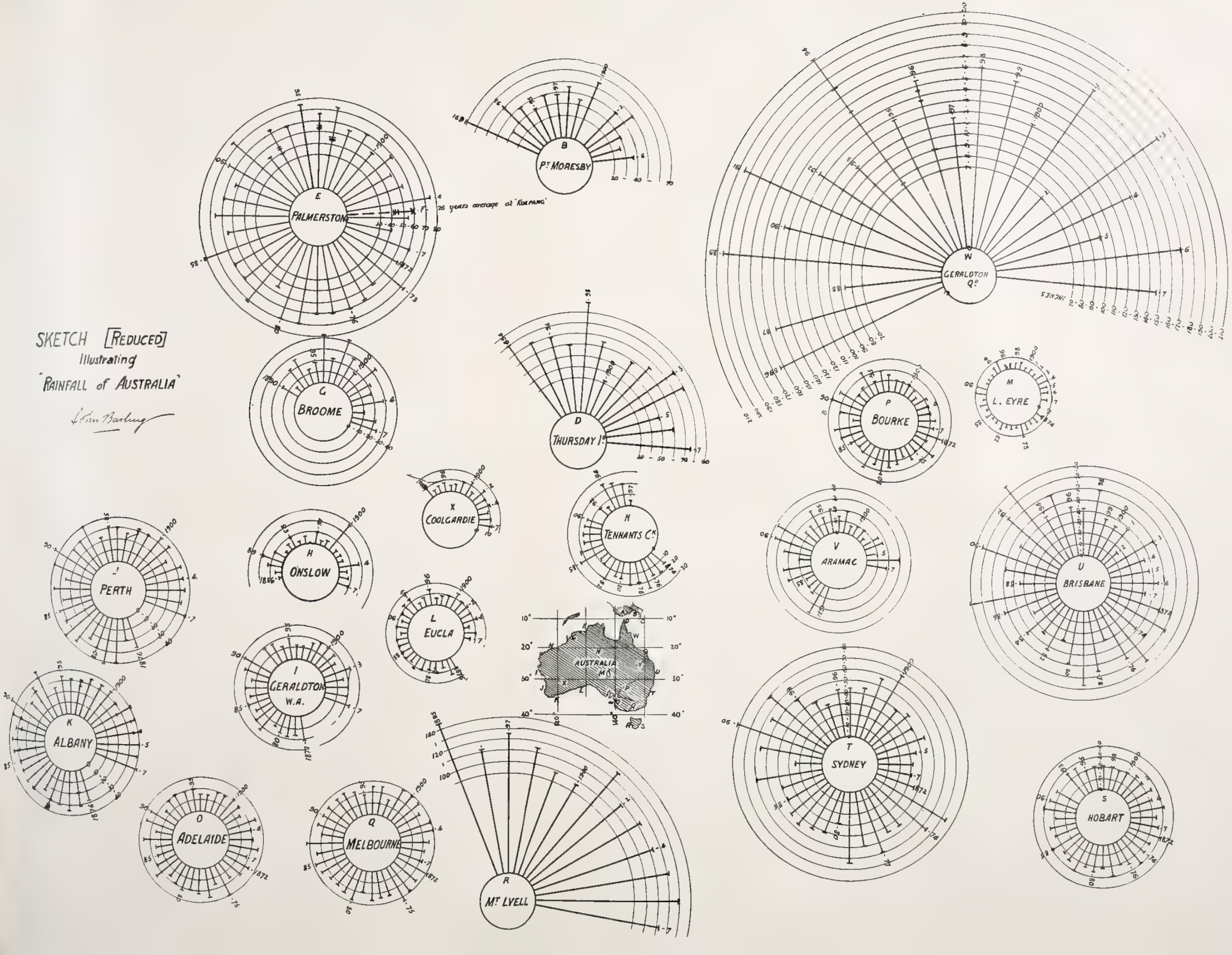
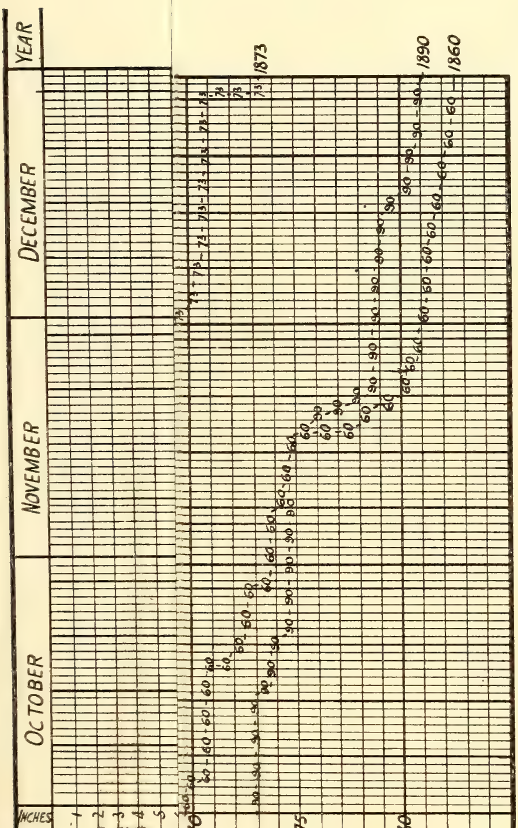
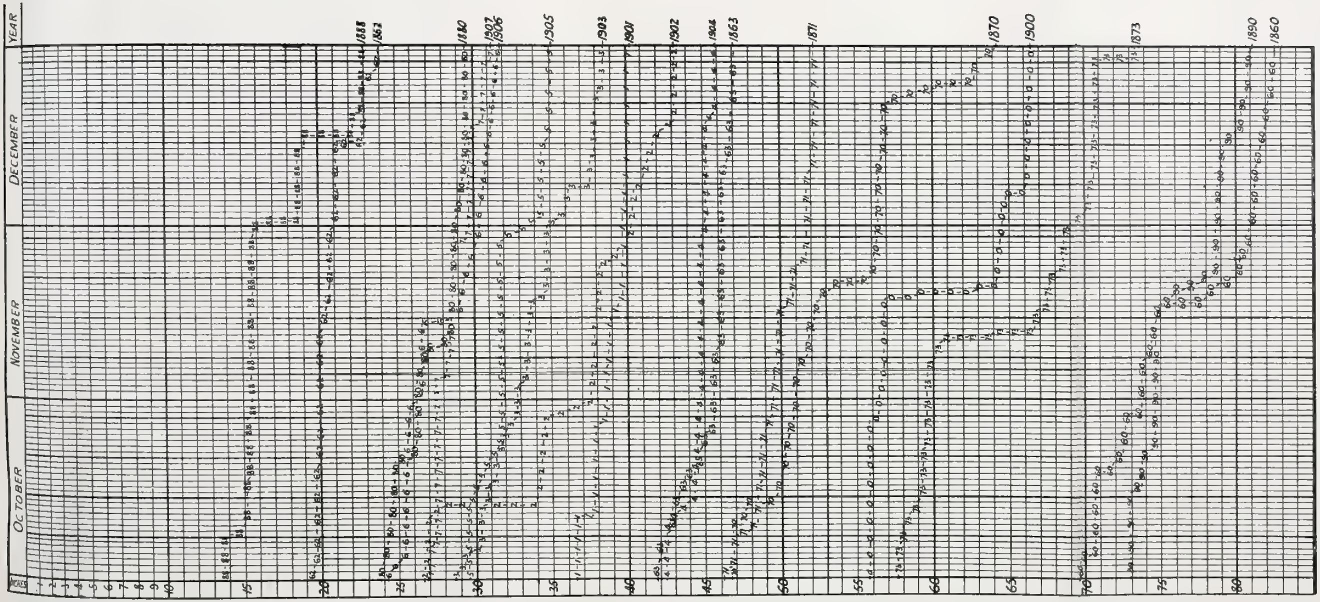

SKETCH [REDUCED]
Illustrating
"RAINFALL of AUSTRALIA"
E PALMERSTON
26 years average at 'Koepang'
B P^T MORESBY
W GERALDTON Q^D
INCHES
G BROOME
D THURSDAY I^D
P BOURKE
M L. EYRE
X COOLGARDIE
N TENNANTS C^K
V ARAMAC
U BRISBANE
J PERTH
H ONSLOW
L EUCLA
AUSTRALIA
I GERALDTON W.A.
K ALBANY
T SYDNEY
S HOBART
O ADELAIDE
Q MELBOURNE
R M^T LYELL

Plate XLI.



Sketch Sheet [Reduced]
Shewing the
SYDNEY RAINFALL

'Rainfall of Australia'



Sketch Sheet [Reduced] Shewing the SYDNEY RAINFALL

'Rainfall of Australia'

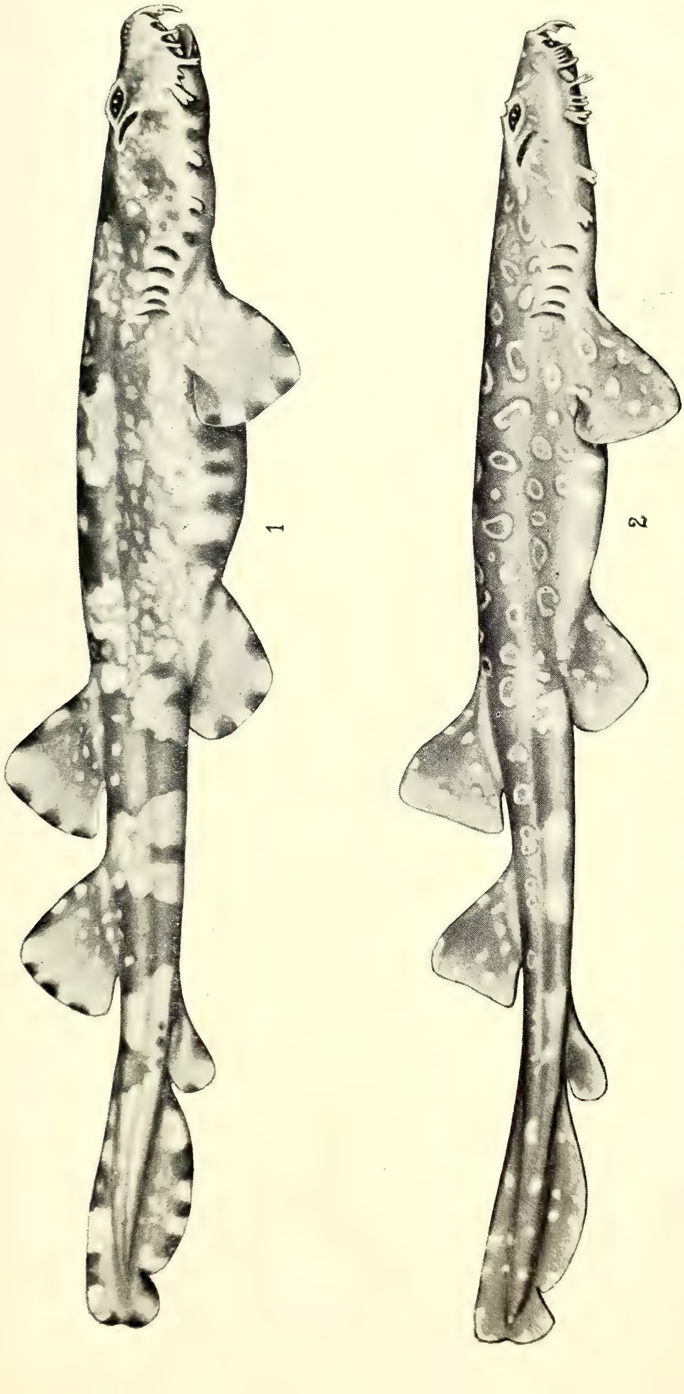


Fig. 1. *Orectolobus ornatus*, De Vis.

Fig. 2. *Orectolobus maculatus*, Bonnaterre.

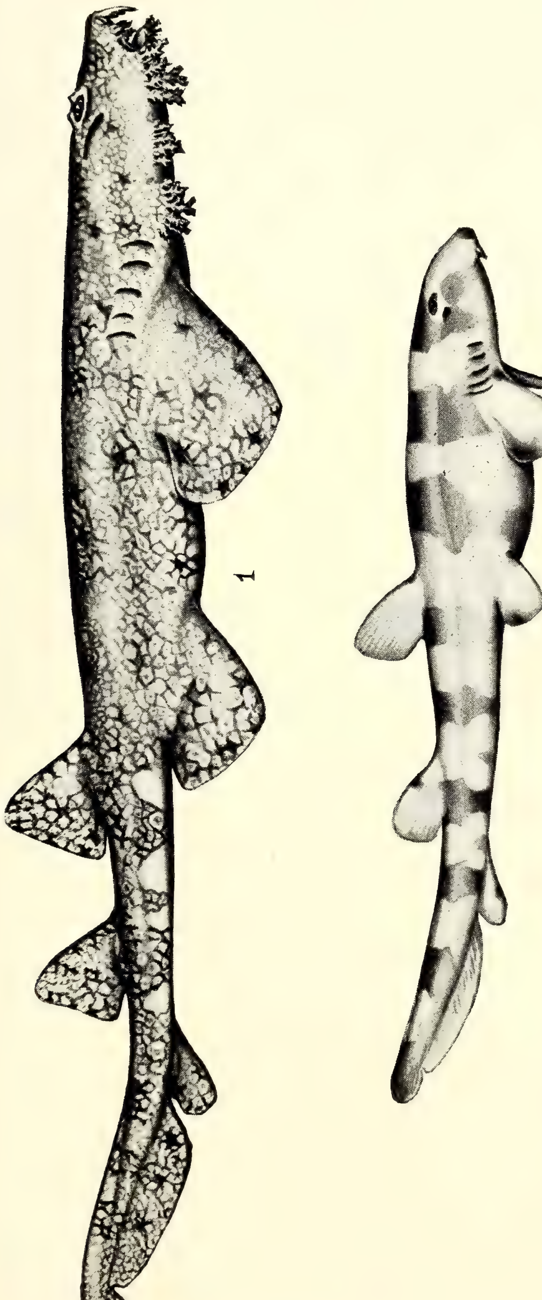
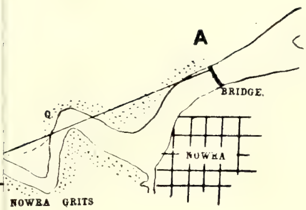


Fig. 1. *Orectolobus dasypogon*, Bleeker. Fig. 2. *Chiloscyllium punctatum*, Müller and Henle.

Plate XLIV.

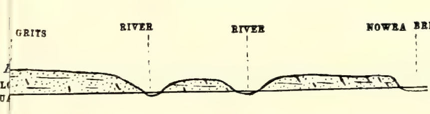


GEOLOGICAL
SKETCH MAP OF
ER SHOALHAVEN RIVER

SCALE 0 1 2 3 Miles.

SCALE APPROX 0 1000 2000 Feet.
SECTION

s of alluvium and river gravels shown thus - - - - - - - Their extent is approximate



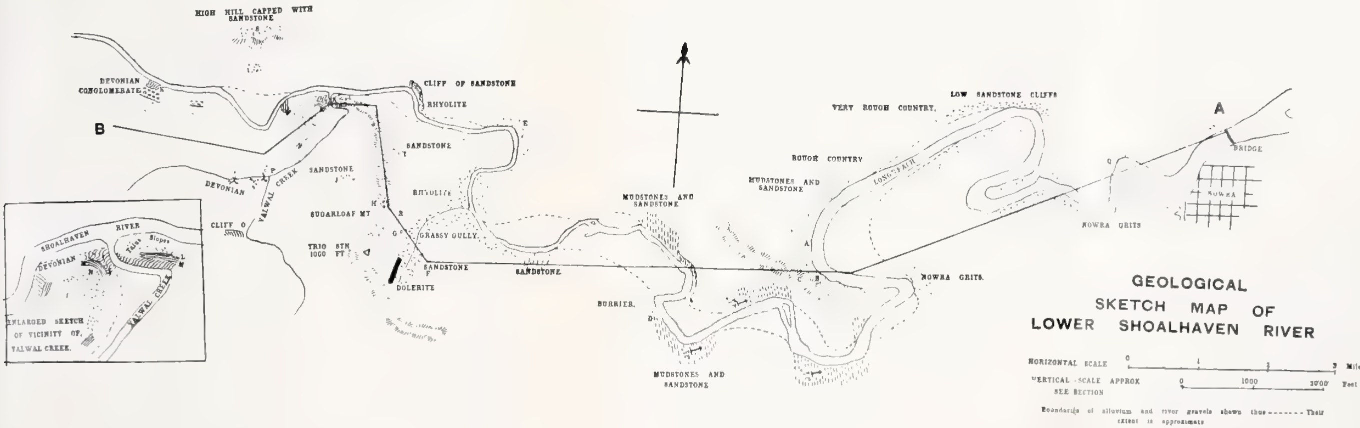
H SECTION
YALWAL CREEK.

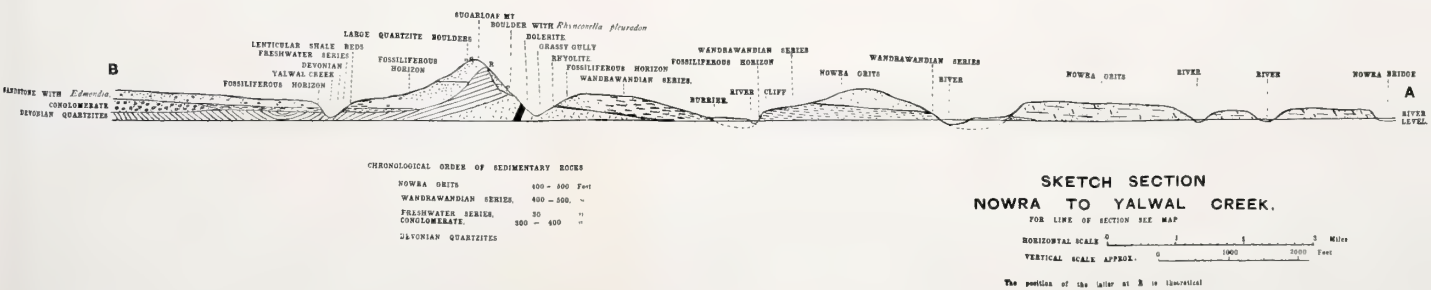
SECTION SEE MAP.

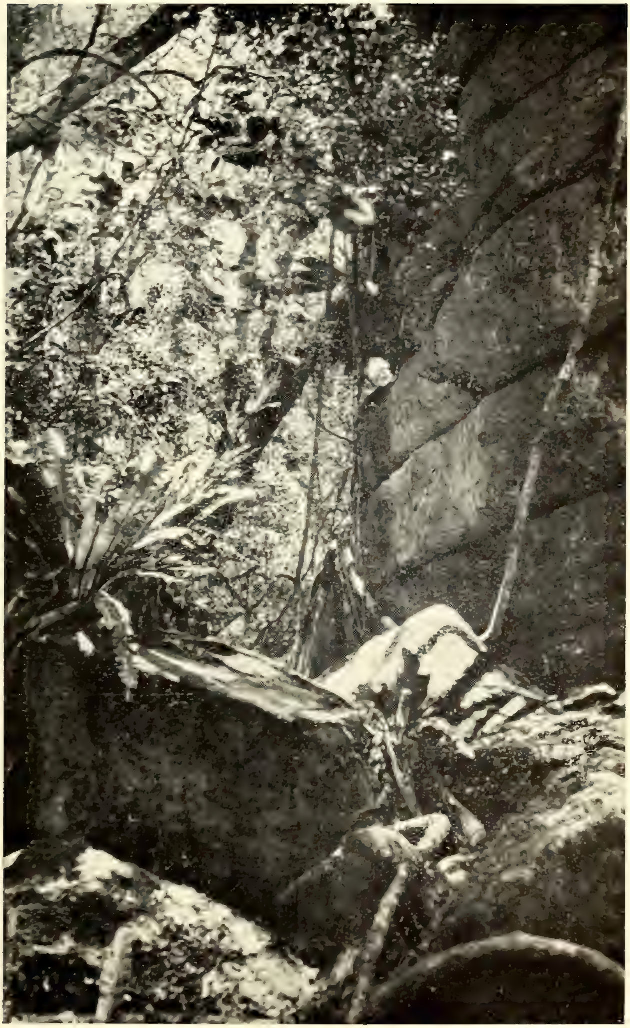
0 1 2 3 Miles

APPROX. 0 1000 2000 Feet

inlier at B is theoretical


HIGH HILL CAPPED WITH SANDSTONE
DEVONIAN CONGLOMERATE
CLIFF OF SANDSTONE
RHYOLITE
B
SANDSTONE
DEVONIAN
YALWAL CREEK
SUGARLOAF MT
CLIFF
TRIG STN 1000 FT
GRASSY GULLY
DOLERITE
MUDSTONES AND SANDSTONE
BURRIER
VERY ROUGH COUNTRY
LOW SANDSTONE CLIFFS
ROUGH COUNTRY
LONG REACH
A
BRIDGE
NOWRA
NOWRA GRITS
SHOALHAVEN RIVER
Talus Slopes
ENLARGED SKETCH OF VICINITY OF YALWAL CREEK.
GEOLOGICAL SKETCH MAP OF LOWER SHOALHAVEN RIVER
HORIZONTAL SCALE 0 1 2 3 Miles
VERTICAL SCALE APPROX SEE SECTION 0 1000 3000 Feet
Boundaries of alluvium and river gravels shown thus ------ Their extent is approximate


SUGARLOAF MT
BOULDER WITH *Rhynconella pleurodon*
LARGE QUARTZITE BOULDERS
DOLERITE
GRASSY GULLY
RHYOLITE
LENTICULAR SHALE BEDS
FRESHWATER SERIES
DEVONIAN
YALWAL CREEK
FOSSILIFEROUS HORIZON
FOSSILIFEROUS HORIZON
WANDRAWANDIAN SERIES
BURRIER
RIVER
CLIFF
NOWRA GRITS
RIVER
NOWRA BRIDGE
B
A
SANDSTONE WITH *Edmondia*
CONGLOMERATE
DEVONIAN QUARTZITES
RIVER LEVEL
CHRONOLOGICAL ORDER OF SEDIMENTARY ROCKS
NOWRA GRITS 400 – 500 Feet
WANDRAWANDIAN SERIES, 400 – 500
FRESHWATER SERIES, 30
CONGLOMERATE, 300 – 400
DEVONIAN QUARTZITES
SKETCH SECTION NOWRA TO YALWAL CREEK.
FOR LINE OF SECTION SEE MAP
HORIZONTAL SCALE 0 1 2 3 Miles
VERTICAL SCALE APPROX. 0 1000 2000 Feet
The position of the latter at R is theoretical



C.F.L., photo.

Nowra Grits. Characteristic scenery. Longreach, Shoalhaven.

C.L.F., photo.

Nowra Grits, showing joint planes dipping to the east, Longreach, Shoalhaven.

GEO. BLACKMORE, photo.

Upper Marine Series resting unconformably upon folded Devonian Quartzites. The talus slope marks the outcrop of the Freshwater Series, Yalwal Creek, Shoalhaven.

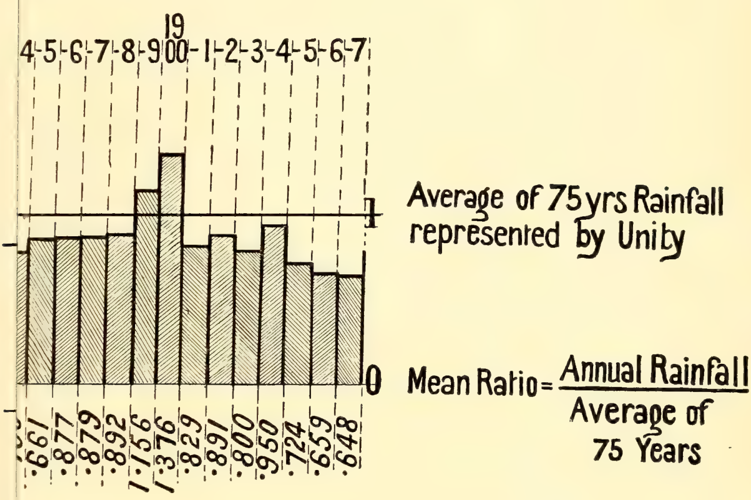
GEO. BLACKMORE, photo.

Shoalhaven River, showing recent river gravels.

ACRAM

/E UNITY 52·5

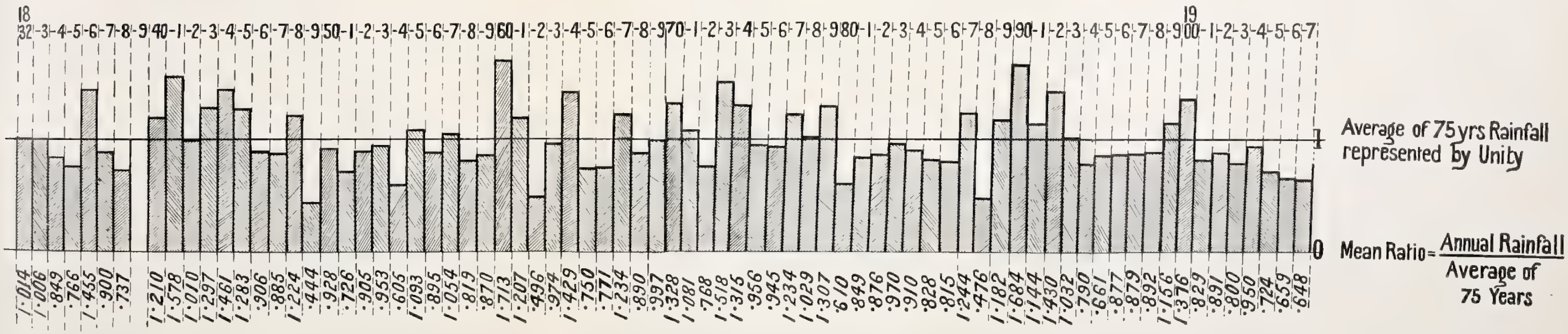
)W " 47·5



SYDNEY RAINFALL PERCENTAGE DIAGRAM

PERCENTAGE OF YEARS ABOVE UNITY 41·3 AVERAGE PERCENTAGE OF RAINFALL ABOVE UNITY 52·5

" " " BELOW " 58·7 " " " " BELOW " 47·5



ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 6, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 6th, 1908.

H. DEANE, M.A., M. Inst. C.E., President, in the Chair.

Thirty-seven members were present.

The minutes of the preceding meeting were read and confirmed.

The Annual Report of the Council was then read and adopted.

ANNUAL REPORT OF THE COUNCIL.

The Council submit to the members of the Royal Society of New South Wales their Report for the year ended 30th April last.

The number of members on the roll on the 30th April, 1907, was 350; 20 new members have been elected during the past year. We have, however, lost by death 7 ordinary (and 4 Honorary) Members, 19 by resignation, and 4 names were removed from the roll for non-payment of subscriptions. There is thus left a total of 340 on the 30th April, 1908; this number, however, does not include the Honorary Members. The losses by death were:—

Honorary Members:

BAKER, Sir BENJAMIN, elected 1901.

ELLERY, ROBERT L. J., elected 1875.

HECTOR, Sir JAMES, elected 1875.

KELVIN, Right Hon. WILLIAM THOMSON, Lord, elected 1903.

Ordinary Members:

HAYCROFT, J. I., elected 1890.

JENKINSON. E. H., elected 1903.

LENEHAN, H. A., elected 1874.

RAMSAY, DAVID, elected 1904.

ROLLESTON, J. C., elected 1885.

SMITH, WALTER A., elected 1886.

WOOLRYCH, F. B. W., elected 1876.

Books and periodicals have been purchased at a cost of £76 10s. 2d., binding books amounted to £22 10s. 11d., making the sum expended upon the Library £99 1s. 1d. A large number of unbound books and periodicals have been and are being covered in a cheap style of binding which will make them accessible to the members.

The number of Institutions on the Exchange List is 425 and the publications received in exchange for the Society's Journal and Proceedings during the past year were:—294 volumes, 2,217 parts, 155 reports, 106 pamphlets, and 21 maps, total 2,793.

During the past year the Society held 8 meetings, at which 20 papers were read; the average attendance of members was 33·2 and of visitors 1·7.

The Engineering Section held 7 meetings at which 2 papers were read and discussed.

POPULAR SCIENCE LECTURES.

A series of Popular Science Lectures, illustrated by lantern slides, was delivered during 1907 at the Society's House, at 8 p.m., as follows:—

May 16—"*The Life History of our Food Fishes,*" by H. C. DANNEVIG, (Superintendent, Fisheries Investigation.)

June 20—"*Some Polynesian and Melanesian Groups and the People who live in them,*" by Rev. Dr. GEORGE BROWN.

July 18—"*The Bi-centenary of Linnœus Birth,*" by J. H. MAIDEN, F.L.S.

August 15—"*Our Health Resorts,*" by T. STORIE DIXSON, M.B., C.M. (Edin.)

September 19—"*Further Chapters in Early Australian History,*" by F. M. BLADEN, F.R.G.S., F.R.H.S. (Lond.), Principal Librarian, Public Library.

October 17—"*Regeneration and Recent Biological Experiment,*" by Prof. J. T. WILSON, M.B. (Edin.)

CLARKE MEMORIAL LECTURES.

A series of five lectures was delivered on the following dates:—

August 22—"*Geography of Australia in the Permo-Carboniferous Period,*" by Prof. T. W. E. DAVID, B.A., F.R.S.

September 11—"*Geography of Australia in the Permo-Carboniferous Period,* Part II." by Prof. T. W. E. DAVID, B.A., F.R.S.

October 9—"*The Geological Relations of Oceania,*" by Dr. W. G. WOOLNOUGH.

October 31—"*Problems of the Artesian Water Supply of Australia,*" by E. F. PITTMAN, A.R.S.M., Under Secretary and Government Geologist, Department of Mines.

November 18—"*The Permo-Carboniferous Fauna and Flora and its Relations,*" by W. S. DUN, Palæontologist, Department of Mines.

The members are not aware perhaps, that the Library may be consulted until 10 p.m., the Council considered that this arrangement might prove of service to such members as were unable to use it during the day time. Unfortunately the library is still very far from being in order, owing to the late alterations etc., it is hoped, however that the Hon. Librarian will shortly be able to commence his voluntary labour of compiling a card catalogue. Meantime the front room on the first floor has been set apart

for American literature; the front room on the ground floor has been shelved and filled with the transactions of various Institutions and Journals. The following publications will be found in the book cases on the basement:—Astronomy, Chemistry, Engineering, Geology, Medicine and Mining.

The Financial Statement for the year ended 31st March 1908, was presented by the Hon. Treasurer, received, and adopted:—

GENERAL ACCOUNT.

Receipts.	£ s. d.	£ s. d.
Subscriptions — One Guinea	50 8 0	
" " Arrears	7 7 0	
Two Guineas	357 0 0	
" " Arrears	93 9 0	
" " Advances ...	4 4 0	
		512 8 0
Parliamentary Grant on Subscriptions received—Vote for 1907-1908	400 0 0	
		400 0 0
Rent		260 8 4
Sundries		28 19 8
Exchange added to Country cheques		0 2 6
Clarke Memorial Fund—Loan		28 7 9
		1230 6 3
Balance on 1st April, 1907		16 18 0
		£1247 4 3

Payments.	£ s. d.	£ s. d.
Advertisements	24 1 9	
Assistant Secretary	270 0 0	
Books and Periodicals	76 10 2	
Bookbinding	22 10 11	
Clarke Memorial Fund—Printing Circulars, &c.	2 3 6	
Collector	6 16 5	
Electric Light	22 6 4	
Freight, Charges, Packing, &c....	4 0 6	
Furniture and Effects	21 14 5	
Gas	7 17 3	
Carried forward	458 1 3	

PAYMENTS—*continued.*	£ s. d.	£ s. d.
Brought forward	458 1 3	
Caretaker	51 13 10	
Insurance	13 0 7	
Interest on Mortgage	129 4 0	
Office Boy	26 0 0	
Petty Cash Expenses	10 4 6	
Postage and Duty Stamps	32 10 0	
Printing	39 3 6	
Printing and Publishing Journal	206 10 4	
Printing Extra Copies of Papers	6 7 0	
Rates	66 19 4	
Repairs	15 15 9	
Rent of Room, 18 Elizabeth-st., for Storage ...	13 4 0	
Stationery	14 3 9	
Sundries	32 15 11	
Shelving for Books	32 13 6	
		1148 7 3
Clarke Memorial Fund—Repaid Loan General Account	28 7 9	
Ditto, Repaid on account of Loan, B. & I. Fund	61 12 3	
Ditto, ditto, Interest, Building and Inv. Fund	7 0 2	
		97 0 2
Bank Charges		1 0 6
Balance on 31st March, 1908, viz.:— Cash in Union Bank...		0 16 4
		£1247 4 3

BUILDING AND INVESTMENT FUND.

DR.	£ s. d.	£ s. d.
Deposit in Govt. Savings Bank 31st March '07	115 15 8	
Interest	0 11 11	
		116 7 7
Loan on Mortgage at 4%		1400 0 0
" " "		1510 0 0
" " "		190 0 0
Clarke Memorial Fund—Loan		289 18 0
		£3506 5 7

CR.	£ s. d.	£ s. d.
Balance 1st April, 1907	{ 1400 0 0 1510 0 0	
		2910 0 0
Contractor's balance of a/c...		373 0 0
Architect's balance of a/c		33 12 0
Sundry accounts paid		188 6 0
Deposit in Government Savings Bank, March 31st, 1908		1 7 7
		£3506 5 7

CLARKE MEMORIAL FUND.

Dr.	£	s.	d.
Amount of Fund, 31st March, 1907	482	11	2
Interest to 31st March, 1908	17	10	8
General Account Repaid on a/c Loan	28	7	9
Building and Investment Fund. Repaid on a/c Loan ...	61	12	3
General Account, Balance...	2	3	6
	592	5	4

Cr.	£	s.	d.
Honorarium and Expenses *re* Lectures, Session 1907 ...	15	13	6
Deposit in Savings Bank of New South Wales, March 31, 1908	248	13	8
Deposit in Government Savings Bank, March 31, 1908 ...	9	12	5
Loan to General Account	28	7	9
Loan to Building and Investment Fund	289	18	0
	£592	5	4

AUDITED AND FOUND CORRECT, AS CONTAINED IN THE BOOKS OF ACCOUNTS.

W. PERCIVAL MINELL, F.C.P.A. } *Auditors.*
WILLIAM EPPS .... }

SYDNEY, 5TH MAY, 1908.

D. CARMENT, F.I.A., F.F.A. *Honorary Treasurer.*
W. H. WEBB. *Assistant Secretary.*

Messrs. R. P. SELLORS and W. J. MACDONNELL were appointed Scrutineers, and Mr. H. D. WALSH deputed to preside at the Ballot Box.

The certificate of one candidate was read for the second time, and of one for the first time.

The following gentleman was duly elected an ordinary member of the Society:—

MARSHALL, FRANK, B.D.S. (Syd.), Dental Surgeon, 141 Elizabeth-street.

There being no other nominations, the following gentlemen were declared duly elected Officers and Members of Council for the current year, viz:—

President:

W. M. HAMLET, F.I.C., F.C.S.

Vice-Presidents:

F. H. QUAIFE, M.A., M.D.,

Prof. T. P. ANDERSON STUART, M.D., LL.D.

HENRY DEANE, M.A., M. Inst. C.E.

Hon. Treasurer:
D. CARMENT, F.I.A., F.F.A.

Hon. Secretaries:

J. H. MAIDEN, F.L.S.	F. B. GUTHRIE, F.I.C., F.C.S.

Members of Council:

JOSEPH BROOKS, F.R.A.S., F.R.G.S.	Prof. POLLOCK, B.E., B.Sc.
A. DUCKWORTH, F.R.E.S.	HENRY G. SMITH, F.C.S.
R. GREIG-SMITH, D.Sc., M.Sc.	WALTER SPENCER, M.D.
CHARLES HEDLEY, F.L.S.	H. D. WALSH, B.E., M. Inst. C.E.
T. H. HOUGHTON, M. Inst. C.E.	Prof. WARREN, M. Inst. C.E., Wh.Sc.

The President made the following announcements:—

1. That the Society's Journal, Vol. XLI for 1907, was in the binder's hands and would be ready for delivery to members in about a week.

2. That the Committee of the Engineering Section for the ensuing Session had been elected as follows:—

SECTIONAL COMMITTEES—SESSION 1908.

Section K.—Engineering,

Chairman: G. R. COWDERY, Assoc. M. Inst. C.E.

Hon. Secretary: W. E. COOK, M.E., M. Inst. C.E.

Committee: PERCY ALLAN, M. Inst. C.E., H. H. DARE, M.E., Assoc. M. Inst. C.E. J. FRASER, M. Inst. C.E., F. M. GUMMOW, M.C.E., R. T. MCKAY, L.S., Assoc. M. Inst. C.E., ALGERNON PEAKE, Assoc. M. Inst. C.E., E. K. SCOTT, M.I.E.E., NORMAN SELFE, M. Inst. C.E., J. M. SMAIL, M. Inst. C.E.

Past Chairmen, *ex officio* Members of Committee for three years: S. H. BARRACLOUGH, Assoc. M. Inst. C.E., J. HAYDON CARDEW, M. Inst. C.E., T. W. KEELE, M. Inst. C.E.

3. That a large number of donations had been received since the last meeting and would be laid upon the table next month.

4. That the Council recommended the election of the following gentlemen as Honorary Members of the Society:

Professor LIVERSIDGE, M.A., LL.D., F.R.S., etc., London.

Sir ALEXANDER B. W. KENNEDY, LL.D., F.R.S., etc., London.

Sir WILLIAM TURNER, K.C.B., D.C.L., Sc. D., F.R.S., Edinburgh.

On the motion of Mr. Maiden seconded by Mr. Merfield, the election was carried unanimously.

5. That the list of the Popular Science Lectures to be delivered during the present Session was in course of preparation.

6. That a Conversazione would be held later on in the Session.

The following letters were received and read:—

Hutt, December 18th, 1907.

Dear Sirs,—From our hearts I and my family thank the members of the Royal Society of New South Wales for their kind expression of sympathy and regret on the death of my husband, and for their words of appreciation of his work and his services to science. Believe me, yours truly, M. G. HECTOR.

Clovelly, Metung, Victoria, April 9th, 1908.

To the Hon. Secretary, the Royal Society of New South Wales.

Dear Sir,—Will you please convey to the members of your Society the sincere thanks of our family for the appreciation of my late father's life and works, contained in your letter of April 4th, and also for the very kind expression of sympathy with us, in our recent great bereavement. Believe me, dear sir, yours very truly, MARY E. B. HOWITT.

The Hon. Secretary (Mr. Maiden) drew the attention of members to the portrait of the late Mr. H. C. Russell, and stated that the list of subscribers was about to be closed when a balance sheet would be displayed for the information of those concerned. He also referred to the Liversidge Portrait Fund, towards a portrait to be hung in the Great Hall of the University, and asked those friends who desired to subscribe, but had not already done so, to kindly take one of the circulars laid on the table.

Mr. Henry Deane, M.A., M. Inst. C.E., then read his Presidential Address.

On the motion of Mr. D. A. Sutherland, seconded by Dr. Quaife and supported by Mr. Hedley and Mr. Maiden a vote of thanks was passed to the retiring President, and

Mr. W. M. HAMLET, F.I.C., F.C.S., was installed as President for the ensuing year.

Mr. HAMLET thanked the members for the honour conferred upon him.

ABSTRACT OF PROCEEDINGS, JUNE 3, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 3rd, 1908.

W. M. HAMLET, F.I.C., F.C.S., President, in the Chair.

Twenty-nine members and one visitor were present.

Dr. COOKSEY and His Honour JUDGE DOCKER were appointed Scrutineers and Dr. SPENCER deputed to preside at the Ballot Box.

The certificate of one candidate was read for the second time, and of one for the first time.

The following gentleman was balloted for and declared a duly elected ordinary member of the Society :—

PYE, WALTER GEORGE, M.A., B. SC., Paddington.

The President made the following announcements :—

1. That the Society's volume for 1907 was being distributed.

2. That the series of Popular Science Lectures for the present Session had been arranged, and a card giving dates of all meetings would be issued in a few days. The first lecture would be delivered on the 18th instant, on "The Blood in Health and Disease," by J.F. FLASHMAN, M.D., CH.M.

3. That a Conversazione would be held later in the year, of which due notice would be sent to members.

4. That the vacancy on the Council caused by the death of Mr. H. A. LENEHAN had been filled by the appointment

of Mr. R. H. CAMBAGE, F.L.S., as ordinary member of Council, and that Dr. WALTER SPENCER had been elected a Vice-President.

5. That 33 volumes, 476 parts, 4 reports, 6 pamphlets, total 519, received as Donations since the December meeting, were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ:

1. "The Viscosity of Water," by RICHARD HOSKING, B.A. (Camb.) [Communicated by Professor POLLOCK, D.Sc.]

2. "Note on a Cupriferous Porphyrite and Quartz Veins in the Nelligen District," by H. I. JENSEN, D.Sc.

EXHIBITS:

Mr. H. I. JENSEN exhibited galena ores from the Ettrema Mine; schists and cupriferous basalts from Nelligen district; alum from vein in trachyte tuff on Mount Flinders, Queensland.

Mr. R. T. BAKER, F.L.S., exhibited a framed series of specimens illustrating the causes of, and the serum remedy for Hay Fever and its varieties. The collection is from the firm of Schimmel & Co., Miltitz, Leipzig, Germany, this firm having acquired the patent belonging to Prof. Dr. Dunbar of Hamburg, for the serum against Hay Fever, called "Pollantin," invented by him. Pollantin is primarily the pollen obtained from composites, grasses, and other plants, the collecting of which is carried out on a large scale at the firm's factory. The series include different kinds of pollen with an estimate of their numbers to the gramme and are classed as generators of Hay Fever. The serum is prepared in two forms, dry and wet, and specimens of both are fully shown as placed on the market for the medical practitioner. Reports from America and Europe speak well of its efficacy as a remedy for this complaint.

Abstract of lecture on "The Blood in Health and Disease," by J. F. Flashman, M.D., Ch.M., delivered 18th June, 1908.—The lecturer showed the physical constitution of the blood of various animals, as distinguished from that of man, pointing out the limitations of this method of investigation as a means of distinguishing human from other forms of mammalian blood. Illustrations were given of the various varieties of white cells, or leucocytes, and the phenomenon of phagocytosis was described, and the effect of the phagocytes as protectors against disease was dwelt upon. Clotting of blood was discussed, and it was shown that blood could be prevented from clotting if the lime salts of the blood were removed. The changes in the blood in such conditions as anæmia, pernicious anæmia, etc., were illustrated, and a general review given of those blood diseases—such as malaria and sleeping sickness—due to parasites. Attention was called to some interesting biochemical relations of the blood, such as agglutination in typhoid fever, bacteriolysis, antitoxin production; the test for human blood by means of the precipitin reaction was described, as was also our present knowledge of opsonins. The method by which the information placed at our disposal by the discovery of opsonins was utilised in the treatment of disease, was demonstrated. The lecture was illustrated by lantern slides and microscopic projections, as well as by exhibits and demonstrations.

ABSTRACT OF PROCEEDINGS, JULY 1, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 1st, 1908.

W. M. Hamlet, F.I.C., F.C.S., President, in the Chair.

Twenty-six members were present.

The minutes of the meetings held May 6th and June 3rd 1908, were read and confirmed.

Dr. W. G. WOOLNOUGH and Mr. W. J. CLUNIES ROSS were appointed Scrutineers, and Dr. QUAIFE deputed to preside at the Ballot Box.

The certificate of one candidate was read for the second time, and of three for the first time.

The following gentleman was duly elected an ordinary member of the Society, viz :—

DUN, WILLIAM S., Palæontologist, Department of Mines.

The President made the following announcements :—

1. That the second Popular Science Lecture of the Session would be delivered on Thursday, July 16th, at 8 p.m., on "Life under increased Atmospheric Pressure," by H. G. CHAPMAN, M.D., B Sc.

2. That a Conversazione would be held on Tuesday the 22nd September, 1908.

3. That 72 volumes, 678 parts, 21 reports, and 29 pamphlets, total 800, received as donations since the December meeting were laid upon the table and acknowledged.

Dr. WALTER SPENCER, Acting Hon. Secretary to the N.S. Wales Branch of the British Science Guild, referred to the aims and objects of the Guild, the good it had already accomplished and the advantages of membership. He invited those present to enrol their names as members at the close of the meeting. Remarks were made by Mr. W. J. MACDONNELL, Mr. F. B. GUTHRIE, and the President.

Mr. MAIDEN moved that Rule XXIX be altered to read "*One professional Auditor*," instead of "*Two Auditors*" as at present. This motion would have to be carried at the Annual General Meeting in May next.

THE FOLLOWING PAPERS WERE READ:

1. "Records of Australian Botanists: (*a*) General, (*b*) New South Wales," by J. H. MAIDEN, F.L.S., Government Botanist and Director of Botanic Gardens.

Remarks were made by the President and Dr. QUAIFE.

2. "On the elastic substance occurring on the shoots and young leaves of *Eucalyptus corymbosa* and some species of Angophora," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

Remarks were made by Mr. F. B. GUTHRIE, Mr. J. H. MAIDEN, and the President.

EXHIBITS.

1. A large number of portraits of Australian botanists, by Mr. MAIDEN.

2. Specimens illustrating paper by Mr. HENRY G. SMITH.

3. Dr. W. G. WOOLNOUGH exhibited specimens of bacterial silt from water main at University. These bacteria exist in absence of light and oxygen and under pressures greater than atmospheric. Bacteria exist under similar conditions in deep lake and sea waters and cause precipitation of ferrous sulphide FeS. This causes the colouration of muds so deposited, and may eventually give rise to formation of marcasite or pyrite FeS_2. Compare the "Brassy Tops" of the Greta Coal Seam.

4. Samples of blue earth, being the matrix of diamonds, from the Premier Diamond Mine, Cullinan, Transvaal, were exhibited by Mr. JOSEPH PALMER.

ABSTRACT OF PROCEEDINGS, AUGUST 5, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 5th, 1908.

W. M. HAMLET, F.I.C., F.C.S., President, in the Chair.

Twenty-five members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. R. H. CAMBAGE and C. A. SÜSSMILCH were appointed Scrutineers, and Dr. R. GREIG-SMITH deputed to preside at the Ballot Box.

The certificates of three candidates were read for the second time, and one for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

BARLING, JOHN, Gentleman, "St. Adrian's," Raglan-street, Mosman.

CHAULEUR, PAUL, Hon. Secretary and Treasurer of the French Chamber of Commerce, Officier d'Academie (France), etc.; 2 Bond-street Chambers.

WILLIS, CHARLES SAVILL, M.B., Ch.M. Syd., M.R.C.S. Eng., L.R.C.P. Lond., D.P.H., Royal Coll. P. and S. Lond.; Department of Public Health.

The President made the following announcements:—

1. That the third Popular Science Lecture of the Session on "An aspect of Modern Electrical Research," by Prof. POLLOCK, D. Sc., fixed for Thursday, August 20, would be postponed, that day having been proclaimed a Public Holiday; due notice of the altered date would, however, be given. The lecture, with demonstrations, would take place in the Lecture Theatre of the Physics Department, Sydney University.

2. That a Conversazione of the Society would be held in the Great Hall of the University on the evening of Tuesday, September 22nd, 1908.

Fifteen volumes, 188 parts, 13 reports, and 4 pamphlets, total 220, received as donations since the previous meeting, were laid upon the table and acknowledged.

A letter was received from Sir ALEX. B. W. KENNEDY, acknowledging his election as an Honorary Member of the Society:—

17 Victoria-street, Westminster, S.W.,
25 June, 1908.

The Honorary Secretary, the Royal Society of New South Wales, Sydney.

Dear Sir,—I have received your letter of the 15th May, telling me that the Royal Society of New South Wales has elected me an Honorary Member of their Society. I am much obliged for your letter, and hope that you will tell the Council of the Society that I consider this election a very great honour, and that I am proud to belong to what I suppose is the oldest of the Colonial Scientific Societies. I have never had the pleasure of visiting Sydney, but I am still not too old to look forward to it as one of the pleasant possibilities of life, and if I find myself there it will give me great pleasure to claim the privileges of membership, and present myself at the Society's House. Believe me to remain with many thanks, Yours very truly, ALEX. B. W. KENNEDY.

THE FOLLOWING PAPERS WERE READ:

1. "The Pines of Australia, Part I.," by R. T. BAKER, F.L.S., Curator and Government Economic Botanist, and H. G. SMITH, F.C.S., Assistant Curator and Economic Chemist, Technological Museum, Sydney.

Remarks were made by Mr. J. H. MAIDEN, Mr. W. FREEMAN and the Chairman.

2. "Contributions to the Flora of Australia," by ALFRED J. EWART, D. Sc., Ph. D., F.L.S., Government Botanist of Victoria and Professor of Botany at the Melbourne University, and Miss JEAN WHITE, M. Sc., Government Research Scholar, assisted by Mr. J. R. TOVEY, First Herbarium Assistant, Melbourne Herbarium. (Communicated by J. H. MAIDEN.)

Abstract of lecture on "Life under increased Atmospheric Pressure," by H. G. CHAPMAN, M.D., B.S., delivered 16th July, 1908.—In diving and sub-aqueous engineering works the entrance of water into the diving suit, or caisson, is prevented by the maintenance of increased atmospheric pressure within the closed apparatus. The pressure is kept at a slightly higher level than that of the water at the depth at which operations are carried on. Under these

conditions the quantity of the gases of the atmosphere dissolved in the tissues of the body increases with the heightened pressure. The amount of gas in solution in the different tissues varies. Vernon has drawn attention to the increased solubility of nitrogen in fats and oils. Tissues containing much fat will therefore dissolve more gas than tissues with little fat. The pressure, as such, has little influence on the bodies of animals. Forms with the most delicate structure abound in the great oceanic depths, at which the pressure may be tons to the square inch. Poiselle, many years ago, shewed that the circulation in the web of the frog's foot continued when the atmospheric pressure was 120lbs. to the square inch. Langley and Priestley have shewn that the tension of carbon dioxide in the alveolar air of the lungs, is maintained at a constant level. This tension determines the depth and rate of breathing. In diving the tension of carbon dioxide in the helmet is allowed to increase. It follows that the quantity of air pumped through the helmet must be increased with the heightened pressure in the helmet. The dyspnœa experienced by the diver is due to inattention to this ventilation. At 210 feet depth Damant experienced no respiratory troubles with the necessary supply of air. Upon release from compressed air, various symptoms are experienced. These vary in degree from slight or severe pain to paralysis and death. They constitute "bends" and diver's palsy. Bert, Schrötter, Hill and others have shewn that these phenomena result from the liberation of bubbles of gas in the tissues. Decompression must be carried out at such a rate that the dissolved gases can escape from the tissues slowly. In diving, Haldane has shewn that the diver should be lowered quickly and raised in stages. The time spent at each stage of the ascent should depend on the degree of saturation of the tissues. The limit of compression is related to the amount of oxygen in the com-

pressed air. Too great a pressure of oxygen produces symptoms of poisoning. An atmosphere of pure oxygen, at 30lbs. to the square inch, kills in a few minutes. Under scientifically controlled conditions, work in caissons and diving can be carried out free from risk.

PRESERVATION OF AUSTRALIAN FAUNA.

The following official correspondence on the above subject is published herewith by direction of the Council:—

The Royal Society for the Protection of Birds,
3 Hanover Square, London, W.
31st January, 1908.

I venture to bring to your notice the treatment which is now being meted out to the Birds of Paradise in New Guinea, owing to the rescission of the Proclamation made in 1904 for the protection of these birds. We have been advised that representations on this subject to the Australian authorities and to the New Guinea Government coming from you would have great weight, so if this matter has not already received attention at your hands, we venture to appeal to you to use your influence to bring about a renewal of the Proclamation which forbade the killing of these beautiful birds, for we feel that to allow them to be exterminated by hunters employed by trading firms would be a disgrace to the whole civilized world, and more particularly to Societies interested in Science, in Art, and in Natural History objects of rarity and beauty.

FRANK E. LEMON, Hon. Secretary.

To the President of the Royal Society of N. S. Wales.

The Royal Society of New South Wales,
The Society's House, 5 Elizabeth-st., N.
22nd June, 1908.

The Hon. the Premier of New South Wales.

Sir,—On behalf of the Council of the Royal Society of New South Wales we have the honour to ask you to be good enough to forward the enclosed letters to the Hon. the Minister for External Affairs of the Commonwealth.

J. H. MAIDEN
F. B. GUTHRIE } Hon. Secs.

The Royal Society of New South Wales,
The Society's House, 5 Elizabeth-st., N.
22nd June, 1908.

The Hon. the Minister for External Affairs, Commonwealth of Australia. (Through the Hon. the Premier for N. S. Wales.)

The Council of the Royal Society of New South Wales have received a letter—a copy of which is enclosed—from the Royal Society for the Protection of Birds, asking them to approach you with the object of having the Proclamation renewed which was at one time in force against the indiscriminate destruction of birds in Papua. The Council of the Royal Society of N. S. Wales unanimously expressed their sympathy with the objects of the Royal Society for the Protection of Birds, and instructed us to bring the letter of this Society before your notice and to urge upon you the desirability of renewing the Proclamation protecting the native birds. As it appears that the slaughter of these beautiful and harmless creatures is carried out solely in the interest of a few trading companies, we feel that we have ample justification on humane grounds for asking you to regulate their destruction and prevent their extermination.

J. H. Maiden } Hon. Secs.
F. B. Guthrie }
Royal Society of N. S. Wales.

Department of the Attorney General and of Justice,
Sydney, 26th June, 1908.

In acknowledging the receipt of your letter of the 22nd instant, forwarding a communication in regard to bird destruction in Papua, for transmission to the Minister of External Affairs, Melbourne, I am directed by the Premier to inform you that your request has been complied with.

J. L. Williams, Under Secretary.

F. B. Guthrie, Esq., F.C.S., Hon. Secretary, Royal Society of New South Wales, Sydney.

Commonwealth of Australia, Department of External Affairs,
Melbourne, 30th June, 1908.

I have the honour to acknowledge, by direction, the receipt of your letter of 22nd instant, transmitted through the Honourable the Premier of New South Wales, written with the object of securing the renewal of the Proclamation which, it is stated, was at one time in force against the indiscriminate destruction of birds in Papua.

2. In 1894, a Wild Birds Protection Ordinance was passed under which a Proclamation was issued on 25th June, 1904, prohibiting throughout the Possession, except under special permit, the destruction of Birds of Paradise.

3. In consequence of a petition received from local residents, a suspension was granted for one year, terminating on 30th April last, covering a limited area, namely, that part of the Central Division which lies between the Kemp-Welch and Brown Rivers. This represents less than one-twentieth of the territory, the prohibition remaining in force over the remainder. No authority has been given for the extension of this period of suspension.

4. I may add that in a recent communication on the subject, the Acting Administrator refers to "the natural desire which has always existed on the part of the Government to preserve these birds from any—even the slightest—danger of extinction"; so that the views of the local administration are in harmony with those of the Federal Government on the subject.

5. Consequent on various representations made to him, the Prime Minister has called for an exhaustive report on the whole question, which is expected to be received at an early date. I am directed to say that no course will be sanctioned which appears to render in the least likely the destruction of any species of the Bird of Paradise.

Atlee Hunt, Secretary.

F. B. Guthrie, Esq., Hon. Secretary, Royal Society of New South Wales, Sydney.

Royal Society of South Australia,
Adelaide, 17 June, 1908.

The Secretary of the Royal Society of N. S. Wales.

The following motion has found a place on the minutes of this Society—"The Council of the Royal Society of S.A. would draw the attentions of the Council of the Royal Society of N. S. Wales and of the Linnean Society of the same State to the necessity for legislation to preserve the Fauna of New South Wales. This may be possibly best effected by providing for the complete protection of the Fauna in all the forests of the State in any legislation which may be introduced on the Report of the Royal Commission on Forests which recently visited this State (S.A.)." My Council quite believe that this important question has not escaped your notice, but feels how very necessary it is for scientific, and possibly other reasons, to preserve the native animals of Australia from extinction.

G. G. Mayo, Hon. Secretary.

Advisory Committee *re* Fisheries and Game Acts in Victoria.
National Museum, Melbourne,
18th July, 1908.

Owing to the great destruction of our native birds, particularly the Egrets, Lyre Birds, and Birds of Paradise, in order to obtain their skins and plumes for ornamental purposes, the above Committee, which has been formed to advise the Victorian Government on matters pertaining to the Fisheries and Game Acts, has decided to approach the Commonwealth Government with a view to action being taken to prevent the exportation of the skins and plumes of these birds. It is particularly desirable that the various Australian Societies interested in the protection of our native fauna should co-operate in this matter, and with this object I have been requested by the above Committee to ask your Society to kindly forward us an expression of its opinion in order to strengthen its hands in approaching the Government. In view of the recent introduction to the British Parliament by

Lord Avebury of the Prohibition of Plumage Importation Bill, it is felt that the present is a peculiarly suitable time at which to take action in regard to this matter in Australia. We should be glad if you would kindly communicate with us at the earliest possible moment.

JAS. A. KERSHAW, Hon. Secretary.

The Royal Society of New South Wales,
5 Elizabeth-st., N., 23rd July, 1908.

The Hon. Secretary, Royal Society of South Australia, Adelaide.

Your letter dated 17th ultimo was duly laid before the Council of this Society at its last meeting, and I have been directed to inform you that the Council is in full accord and sympathy with the object you have in view, viz., the necessity for legislation providing for the complete protection of the Fauna in all the forests in this State. I may mention that at the request of the Royal Society for the Protection of Birds, London, we recently wrote to the Hon. the Minister for External Affairs, Commonwealth of Australia, urging upon him the desirability of renewing the Proclamation protecting the native birds in Papua. A letter has also just been received from the Advisory Committee *re* Fisheries and Game Acts in Victoria, inviting the Royal Society of N. S. Wales to forward an expression of its opinion on action being taken for the protection of our native fauna; this matter will come before the Council for consideration at its next meeting.

J. H. MAIDEN, Hon. Secretary.

The Royal Society of New South Wales,
31st July, 1908.

The Hon. Secretary Advisory Committee *re* Fisheries and Game Acts in Victoria, National Museum, Melbourne.

Your letter of the 18th instant was duly laid before the Council of this Society, at its meeting on Wednesday last, and I am directed to inform you that the Council is in full accord and sympathy with your proposal to approach the Commonwealth Government, with a view to action being taken to prevent the

exportation of the skins and plumes of Australian native birds. I may mention that at the request of the Royal Society for the Protection of Birds, London, we recently wrote to the Hon. the Minister for External Affairs, Commonwealth of Australia, urging upon him the desirability of renewing the proclamation protecting the native birds in New Guinea. The Royal Society of South Australia has also been in communication with this Society respecting the necessity for legislation providing for the complete protection of the fauna in all the forests in this State, a matter which obviously commends itself to our heartiest approval and sympathy, and we shall be only too pleased to do our utmost to further all these desirable objects.

J. H. MAIDEN, Hon. Secretary.

Advisory Committee *re* Fisheries and Game Acts in Victoria.

National Museum, Melbourne,

5th August, 1908.

We beg to thank you for your letter of 31st ultimo, expressing the sympathy of your Society with the object of the proposed deputation to the Prime Minister of the Commonwealth, in regard to the prohibition of the exportation of the skins and plumes of Australian birds.

The deputation waited upon the Honorable the Prime Minister on Tuesday, August 4th, and was most favourably received. We enclose a cutting from the *Age* of August 5th, in which the reply of the Prime Minister is given, and will communicate again with you in the event of it being thought necessary to take any further steps.

W. BALDWIN SPENCER, Chairman.

JAS. A. KERSHAW, Hon. Secretary.

The Hon. Secretary
Royal Society of New South Wales.

See also lengthy reports in the *Sydney Morning Herald* and *Sydney Daily Telegraph* of 5th August.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 2, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 2nd, 1908.

W. M. HAMLET, F.I.C., F.C.S., President, in the Chair.

Thirty-two members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

Two new members enrolled their names and were formally introduced.

Dr. MARDEN and Mr. L. HARGRAVE were appointed Scrutineers, and Mr. H. DEANE deputed to preside at the Ballot Box.

The certificate of one candidate was read for the second time.

The following gentleman was duly elected an ordinary member of the Society:—

MEARES, FREDERICK THOMAS DEVENISH, Engineer, 37 Wynyard Square.

The President made the following announcements:—

1. That the monthly meeting of the Engineering Section would be held on Wednesday, September 16th at 8 p.m.

2. That the fourth Popular Science Lecture of the Session on "Carbon Dioxide and some of its Properties," by T. STEEL, F.L.S., (illustrated by experiments) would be delivered on Thursday, September 17th, at 8 p.m.

3. He reminded the members that the Conversazione would be held on Tuesday evening September 22nd in the Great Hall of the University, and that particulars of exhibits should be sent to the Hon. Secretaries as soon as possible, so as to appear in the catalogue.

Twelve volumes, 190 parts, 14 reports, and 1 pamphlet, total 217, received as donations since the previous meeting, were laid upon the table and acknowledged.

Letters were received from Prof. LIVERSIDGE, London, and Sir WILLIAM TURNER, Edinburgh, acknowledging their election as Honorary Members of the Society:—

United University Club, Pall Mall East, S.W.
July 1, 1908.

J. H. Maiden, Esq., F.L.S., Hon. Secretary Royal Society of N.S.W.

My dear Sir,—I have the pleasure to acknowledge the receipt of yours of May 15th, in which you inform me that I have been elected an Honorary Member of the Royal Society of New South Wales. I need hardly say that I value this honour most highly, and I greatly appreciate the kind and generous terms in which you inform me of this unexpected distinction. As you and the other members of the Society are aware, my connection with the Society throughout the past thirty-five years has always been a pleasure to me, and especially when I was able to further its aims and objects, and I shall be extremely glad if I can render it any service in the future; one of my great regrets in leaving Sydney is that I am not able to take the same part in the work of the Institutions and Societies. Will you kindly convey to the Council and Members my most cordial thanks for this kindly remembrance of me and for their good wishes? I am yours truly, A. LIVERSIDGE.

University of Edinburgh, July 22nd, 1908.

My dear Sir,—I have the honour to receive your letter of 15th May in which you communicate to me the resolution of the Royal Society of New South Wales, that I have been elected an Honorary Member. I have received intimation of this with much pleasure and wish you to express my grateful thanks to your members for the honour bestowed on me. I remain, very faithfully yours.

WM. TURNER.

PRESERVATION OF AUSTRALIAN FAUNA.

In further reference to the above subject (*vide* Abstract for August, 1908, pp. xix-xxiv), the following letter has since been received, and is published herewith by direction of the Council:—

Linnean Society of New South Wales,
23 Ithaca Road, Elizabeth Bay.
Sydney, August 21st, 1908.

The Hon. Secretaries Royal Society of New South Wales, Sydney.

Gentlemen,—The members of the Society, and others interested in the question of the preservation of the Australian fauna and

flora, are being invited to give special consideration to what is being done, and what more can be done, to protect native animals and plants from extermination, at the next meeting of the Society, on Wednesday evening, 26th instant. I have much pleasure in asking you to convey to the Council of your Society a cordial invitation, from the President, to be represented on the occasion referred to. The subject is one which may be advantageously publicly ventilated just now; and the co-operation and support of all who are interested in Australian animals and plants are very desirable. Yours faithfully, J. J. FLETCHER,

Secretary.

The Hon. Secretary (Mr. J. H. MAIDEN) was asked to attend the meeting on behalf of the Council, and to inform the Linnean Society of the steps already taken by the Royal Society of N.S.W. in the matter. This request was duly complied with.

A circular letter was received from the Royal Society of Victoria:—

Royal Society of Victoria, Royal Society's Hall,
Victoria Street, Melbourne, 13th July, 1908.

The Hon. Sec., Royal Society of N.S. Wales.

Dear Sir,—On 14th May a Committee of the Society was appointed to consider the question of establishing some memorial of the late Dr. A. W. Howitt. The Committee suggests that the best practicable way of perpetuating his memory is that of establishing a "Howitt Medal," to be awarded from time to time by the Council of the Society to the author of distinguished work dealing especially with the Natural Science of Australia. In order to carry out this idea it will be necessary to raise a fund of about a hundred pounds. It is hoped that the movement will meet with your approval and co-operation. Subscriptions may be sent to the Hon. Treas. of the fund, Dr. T. S. Hall, addressed to the University of Melbourne.

(Signed) W. BALDWIN SPENCER, Chairman.
E. W. SKEATS.
RICHD. J. A. BERRY.
A. J. EWART.
T. S. HALL, Hon. Treasurer.

HOWITT was a many sided man. He was explorer and geographer, petrologist and geologist, ethnologist and botanist (student of Eucalyptus chiefly), and attained excellence in every branch of

science he undertook. His personality was charming. He lived mostly in Victoria, but no man of science more fully deserves the broader title of Australian than HOWITT. His scientific reputation requires no adventitious memorial, but he had many friends in New South Wales, and it is believed that some of them will gladly avail themselves of the opportunity of contributing to the proposal which has been made to stimulate interest in some of the branches of study in which he delighted. If it is any convenience to our members, the Honorary Secretaries of the Royal Society of N.S. Wales will gladly transmit subscriptions to Dr. T. S. HALL at Melbourne.

THE FOLLOWING PAPERS WERE READ:

1. "The Discharge of Electricity from Glowing Carbon," by J. A. POLLOCK, D.Sc., Professor of Physics in the University of Sydney, and A. B. B. RANCLAUD, B.Sc.

2. "The Relighting of the Carbon Arc," by J. A. POLLOCK, D.Sc., E. M. WELLISCH, M.A., and A. B. B. RANCLAUD, B.Sc.

Questions were asked by Dr. SPENCER, to which Prof. POLLOCK replied.

3. "Evidence of Recent Submergence of Coast at Narrabeen," by T. W. E. DAVID, B.A., F.R.S., Professor of Geology, University of Sydney, and GERALD H. HALLIGAN, F. G. S., Hydrographic Officer, Works Department.

The paper was read by the Hon. Secretary (Mr. MAIDEN).

Remarks were made by Mr. R. H. CAMBAGE, Dr. WOOLNOUGH, Mr. H. DEANE, Mr. C. SUSSMILCH, Dr. SPENCER, Mr. MAIDEN, the PRESIDENT, and Mr. HALLIGAN.

EXHIBIT.

W. J. CLUNIES ROSS, B.Sc., F.G.S., exhibited specimens to illustrate the forms assumed by crystals, when placed in a solution of silicate of soda. It was shewn that each compound developed distinct forms. Ferrous sulphate, copper

sulphate, zinc sulphate, all developed aborescent forms, but differing in shape. Other compounds, such as ferric chloride, assume shapes which simulate fungoid growths. The growths are rigid and consist probably of silicate of the metal, but have not yet been analysed.

Remarks were made by Acting Professor SCHOFIELD, Dr. WOOLNOUGH, Mr. MAIDEN and the PRESIDENT.

The following letter was read before the Annual General Meeting in May, and was inadvertently laid aside :—

Department of Public Health, New South Wales,
Sydney, 27th March, 1908.

Sir,—Referring to my communication of 1st February, 1906, with respect to the request of the Natural History Branch of the British Museum, for specimens of the various species of blood-sucking insects, I have the honour, by direction, to inform you that from a later communication from the Colonial Office, it appears that you are desired to be good enough to forward further specimens of blood-sucking insects collected in this State to the Quick Professor of Biology, New Museums, Cambridge, similar to those already forwarded, and, as far as possible, that future contributions should be divided between and simultaneously despatched to, the Director, Natural History Museum, and the Professor of Biology already mentioned.

2. I am directed by the Chief Medical Officer of the Government to add that the opportunity is taken of again commending to the attention of the members of your Society the importance of forwarding the collective enquiry in progress, in view of the part played by various insects in the transmission of human and animal diseases, and of pointing out that by the two institutions the subject will be regarded from rather different points of view. I have the honour to be, Sir, your obedient servant,

JAMES J. POTTER, for Secretary.

The Secretary to the Royal Society,
Royal Society's House, Elizabeth-street, City.

CONVERSAZIONE, SEPTEMBER 22, 1908.

A Conversazione was held in the Great Hall of the University, on Tuesday, 22nd September, 1908, at 8·30 p.m. under the management of the Officers and Council of the Royal Society. The Hall and approaches were tastefully decorated with palms, ferns and rare pot plants provided by the Director of the Botanic Gardens. The paths were enclosed with canvas screens, and were illuminated with electric light, thus enabling the guests to conveniently visit the various Laboratories which were thrown open.

The number of guests present was between 500 and 600.

His Excellency the State Governor and Miss RAWSON, His Excellency the Admiral and Lady POORE were absent from Sydney. The Officers of the Ships of War in harbour were present, also the Colonial Treasurer, the Colonial Secretary, the Secretary for Lands and the Secretary for Mines and Agriculture; various members of both Houses of Parliament, the Consuls-General and Vice-Consuls, the Vice-Chancellor and Members of the University Senate, the Rt. Hon. The Lord Mayor, the Lady Mayoress, and others.

Mr. J. FRENCH LYDALL, B.A., F.R.H.S., presided at the Organ.

EXHIBITS:

[NOTE.—The names of Exhibitors are arranged in alphabetical order.]

MR. R. T. BAKER, F.L.S., Curator Technological Museum—

"Enlarged Micro-Photographs," on Glass, of sections of the timber of the Australian White Pine, *Callitris glauca.*

These are shown to demonstrate the remarkable antiquity of these trees as judged from the investigation of the fossil timbers of America. These are exhibited by the aid of artificial light.

"Vegetable Pottery."

This exhibit, which occupies an entire case, consists of numerous articles used by natives in various countries for household and other purposes. It consists of gourds of various shapes, bamboo vessels, plain and carved, together with wooden dishes and plates.

"Pottery Decorated with designs of Australian Flowers," by Bilton.

This collection consists of eight specimens of pottery in various shapes, manufactured by Doulton and Co., England.

"Vegetable Sheep."

This is an entire plant (*Raoulia mammilaris*, Hook., fils.) belonging to the Family Compositae. It is found above the snow line on the mountains of New Zealand at an elevation of 7,000 feet. It derives its common name from its resemblance to a sheep, and when seen in any number, gives the appearance of a flock of sheep pasturing.

"Artificial Camphor."

This product is identical in composition with native camphor; it is now made synthetically. The raw material is pinene of which terpene, ordinary turpentine, so largely consists. This artificial camphor is now an article of commerce.

"Model of the Tunny," *Germo maccoyi*, Fam. Scombridae.

This is the cast of probably the first fish of this species recorded in Australia.

MR. F. M. BLADEN, Principal Librarian, Public Library—
(On behalf of THE TRUSTEES OF THE PUBLIC LIBRARY OF N.S. WALES)—

"Engravings, Prints, etc.":—

'Captain James Cook.' (Artist, G. Webber; engraver, F. Bartolozzi, 1784.)

'Mort du Capitaine Cook.' (Artist, J. Clevely; engraver, Piringer.) The English engravings representing the murder of Captain Cook are well known, but not so the French ones, which are comparatively rare.

'Karakakoa Bay, Hawaii, 1814.' (Artist, T. Heddington; engraver, M. Dubourg.) Coloured engraving of the Bay where Captain Cook was murdered, 1779.

'Sir Joseph Banks.' (Artist, T. Phillips; engraver, S. W. Reynolds, 1828.)

'La Pérouse.' (Proof engraving by Woolnoth.)

'Bligh transplanting Bread-fruit Trees from Otaheite to the West Indies.' (Painted and engraved by Gosse.)

'Sydney in 1804.' Coloured engraving, (Artist, E. Dayes; engraver, F. Jukes).

'Sydney in 1812.' (Engraved by P. Slaeger; published by A. West.)

'Sydney in 1812.' Selection of 3 engravings (drawn by J. Eyres; engraver, W. Preston).

'Sydney in 1814.' Coloured engraving (published by Jas. Whittle and R. H. Laurie).

'Sydney about 1814.' (Engraved by Moffat.)

'Sydney about 1831.' (Lithographed by C. Couzens.)

'Plan of Sydney, 1807.'

'Plan of Sydney, 1822.'

'Plan of Sydney, 1837.'

'Earliest View of Melbourne.'

'Melbourne in 1854.' (Artists, Whittock and Teale.)

'Adelaide in 1837.' Coloured engraving of Colonel Light's picture of the site selected for the Capital of South Australia. (Engraver, W. Havell.)

'Swan River, 1827.' (Artist, Huggins; Engraver, E. Duncan). Coloured engraving, showing Capt. Stirling's exploring party. Stirling became the first Governor of Western Australia.

'First Coloured Engraving of Auckland, New Zealand.'

'Charlotte Sound, New Zealand.' (Mezzotint—Artist, J. Cleveley.)

'Wellington, New Zealand, 1841.' (Artist, C. Heapy; Lithographer, T. Allom.)

'Hobart in 1817.' (Artist, Lieut. C. Jeffreys.)

'New Toll Gate, Parramatta Road, Sydney, 1836.' (Colour print by J. G. Austin.)"

Mr. C. Bogenrieder—

"Petrological Microscope," Model 1908, of Berlin, R. Fuess, constructed after the advice of Dr. Feodorowitch, Prof. Klein and Dr. Gothe. Bought from the General Agents for Feuss, Lohmann and Co., Sydney.

"Spectroscope," for use in laboratories for studying Flames and Liquids. Latest Model, 1908. Constructed by Schmied and Haenschlim, Berlin.

J. Haydon Cardew, M. Inst. C.E., Lecturer in Surveying, the University—

"A precise levelling instrument" by E. Sprenger, Berlin.
"A Tachometer" by Troughton and Sims.
"An 8 inch Theodolite" by Troughton and Sims.
"A 14 inch Theodolite" by Troughton and Sims.

Mr. D. Carment, F.I.A., F.F.A., Australian Mutual Provident Society—

"Calculating and Adding Machines"—The Millionaire, Arithmometer and Brunsviga calculating machines; Burroughs, Comptometer and Centigraph adding machines.

His Honor Judge Docker—

"Stereoscopic Slides of photographs taken by the exhibitor in his travels in and out of Australia."

Mr. J. Arthur Dowling, Honorary Secretary of the Australian Historical Society—

"Pictures." 1. Francis Forbes, Esq., the first Chief Justice of tbe Colony (he was knighted after he resigned office). 2. James Dowling, Esq., the second Chief Justice, formerly Second Puisne Judge (Knight when appointed). 3. The First Railway Station at Redfern. 4. The Landing of Captain Cook. 5. Port Macquarie.

Mr. A. Duckworth, F.R.E.S.—

"Original Sketch by J. Skinner Prout, dated. 'The Tank Stream of Old Sydney in 1846.'"

Mr. William Freeman—

A rare work entitled "Di Gerusalemme Conquistata." Del Sig. Torquato Tasso. Libri 23. In Roma 1593.

Mr. E. J. Goddard, B.A., B.Sc., Department of Biology, the University of Sydney—

"Preparations of Australian freshwater Leeches, *Glossiphonia*, *Nephelis*, *Semilaganeta* (new genus). Preparations of Australian freshwater Worms, *Astacopsodrilus* (new genus); a *Lumbriculid* from Tasmania. Freshwater Polyzoa."

Mr. F. B. Guthrie, F.I.C., F.C.S., Department of Agriculture

"Form of Soil Elutriator."

"Collection of specimens of wheat and products."

Mr. Gerald H. Halligan, F.G.S., Hydrographic Officer, by permission of Hon. the Minister for Public Works—

'Mercurial Tide Gauge," described in paper read before the Royal Society, N.S.W., June 3rd, 1903.

New Tide Guage, designed by exhibitor, and made by Hy. Alexander, instrument maker, Public Works Department. It is claimed for this gauge that it is the simplest automatic tidal recorder yet made. The drum carrying the record revolves once in 48 hours, so that one week's tide may be shown on each sheet, without confusion cf lines. The float is of earthenware or glass, and is practically indestructible. The cost of the gauge is about £9.

"Diagrams," showing existing types of Tide Gauges in various countries.

"Sample Sheets," showing 2 weeks records of the new Tide Gauge.

Mr. W. M. Hamlet, F.I.C., Government Analyst—

"Zeiss Dipping Refractometer."

"Abbè Refractometer."

"Microscope."

"Arctic Medal."

"Photograph of 'H.M.S. Intrepid' gripped by the Ice."

"Sundry Coins."

Prof. W. A. Haswell, M.A., D.Sc., F.R.S., Department of Biology, Sydney University—

"A Variety of Specimens and Preparations under the Microscope."

"Foraminifera. Noctiluca. Sections of Sponge. A Zoophyte. Head of Mosquito. Eye of Insect, vertical sections. Embryo of Fowl. Sections of Stems of Plants. Sections of Leaves.

"Some Deep-Sea Animals from the Tasman Sea."

[In the Biological Laboratory].

Mr. R. Helms, Department of Agriculture—

"A large Collection of Coins."

Dr. Andrew Houison—

1. " Bible and Prayer Book."

Brought out from England by the Rev. Richard Johnson, and used by him in the early services of the Church, first in the open air, and afterwards in the Church, which was opened August 25th, 1793, and destroyed by fire October 1st, 1798. They were afterwards used in Old St Phillip's Church, and are now the property of the Trustees of St. Phillip's.

2. " Large Volume of Photographic Reproductions of many early engravings showing the early days of Sydney.

3. " History of the Post Office and of the issue of Postage Stamps in New South Wales, 1890, by Dr. Andrew Houison.

Very scarce, the Government having caused all available copies to be destroyed in consequence of the representations of the stamps having been made from the original dies.

4. " Photographs of buildings condemned and pulled down in Sydney.

This volume shows many of the old " rookeries " which occupied a prominent place in the streets of Sydney a few years ago.

5. " Sydney in 1848, by J. Fowles."

This copy gives the residences and many old buildings of the city as far back as the year 1832.

6. " Three framed Views of Sydney in 1820, by Major Taylor."

On each frame there is a small sketch giving the details of the picture.

7. "Electrotype of the Great Seal of New South Wales."

This is virtually the same seal as the first Great Seal of the Colony, the only difference being in the alteration of the name of George the Third to that of George the Fourth.

8. " Water Colour of Old Government House by Chas. H. Woolcott."

This gives an admirable picture of the old building as it was in 1841.

9. " Pen and Ink Sketch of Tank Stream, by C. H. Woolcott."

Showing the position of the tanks by the pump which was erected in Pitt-street, near Hunter-street.

Mr. S. J. Johnston, B.A., B.Sc., Department of Biology, the University of Sydney—

" Trematodes from Frog, Platypus and Man." Cysticercus of Tapeworm. Head of Lizard, longitudinal and transverse sections."

Hon. ALEX. KETHEL, M.L.C.—

"History of the World by Sir Walter Raleigh." First Edition of the year 1617 in original calf binding.

MR. ALFRED LEE—Valuable historical Australian relics :—

"Old Wedgewood Medallion" (in white) made from Sydney clay, 1789. Extremely rare.

"Portrait of Sir Jos. Banks."

"Large Portrait of Dr. Solander," who accompanied Cook and Banks. Very rare.

"Cook Gold Medal," struck in honor of Captain Cook. Almost unique—the only other one known to exist is in the British Museum!

"Cook Silver Medal."

"Tasmanian Shilling." (Token) 1823. Rare.

"Victorian One Shilling." Rare.

"*Biblia Latina.*" Fine specimen of very early printing, published 1478.

Mr. W. J. MACDONNELL—

"A Collection of Greek Coins," from Southern Italy, Sicily, Greece and Islands, Asia, Egypt, and some miscellaneous coins.

Mr. J. H. MAIDEN, F.L.S., Botanic Gardens—

"Table of Australian Native Flowers."

"Table of Orchids and other rare and interesting living plants." The collection includes the following:—Orchids, *Cattleya guttata*, Lindl. var. *Prinzii; C. labiata*, Lindl. var. *Schroderæ; C. Lawrenciana*, Warsc.; *Coelogyne flavida*, Hook.; *Cypripedium concolor*, Batem, var. *Madame de Coute* var. *purpureum; C. Sedenii*, Reichb. var. *candidulum; Dendrobium aggregatum*, Roxb.; *D. Dalhousianum*, Paxt.; *D. Jenkinsii*, Lindl.; *Lawrenciana*, Reichb., fil.; *D. nobile*, Lindl. var. *nobilius; D. superbum*, Reichb.; *Phalænopsis Lueddemanniana*, Reichb.; *Schomburgkia undulata*, Lindl. Palms and Miscellaneous :—*Daemonorops augustifolius*, Mart.; *Borassus flabelliformis*, Murr.; *Livistona Woodfordii*,

Ridley; *Oncosperma fasciculata*, Thwaites; *Oreodoxa oleracea*, Martius; *Pinanga acaulis; Rhopaloblaste hexandra*, Scheff.; *Adiantum dolabriforme*, Hook.; *Dracaena Sanderiana*, Hort.; *D. Goldieana*, Hort.: *Rhododendron amaenum*, Planch. var. *Magnet; R. indicum*, Linn. var. *Phryne; Tydaea pandora.*

Mr. J. Nangle, F.I.A.—

"Astronomical Micrometer and Position Circle with dark field illumination. Microscopes with specimens of rock and diatoms."

Mr. Edward F. Pittman. A.R.S.M., Under Secretary for Mines and Government Geologist, assisted by Mr. George S. Card, A.R.S.M., Curator of the Mining and Geological Museum—

"Recently Discovered Minerals and Fossils," including Ordovician graptolites from new localities, fish from St. Peters, Native Arsenic, Fluorite, Emery, etc., etc.

"Photographs of scenes of Geological and Geographical interest in New South Wales. A large and specially important collection.

Prof. J. A. Pollock, D.Sc., and Mr. U. Vonwiller, B.Sc., Physical Laboratory of the University—

1. "Magnetic Model" of an atom on the corpuscular theory of matter. First described by Professor Mayer.

A number of small bar magnets, held vertically with their south poles upwards by corks floating in water, represent the electrons or corpuscles, while a large bar magnet is placed above the water with its north pole pointing downwards, this representing the positive electricity distributed through the atom. The small magnets are attached by the large one but mutually repel one another, and as a result take up definite positions of equilibrium, arranging themselves in some symmetrical manner depending on the number present. If they are all removed and put in the water near the side of the dish, one by one, they are seen to move rapidly towards the centre and take up their positions of rest. Three arrange themselves so as to form a triangle, four a square, five a pentagon (generally), six a pentagon with one inside, and so on; a series of concentric rings being formed as the number increases. It is interesting to remove the centre magnet when seven are present, the ring of six cannot remain long without a magnet inside, one very soon moving to the centre leaving an outer ring of five.

The electrons in an atom may be supposed to arrange themselves in a similar manner and on this view the periodic law, and the laws of chemical combination have received a physical explanation.

2. "Photographs of stages of the development of the electric arc," after the circuit has been broken and restored without movement of the carbons.

3. "Photographic records," shewing the diurnal periodicity in the spontaneous ionisation of air within an hermetically sealed vessel.

4. "Lightning conductor crushed by the discharge," presented to the Physical Laboratory by H. G. Clark, Esq.

5. "A form of radium clock."

6. "Illustration of the ordinary method of comparing the radio-activity of minerals.

7. "Wilson's experiment," showing the effect of Röntgen rays in promoting the formation of clouds when air is suddenly expanded.

8. "A modified form of Sprengel vacuum pump."

9. "Glass plates for testing the flatness of surfaces by optical means.

MR. W. J. CLUNIES ROSS, B. Sc., Lecturer in Chemistry, Technical College—

"Deposits" formed by placing crystals of salts in silicate of soda solution (water glass). Each salt shows a characteristic form of growth.

(Mr. Ross recently brought this phenomenon, which is new to Australian scientific men, and perhaps altogether new, under the notice of the Society.)

"Colloidal Gold." The gold is in the metallic state, the particles are believed to be about $\frac{1}{10000000}$ inch in diameter.

THE ROYAL SOCIETY OF N.S. WALES—Exhibits formerly the property of Professor Faraday.

"One piece electrical apparatus. Native silver. Iridesent antimonite. Clausthalite (Selenide of Ag. and Pb.). Barium peroxide, BaO_2, One piece of glass made by Faraday. Rod of antimony."

These interesting exhibits were the gift of Professor Liversidge.

Acting-Prof. J. A. Schofield—

"Vacuum Tubes, Rontgen Ray Tubes, Glew's Scintilloscope and Specimens of Radium Bromide."

"Copper Mirrors on Glass."

"Combined Chemical and Assaying Balance."

Maximum load 10 grams or 150 grains, sensitive to ·000025 grams or ·0004 grains, with platinum crucible weighing about 5 grams for use with the balance.

(In the small Chemical Lecture Room.)

Mr. R. C. Simpson, Lecturer in Charge, Dept. of Electric. Engineering and Physics. Apparatus made by the staff or students at the Technical College, Sydney—

"Variable Standard of Self Induction." Range ·25 to ·89, Henry.

"Standard Cells."

"Two Kelvin Balances of different Ranges."

Mr. W. Slade, Architect, A collection of photographs by the exhibitor.—

"Views of the Hawkesbury River"—

1. As seen from Berowra, towards Peat's Ferry; Casuarinas in the foreground.
2. Near Windsor, study of Weeping Willows.
3. Old Mill below Wiseman's Ferry,
4. Towards Berowra,' the track to Tootagraragie.
5. Barr Island,
6. Berowra Creek,
7. Sandstone Bluff, at head of Wiseman's Ferry.
8. Entrance to Macdonald River, near its confluence with the Hawkesbury at Wiseman's Ferry.
9. Wiseman's Ferry.
10. One of the Upper Reaches of the Hawkesbury, midway between Windsor and Wiseman's Ferry.
11. Berowra Mangroves. (*Avicennia.*)
12. Near Berowra, the Glen light. The champion picture of the Photo. Exhibition of the Railway Institute, 1906.
13. Aborigine and maize patch, Hawkesbury.

14. Rock Study (of Sandstone weathering) Long Island.
15. Rock Study (of erosion).
16. Rock Study, with Eucalyptus on top; illustrates the tenacity of life of some trees.
17. Rock Study (of erosion).
18. Rock Study, a remarkable capped rock, simulating a human bust, showing vertical striæ. A study in erosion.
19. Rock Study (of erosion).
20. Hawkesbury Railway Bridge, interior view.

Sir John Robertson at Clovelly, Watson's Bay, 1888.

Sir Henry Parkes at Faulconbridge, N.S.W., 1888.

London in the time of Henry VIII. Print by H. W. Brewer (Inv. and Del. 1887).

Dr. Walter Spencer—

"Medals" (with clasps) of Captain Charles Serbutt and James Serbutt, R.H.A., for the Crimean, Waterloo and Peninsula campaigns.

"Framed Certificate" (bearing official endorsement)—

D. Battery, B. Brigade, of continuous service by the latter under Wellington from Portugal to Paris during which he took part in 61 engagements.

"A few other Medals."

"Coins of Old Japan," gold, silver, silver-gilt and copper. Ancient Chinese copper coin, sword-shaped.

"Chinese Ornaments and Articles of common use." Ancient Chop-stick case of Cloisonné enamel. Some Manchurian toys. Elaborately carved ivory fan. Fan with scene on each side containing 120 figures; the faces of painted ivory, the dresses of silk appliqué. Drawings of Chinese punishments. Very ancient bronze lamp, silver inlaid.

"Old English coloured Embroideries" (4).

"Old Miniature Portraits" (7).

"Photo.-Album," Types of Chinese, Malays, Phillipinos, Peruvians, etc.

"Sketch," Heads of two Maori Chiefs; contrasted types.

"Rare Book by Dr. Hagen, Missionary," folio, 1801; (with copy of the most ancient inscription in China).

"Prints from Paintings of 15th to 17th Century, representing the stages of medical and surgical practice.

The Doctor from being hailed as Saviour is, invariably when he presents his account after the cure, denounced as the Devil. The changing conditions through the centuries of domestic interiors, furniture, etc., are interesting; no glass appears in the windows of the earliest.

Dr. Frank Tidswell, Bureau of Microbiology.

1. 'Photographs' showing the microscopical characters of some common diseases producing bacteria.
2. 'Glass Models' showing the principles of the common and the force pumps.
3. 'Glass Models' showing the principles of house drainage.
4. 'Lower Jaw Bones of Cattle' showing the ravages of the Actinomyces parasite (Lumpy Jaw).
5. Specimens illustrating the life history of the hydatid of rabbits. (*a*) The hydatid phase in a rabbit.
   (*b*) The tapeworm phase in a dog.
6. 'Portion of the Stomach of a Horse,' showing the larvæ of the bot fly.
7. 'Cattle Ticks' adherent to the skin of a bullock.

The University of Sydney—

"Rare and Interesting Books."

(These are lent by permission of the Senate, through the kind intermediary of Mr. R. A. Dallen, Acting Registrar, and Mr. J. Le Gay Brereton, Assistant Librarian.)

Mr. F. Walker, Chatswood.

"Three framed Drawings of old buildings in 'Rocks Area' and Sydney." Original sketches from which the blocks were made for illustrated article 'Old and New Sydney,' published in 'Australian Field.'

"Two unframed, mounted series of photographs," specially taken for illustrating specimens of 'Early Australian Architecture.'

"Framed drawing, portrait of Governor Macquarie, with original signature at back."

"Portfolio of Water-colour Drawings, illustrating Ancient Egyptian Temples, and Decorations, Ornamental Stone and Wood-work, Temple Architecture etc." (40 drawings)

"Model of Ancient Egyptian boat, Mummy Cloth, etc."

"Series of photographs taken at Port Macquarie, showing old St. Thomas' Church of England, interior of Gaol, etc."

Mr. Fred. Walsh—

"Two Thick Volumes," containing a collection of rare patent specifications, relating to the shearing of animals by machinery.

Professor J. T. Wilson—(Department of Anatomy).

"Various Microscopes, with a number of interesting slides."

Acting Professor W. G. Woolnough, D.Sc., (Department of Geology)—

"Geological Maps," prepared by the United States Survey. These illustrate some of the finest work of this kind published.

"Jolly's Balance and Walker's Balance." Balances for determining specific gravity. Specific gravity is the relative weight of a substance as compared with that of an equal bulk of water.

"Models to show Symmetry of Crystals." Observe that the single piece of cardboard is reflected in the mirror so as to produce a figure similar in form to a crystal.

"Sclerometer." An instrument for determining the hardness of minerals. A polished plate of mineral is adjusted on the table of the instrument, and the counterpoised steel (or diamond) point is pressed against it by a weight. The carriage is moved and the hardness of the mineral determined by the weight necessary to produce a scratch.

"Blowpipe Apparatus," for determining the chemical composition of minerals.

"Microscopes," with thin sections of rocks from Antarctica, also examples of Foraminifera and Radiolaria.

"Six Large Framed Photographs," illustrating Australian Geology, etc.

"Large Specimen of Kenyte," a basic lava from Mt. Erebus, Antarctica.

"Petrological Lathe" for cutting rock sections.

ABSTRACT OF PROCEEDINGS, OCTOBER 7, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 7th, 1908.

W. M. HAMLET, F.I.C., F.C.S., President, in the Chair.

Thirty-five members were present.

The minutes of the preceding meeting were read and confirmed.

Two new members enrolled their names and were formally introduced.

The certificates of four candidates were read for the first time.

The President made the following announcements:—

1. That the Fifth Popular Science Lecture of the Session on "The Economic Use of Timbers," by G. A. JULIUS, B.Sc., M.E., would be delivered on Thursday, October 15th at 8 p.m.

2. That the Monthly Meeting of the Engineering Section would be held on Wednesday, October 21st at 8 p.m.

Eight volumes, 207 parts, 17 reports and 9 pamphlets, total 241, received as donations since the previous meeting, were laid upon the table and acknowledged.

With the consent of the President, the following announcement was made for the information of members by Mr. J. H. Maiden :—

The Australasian Association for the Advancement of Science meets in Brisbane on January 11th next. The Association comes of age next year, and the meeting will inaugurate the Jubilee year of Queensland, whose history as a separate State dates from 1859. The new President is Professor W. H. Bragg of Adelaide, while the Sectional Presidents are Professor Pollock of Sydney (Astronomy, Mathematics and Physics); Professor Easterfield of Wellington, N.Z. (Chemistry); Professor Skeats of Melbourne (Geology and Mineralogy); Mr. Charles Hedley of Sydney (Biology); Mr. A. H. S. Lucas of Sydney (Geography); Mr. Augustus G. Hamilton of Wellington, N. Z. (Ethnology and Anthropology); Mr. G. H. Knibbs of Melbourne (Social and Statistical Science); Mr. H. W. Potts of the Hawkesbury College (Agriculture); Professor R. W. Chapman of Adelaide (Engineering and Architecture); Dr. J. Mason of Wellington, N.Z. (Sanitary Science and Hygiene); Mr. Peter Board of Sydney (Mental Science and Education). The Acting Permanent Secretary, Mr. J. H. Maiden can be addressed at the office of the Association, Royal Society's House, Sydney, and will be glad to give further particulars and to enrol members for New South Wales.

THE FOLLOWING PAPER :

"On the influence of infantile mortality on birthrate," by G. H. Knibbs, F.R.S.S., F.R.A.S., Commonwealth Statistician, was, in the author's absence, read by Mr. D. Carment.

Some remarks were made by the following gentlemen :—Dr. R. Greig-Smith, Mr. F. B. Guthrie, Mr. J.H. Maiden, the President, and Dr. T. Storie Dixson.

EXHIBITS:

An Adding Machine by LAWRENCE HARGRAVE.—Most of us at some period of our lives have felt the deadly drudgery of some monotonous task; this causes the feeling that some mechanical contrivance may be devised that will relieve the strain, and is the germ of all labour-saving inventions. This implement was thought out in 1880, and the origin of the attempt to make it was *Meteorological Returns.* Four machines were made, the best was given to the late H. C. RUSSELL; they were all unreliable and examples of the futility of the conceptions of the heart and contrivances of the brain when unsupported by ready and skilful hands. Experts will notice details of construction and design that are embodied in modern patents which might be rendered void on the ground of lack of novelty.

Remarks were made by the President, Mr. MAIDEN, Mr. R. T. BAKER and Mr. CARMENT.

Mr. MAIDEN exhibted a ripe cone of *Pandanus Forsteri*, from Lord Howe Island, which had been collected by Mr. CHARLES HEDLEY on his recent visit. Mr. HEDLEY'S researches tend to prove that this is the only species growing on the island. The botany of *Pandanus* was briefly touched upon and also the use of the fruit for food. He also exhibited a series of leaves of *Quercus virginiana* (*virens*) the North American "Live Oak," cultivated in Sydney, showing the remarkable variation in shape in two generations of trees. The protean character of this species has caused some difficulty to taxonomists in times gone by.

Remarks were made by Mr. C. HEDLEY, His Honor JUDGE DOCKER, Mr. J. T. WILSHIRE and the Exhibitor.

Abstract of lecture on "Carbon Dioxide and some of its properties," by THOS. STEEL, F.L.S., delivered 17th Sept., 1908. The universal distribution of carbon dioxide in the atmosphere, the ocean, in combination in rocks such as

limestone, chalk and coral, and occluded in igneous and other rocks, was described. It was mentioned that ordinary igneous and metamorphic rocks, such as granite, schist, gneiss, basalt, etc., contain several times their own volume of gas occluded in a compressed state in minute cavities, of which a considerable percentage consists of carbon dioxide. The importance of the minute proportion of carbon dioxide present in the atmosphere was emphasized, its influence being as profound as that of water itself, because of its forming the source of supply of carbon to all plant life and thus indirectly of food for man and the entire animal kingdom. Further through its physical properties it exerts the controlling influence on climate, in acting as a blanket hindering the radiation from the earth of the heat received from the sun. A large series of fine experiments was successfully carried out, including the combustion of magnesium in carbon dioxide gas, and the production of quantities of the gas in the form of snow which was passed round on plates for the inspection of the audience, the snow being used for freezing mercury, which was shewn in solid sheets and blocks, the latter being used to drive nails into a board.

ABSTRACT OF PROCEEDINGS, NOVEMBER 4, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 4th, 1908.

W. M. Hamlet, F.I.C., F.C.S., President, in the Chair.

Twenty members were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. L. HARGRAVE and W. J. CLUNIES ROSS were appointed Scrutineers, and Mr. D. CARMENT deputed to preside at the Ballot Box.

The certificates of four candidates were read for the second time.

The following gentlemen were duly elected ordinary members of the Society:—

ABBOTT, GEORGE HENRY, B.A., M.B., Ch. M., 'Kylemore,' 181 Stanmore Road, Petersham.

ESDAILE, EDWARD WILLIAM, Optician, 54 Hunter-st.

SENDEY, HENRY FRANKLIN, Manager of the Union Bank of Australia, Ltd., Sydney, Union Club.

WEATHERBURN, CHARLES ERNEST, M.A., B.Sc. Sydney, B.A. Cantab., 11 Myrtle-street.

The President made the following announcements:—

1. That the Sixth Popular Science Lecture of the Session on "John Dalton and One Hundred Years of the Atomic Theory," by F. B. GUTHRIE, F.I.C., F.C.S., would be deliverd on Thursday, November 19th, at 8 p.m.

2. That the Monthly Meeting of the Engineering Section would be held on Wednesday, November 18th at 8 p.m.

3. That the Council had decided that the Society's Journal, beginning with Vol. XLIII, be published four times a year. For the convenience of those members who desire it, the annual volume will be supplied to them as heretofore, instead of as in parts.

Twenty-three volumes, 196 parts, 16 reports, 6 pamphlets and 11 maps, total 252, received as donations since the previous meeting, were laid upon the table and acknowledged.

THE FOLLOWING PAPER WAS READ:

"Note on Pucherite from West Australia" by E. GRIFFITHS, Caird Scholar, University of Sydney. (Communicated by J. A. SCHOFIELD, Acting Professor of Chemistry, University of Sydney).

The subject of this note was contained in a few grams of concentrates from Niagara, W.A., forwarded by Mr. C. F. de J. Grut, M.A., B.E., of Kalgoorlie. It gave on analysis the following result:—Bi_2O_3 73·77; V_2O_5 25·31; Fe_2O_3 0·36; P_2O_5 trace; residue (insol. in HCl.) 0·81. The physical properties and composition of the mineral agree with those recorded in Dana's "System of Mineralogy" for the mineral Pucherite. This is believed to be the first recorded occurrence of Pucherite in Australia.

Remarks were made by Mr. W. J. Clunies Ross and the President.

EXHIBITS.

Mr. Maiden brought under notice of members the poisoning of human beings by a climbing plant known as *Rhus radicans* or "Poison Ivy," from North America, and occasionally found in gardens in New South Wales. It is a really dangerous plant causing acute skin irritation, and a perfectly harmless plant, *Ampelopsis Veitchii*, is often mistaken for it. He showed how the two plants may be readily distinguished. "Poison Ivy" is far too poisonous a plant to be permitted in gardens, especially as it is not necessary to actually touch it to be affected by it. He also exhibited a plant of the beautiful *Primula obconica*, and showed a photograph to illustrate the very serious skin irritation induced in some persons who handle it. He explained that the irritating principle in the case of the *Primula* is the glandular hairs; in the case of the *Rhus*, known also as Poison Ivy, it is a peculiar oil.

A discussion ensued in which the following gentlemen took part, viz.:—The President, Messrs. L. Hargrave, W. J. Clunies Ross, Dr. Spencer, Messrs. J. A. Schofield, L. Whitfeld, H. G. Smith, and A. Duckworth. Mr. J. H. Maiden replied and promised to bring forward the matter

of some other poisonous garden plants on some future occasion.

His Honor Judge DOCKER exhibited stereoscopic views of *Pandanus Forsteri*, the "Screw Pine," and *Ficus columnaris*, the "Lord Howe Banyan Tree," taken by him at Lord Howe Island.

Dr. WALTER SPENCER exhibited modern medical instruments of precision, and demonstrated two examples in common use.

Mr. A. DUCKWORTH exhibited photographs from Yass, showing Devonian fossils:—*Spirifera*, *Chonetes*, and *Leptaena*.

ABSTRACT OF PROCEEDINGS, DECEMBER 2, 1908.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 2nd, 1908.

W. M. HAMLET, F.I.C., F.C.S., President, in the Chair.

Forty-seven members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

One new member enrolled his name and was formally introduced.

Mr. W. PERCY MINELL and Mr. WILLIAM WELCH were appointed Auditors for the current year.

Ten volumes, 118 parts, 8 reports, 8 pamphlets and 4 engravings, total 148, received as donations since the

previous meeting, were laid upon the table and acknowledged.

The President reminded members present of the meeting of the Australasian Association for the Advancement of Science which takes place in Brisbane, beginning January 11th next.

Mr. LAW. HARGRAVE exhibited a series of lantern slides (74 in number) illustrating the "Evolution of the Flying Machine," viz.:—

1. Two wave moved objects. Two trochoided plane propelled boats. Wave propelling. Propeller waving. Converse propositions.

2. Two boats connected by guide, crank and connecting rod, trochoiding one another.

3. Anemometer or wind mill. The wind acting on planes fixed at right angles to connecting rods, rotate the crank shaft. This shows the soul of natural motion. The square moving in a circle guided by a straight line.

4. A spiral wire rotated between guides, trochoids the sections of artificial fishes.

5. A spiral wire simulates centipede and leech motion.

6. A spiral wire simulating 6 footed progression. Automatic horizontal rudder for aeroplanes.

7. The handle is turned, the return cranks at the centre trochoid the sections of the snake and it runs round the track. The snake and its vertical shaft is replaced by the other shaft seen to the left, the two connecting rods trochoid the single wheel, which then runs round the track.

8. A few small flying machines.

9. An excellent model, about the best that can be done with clock work. Note the weakness of the spring and small pinion.

10. India rubber driven flying machine.

11. Another, the head surface has disappeared.

12. Another; an attempt to make the body plane more stable.

13. Another; the portion of a bat's wing near the body is only aeroplane, the wing tip only propels.

14. Another on the same principle.

15. A very good 48 band india rubber driven flying machine. By an unfortunate chance this machine is perfectly balanced and flies quite straight; this led to many more flat machines being made before the inherent instability of a single plane was recognised.

16. The same, showing arrangement of purchase and winder.

17. Trochoided wing with very short connecting rod. Vessel with interchangeable screw and twin trochoided planes.

18. Large machine to see what effective push I could exert. The seat is the bar under the two foot rule; the stretcher for the feet is to the left of the picture; the hands grasp the handles showing just above the detached wing standing against the sheet. The handles are pulled over the top centre and pushed at the bottom centre. The dynagraph was attached to one of the parallels at the wing roots.

19. First compressed air engine. Richard's indicator (home made). Two sorts of reducing valve. This engine always stuck on the centre till the india rubber band was attached as shown. Enlarged view of valve setting, to the right.

20. Arrangement of gear to test the push of engine with three cylinders revolving on a fixed crank shaft. Air pump and receiver. Clock for driving the drum. Seconds marker. Fan to steady the drum. Bending stick to push against. Calibrating gear.

21. Bow and stern screw dihedral-angle machines.

22. Forty-eight band stern screw machine.

23. Attempt at a naphtha engine machine.

24. Shows the figure of eight described by the trochoided plane

25. Three cylinder engine revolving on fixed crank shaft.

26. Compressed air flying machine, showing the abolition of the crank and connecting rod. Cord (hanging down) was put round the left wrist and withdrew the wire that allowed the spring to open the stop valve when the machine was let go. Sand glass hanging to right wrist for taking time of flight. See the lead on the end of the breaking stick forward showing that nearly all the dihedral surface aft was merely guiding surface and not lifting surface. Two air pumps.

27. A larger compressed air flying machine. See reducing valve. Wing stroke counter. Spring valve gear. Indicator. Cooling tank for air pump.

28. Compressed air bow screw machine. Fixed cylinders, Reducing valve, revolution counter. Counterpoise to the left of the picture on the body plane to counteract torque of screw. Splices where sticks have been broken.

29. An excellent compressed air flying machine. Given to the Field Columbian Exhibition, Chicago, and now in the Smithsonian Institution, Washington.

30. Wave propelled vessel, $12\frac{1}{2}$ lbs. weight. Has been improved till it now goes $\frac{3}{4}$ of a mile per hour against the wind. It will continue going till it is worn out. The propeller is forward to keep her head to wind. Various experimental propellers to clamp on to the bow. The clamp is to enable the propellers to be tried at different depths.

31. A duplicate of the engine sent to America, shows spring valve gear worked by one of the cross-head pins. Wing stroke counter.

32. Steam engine that flaps wings of the same length and area as those shown in the photograph No. 29, making the same number of flaps per minute. See the abolition of spring valve gear. Wing stroke counter. Feed pump ram a continuation of piston rod. Flash boiler. Methylated spirit fuel and burner. If this engine was loaded up with water and spirit till it was the same weight

as the compressed air machines that have the same sized wings, it has a possible range of 1,640 yards.

33. Another larger steam engine and wings.

34. Some steam jet motors.

35. The evolution of the cellular kite. *A* is the first one made, it is constructed of drawing paper. *B* is aluminium.

36. More evolution.

38. The four kites I managed to lift myself with. James Swaine who helped me. The reel and line. The bags (filled with sand on the beach). The spring balance to read the pull when Swaine had let out all the line. The anemometer to read the wind velocity. The fishing line to plumb the vertical height. The slung seat (better than any basket). The barrow to convey the gear down to the beach at Stanwell Park.

39. Small Laval turbine on a screw. Donkey pump to test evaporative power of boiler shown in photograph 40.

40. Steam engine. Flash boiler. Balanced wings. Apertures in wings to give more leading edge to wing surface. Kerosene fuel.

41, 42, 43, 44, 45. Method of trying various objects in the wind without having them broken every time.

46. Two more soaring objects.

47, 48. Steam engine. Two large diameter short stroke cylinders revolving with the screw on a fixed crank shaft. Flash boiler. Kerosene fuel. Fuel in centre upright of the frame; water in the rest of it.

49, 50, 51. More objects showing that it is possible to soar in horizontal wind.

52, 53, 54, 55, 56, 57. Other objects that further strengthened the previous opinion, but made it obvious that nothing definite could be found till they were tried as accessories to and economisers of power on a propelled aeroplane.

58, 59. An attempt at a four cylinder, Otto cycle, one crank motor.

60, 61, 62, 63, 64. Engine and floats of aeroplane machine to run on and rise from the water.

65, 66. Two views of twin double acting cylinders to flap eight wings, water cooled pistons, explosion to open and keep open the exhaust of the previously exploded charge.

67. Four decked model, compressed air driven. Three cylinder engine. Two equal screws driven in opposite directions by a pair of plain gear wheels.

68. One celled kite.

69. Two celled kite.

70. Four celled kite, equal lifting surface, more luff, and less weight than photograph 69.

71. Eighty foot two celled kite.

72. Eighty foot three celled kite, equal lifting surface, more luff, and less weight than photograph 71.

73, 74. Two views of four winged balanced motor, one cylinder no fly wheel, one tiller for universal steering on three celled aeroplane flying machine.

A summary of these lantern slides may be put in this form:—The flying machine and the wave propelled vessel each consist of two parts, viz., the float and the propeller; each of these is capable of infinite variation. The addition of more parts tends to defeat the object in view. The object in view is knowledge. Knowledge of our neighbours and surroundings to dispel the dark clouds of prejudice and oppression.

THE FOLLOWING PAPERS WERE READ:

1. "Diagram shewing the Rainfall of Australia," by JOHN BARLING.

Remarks were made by Messrs. T. W. KEELE, W. FREEMAN, J. BROOKS, and the President.

2. "Revision of the Australian Orectolobidæ," by J. DOUGLAS OGILBY and ALLAN R. McCULLOCH. (Communicated by C. HEDLEY, F.L.S.)

3. "Some Geological Notes on the Country behind Jervis Bay," by H. I. JENSEN, D.Sc.

4. "Vocabulary of the Ngarrugu Tribe, N. S. Wales," by R. H. MATHEWS, L.S.

5. "The Sedimentary Rocks of the Lower Shoalhaven River," by CHAS. F. LASERON. (Communicated by R. T. BAKER, F.L.S.)

Some remarks were made by Mr. R. T. BAKER.

6. "The Discontinuity of Potential at the Surface of Glowing Carbon," by J. A. POLLOCK, A. B. B. RANCLAUD, and E. P. NORMAN.

Abstract of lecture on "John Dalton and One Hundred Years of the Atomic Theory." (Illustrated by diagrams and models) by F. B. GUTHRIE, F.I.C., F.C.S., delivered 19th November, 1908. The lecturer after shortly reviewing Dalton's life, discussed the position of the Atomic Theory in the development of the science. The history of chemistry since Dalton, has been the development, extension and modification of the theory. Previous conceptions of the atomic structure of the Greek were then discussed, notably those which we owe to the Greeks and Lucretius, and it was shown that though it is customary to regard Dalton's theory as a development of the Greek, Dalton's conception of the atoms differed fundamentally from theirs. As first enunciated the law explained satisfactorily certain phenomena then for the first time noticed, but was not free from objection owing to confusion arising between the conceptions of atoms and of compound atoms or molecules, and owing also to an arbitrary assumption on Dalton's part as to the proportions in which the elements combine, as well as to the difficulty in correctly determining the atomic weights. These difficulties were got over largely by the acceptance of the important law known as Avogadro's law and the discovery of relationships between the atomic weights and the

physical properties of the elements which enabled the atomic weights to be verified with considerable accuracy. It was soon found that a very profound and highly significant relationship existed between the atomic weights of the elements and their general properties. This was first observed by Newlands the English chemist, but developed later by Mendeleef into the Periodic law. This highly important generalization, based as it is on the Atomic Theory, is one of the most important achievements of this theory. In other directions the Atomic Theory has developed in ways equally important and unforeseen. By its means chemists have been able to learn something of the constitution of the most complex forms of matter. The doctrine of valency introduced by Frankland is a direct corollary of the atomic theory. The modern development of the theory of valency has led us to the most ingenious and beautiful explanations of the internal groupings of the atoms in chemical substances, and has been especially prolific in the discovery and synthesis of new substances in the Benzene group, notably the dyes and other remarkable substances known as the coal tar derivatives. It has also served to explain the remarkable optical behaviour of substances otherwise identical. At the present time we are undergoing a change in our conception of the nature of the atom. Research into the electrolysis of solutions, the ionization of gases and radio-activity have familiarized us with the idea that the atom is not to be regarded as indivisible, but as composed of yet smaller particles—electrons—the escape of which from the atom give rise to the phenomena of radio-activity. All these manifestations can only be satisfactorily explained on the assumption that what we observe is the disintegration of the atom, and that the energy is derived from the internal energy, a view which brings us to the new conception that the atomic weight is a

function of the internal energy of the atom. We are also familiarizing ourselves with the idea that it is quite possible that the elements are mutually convertible. We have become familiar with the notion that the so-called Radium emanation passes over into Helium, and in recent papers by Ramsay and Cameron these authors consider that the effect of the action of emanation upon water and copper sulphate is to produce the gases Neon and perhaps Argon, whilst in the case of the action on copper sulphate the copper would appear to be degraded into lithium and sodium. In the case of the formation of Neon the authors consider it to be indisputably proved. In the other cases they are less certain. These modifications must not be regarded as upsetting or supplanting the atomic theory, but merely as rendering necessary some modification of our present conceptions of the atom: notably its invariability and indivisibility.

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(The Names of the Donors are in *Italics*)

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PROCEEDINGS

OF THE

ENGINEERING SECTION.

PROCEEDINGS OF THE ENGINEERING SECTION.

(IN ABSTRACT.)

GENERAL Meeting of the Engineering Section held on Wednesday, 15th April, 1908.

Mr. T. W. KEELE in the Chair.

Nine members were present.

The minutes of previous meeting were read and confirmed.

The Chairman announced that as no nominations had been received in addition to those proposed by the outgoing committee, he would declare the following officers and members of committee duly elected for the current year:—

Chairman : G. R. COWDERY, Assoc. M. Inst. C.E.

Hon. Secretary: W. E. COOK, M.E., M. Inst. C.E.

Committee : PERCY ALLAN, M. Inst. C.E., H. H. DARE, M.E., Assoc. M. Inst. C.E., J. FRASER, M. Inst. C.E., F. M. GUMMOW, M.C.E., R. T. McKAY, L.S., Assoc. M. Inst. C.E., E. KILBURN SCOTT, M. Inst. E.E., NORMAN SELFE, M.Inst.C.E., M.Inst.Mech.E., J. M. SMAIL, M. Inst. C.E.

Past Chairmen, *ex officio* Members of Committee for three years : S. H. BARRACLOUGH, Assoc. M. Inst. C.E., J. HAYDON CARDEW, M. Inst. C.E., T. W. KEELE, M. Inst. C.E.

The Chairman announced that he would deliver his address at the next meeting in May.

The Chairman informed the meeting that Mr. J. I. HAYCROFT an old and prominent member of the Society and an active worker as committee man had recently died.

The Hon. Secretary was instructed to send a letter of condolence to the widow.

Annual General Meeting, Wednesday, May 25th 1908.

Mr. T. W. KEELE in the Chair.

Thirty-six members and visitors were present.

Minutes of previous meeting were read and confirmed.

The retiring Chairman reviewed the work of the past Session and referred to the loss to the Society by the death of H. A. LENEHAN, J. I. HAYCROFT, and W. A. SMITH.

The retiring Chairman then gave his address entitled, " The Water Supply of Sydney, Past, Present, and Future," illustrated by lantern slides. At the conclusion of his address Mr. KEELE installed Mr. G. R. COWDERY the newly elected Chairman.

A vote of thanks was passed to the retiring Chairman.

The retiring Chairman having stated that he would be pleased to have his address discussed it was decided to discuss it at the next meeting.

Mr. COWDERY briefly returned thanks for the honour conferred upon him.

General Monthly Meeting, 17th June, 1908.

Mr. G. R. COWDERY in the Chair.

Twenty-five members and visitors were present.

The minutes of the previous meeting were read and confirmed.

At the request of several members Mr. KEELE showed some of the lantern slides illustrating his address on "The Water Supply of Sydney, Past, Present, and Future."

The discussion of the address then followed, in which the following gentlemen took part Messrs. SELFE, CARDEW, DEANE, HOUGHTON, and Dr. STOKES.

Owing to the late hour it was decided to adjourn the discussion until next meeting.

General Monthly Meeting, 15th July, 1908.

Mr. G. R. Cowdery in the Chair.

Thirteen members and visitors were present.

The minutes of the previous meeting were read and confirmed.

The adjourned discussion on retiring Chairman's address "The Water Supply of Sydney, Past, Present, and Future'" then took place. The Hon. Secretary read a written communication, 'Notes on Mr. Keele's address by Professor Kernot, Melbourne University.' Messrs. Smail and Cardew took part in the discussion. The discussion was again adjourned.

The Chairman announced that at next meeting Mr. E. K. Scott would read a paper entitled "Hydro Electric Installations," illustrated by lantern slides.

The General Monthly Meeting in August was not held owing to the visit of the American Fleet to Sydney.

General Monthly Meeting, Wednesday, 16th September, 1908

Mr. G. R. Cowdery in the Chair.

Twelve members and visitors were present.

The minutes of the previous meeting were read and confirmed.

The discussion of retiring Chairman's address was continued by Mr. R. T. McKay.

Mr. Keele then replied to the remarks of the various speakers on the three evenings over which the discussion had extended. He suggested that the Board of Water Supply and Sewerage should erect a tablet to perpetuate the memory of the late Mr. E. O. Moriarty, who had done so much for the Sydney Water Supply.

Mr. E. K. SCOTT read a paper entitled "Hydro Electric Installations," illustrated by lantern slides.

A vote of thanks was given to the writer.

Owing to the lateness of the hour it was decided to adjourn the discussion till next meeting.

General Monthly Meeting, Wednesday, 28th October, 1908.

Mr. G. R. COWDERY in the Chair.

Fifteen members and visitors were present.

Minutes of previous meeting were read and confirmed.

The adjourned discussion on Mr. E. K. SCOTT'S paper, "Hydro Electric Installations," then followed. At the request of the Chairman, Mr. E. K. SCOTT rapidly shewed a number of the lantern slides again for the benefit of several members who were not present at previous meeting.

The following gentlemen took part in the discussion Messrs. SELFE, CARDEW, SHIRRA, CORIN, and HOUGHTON.

Mr. SCOTT replied to the remarks of the various speakers.

A vote of thanks to Mr. SCOTT for his paper was passed.

The Chairman announced that no other meeting would be held this Session.

CHAIRMAN'S ADDRESS.

By T. W. KEELE, M. Inst. C.E.

[With Plates I. – III.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, May 20, 1908.*]

The Water Supply of Sydney, Past, Present, and Future.

In considering the question of a suitable subject for an address to the members of this Section, it has occurred to me that I could not do better than describe, in a general way, the water supply of Sydney, it being a subject to which I have given a considerable amount of attention, and one which will no doubt afford ample scope for discussion, if members think it desirable to enter upon it when I have finished what I have to say on the question.

No paper on this subject would be complete without a description of the manner in which the first settlers provided themselves with this necessary commodity, and in doing this, I shall quote largely from a most interesting paper by the late Professor Smith, read before the Royal Society on 14th October, 1868, to which members are referred for more complete information. Professor Smith went to an immense amount of trouble in searching old records, to enable him to prepare his paper, and as the volume in which it was published is now out of print, the information he collected 40 years ago, will, I am sure, be interesting to those who are studying the question at the present time.

The Tank Stream 1783 to 1830.—He states that the first fleet which arrived in Botany Bay on 18th, 19th, and 20th January, 1788, being disappointed with the capabilities of that locality for the founding of a settlement, was brought round to Port Jackson, and the whole of the people, num-

bering 1,030 souls, were landed by the 6th February at Sydney Cove, where, on the banks of the clear running stream, the tents and huts of the infant settlement were erected.

The area drained by this stream was not more than 178 acres, which, although small, was well fitted for the retention of water, there being a spongy swamp at the head of it, extending from where King Street is now situated, back toward Park Street, and laterally between George and Castlereagh Streets.

With so considerable a number of people depending on this stream, it was not long before the supply of water became a source of anxiety, and before the settlement was in its second year, it fell into great straits for want of water, owing to an intense drought in 1789. Wells were sunk, and the rivulets falling into other parts of the harbour, such as the Blackwattle Swamp, were laid under contribution, but for a number of years the Tank Stream, as it was called, appears to have been the main dependence, and strenuous efforts were made from time to time to husband the supply, and preserve its purity.

About the year 1802, three tanks were hewn out of the rock close to where Hunter and Pitt Streets intersect, and these were fenced round, to prevent pollution. These tanks appear to have served their purpose, together with supplies drawn from Blackwattle Swamp, and other streams up to the year 1830, when water from Busby's Bore first became available.

Busby's Bore, 1830 to 1858.—This source of supply is extremely interesting, and is thus referred to by Professor Smith:—

"In 1824, Mr. John Busby had arrived in the Colony, with the appointment of Mineral Surveyor to the Government, and his labours were soon turned to a search for water by Sir Thomas

Brisbane. After examining several localities near Sydney, he ultimately reported in 1826 in favour of the Lachlan Swamp, lying to the south-eastward of Sydney, in the hollow between Paddington and Randwick. Mr. Busby's plan was adopted, and the work of driving a tunnel from Hyde Park to the swamp was commenced in September 1827. From the unmanageable and unskilful character of the labourers employed, (convicts) and from unforeseen difficulties in the strata that had to be gone through, the undertaking was much more tedious and difficult than had been anticipated, and it was not until June 1837, that it was brought to a successful termination. The tunnel however, began to supply Sydney with water as early as 1830, by virtue of drainage from the surrounding rocks. The whole length of the tunnel is 12,000 feet, upwards of 2¼ miles, with an average width of four feet, and height of 5 feet. Twenty-eight vertical shafts were sunk from the surface, varying in depth from 20 to 80 feet; the whole mass of excavation amounted to 255,930 cubic feet, fully nine-tenths being through solid rock; and the total cost was £24,000. The catchment basin of the Lachlan Swamp is about two square miles; but probably only about half that area actually drains into the tunnel, and as no provision was made for retaining storm waters at the swamp, a great proportion of the rainfall ran down to Botany Bay. The tunnel remains in good order to the present day, (1868), and is used to supply the lower parts of Woolloomooloo, and a portion of the city along Darling Harbour, between Bathurst Street and Erskine Street. The termination in Hyde Park is about 104 feet above high water mark. The daily delivery varies much with the state of the weather, but it may be taken at somewhere between 300,000 and 400,000 gallons, which at the time the tunnel was opened, was a fair supply for the population of 20,000 persons that then existed in Sydney. This quantity represents less than one-fifth of the annual rainfall on the area draining into the tunnel. An important feature of the original scheme was to have a reservoir excavated in Hyde Park, capable of holding 15 million gallons, but this unfortunately was never carried out."

As no further improvement to the water supply appears to have been carried out until the year 1854, when the population of the city depending upon it had amounted to about 80,000, it will be interesting now to refer to a diagram (1) of the rainfall at Sydney, which I have prepared for the purpose of illustrating the rise and fall of the rain with reference to the mean rainfall. Unfortunately the record does not extend further back than 1832 ; but it shows very clearly by the help of the residual mass curve, the accumulated gain or loss of rain above or below the mean, and as this curve has been proved elsewhere to be in general agreement with the fluctuating level of the ground water, it illustrates in the best possible way the periods of dry and wet years, and their cumulative effect upon the ground water, upon which the flow of the streams so much depends in the absence of rain.

Professor Smith refers to heavy rains having fallen in 1811 after a long drought, which continued, with the exception of 1814-15, for a number of years, floods being so frequent and so destructive, that fears were entertained that the cultivation of the alluvial flats of the Hawkesbury, on which Sydney then greatly depended, would have to be given up. He goes on to say that in 1820 there were floods, which probably marked the end of the wet season, for he quotes from the *Gazette* of October 28th, 1820, as follows :—

"The present dry season of the year being indicative of an approaching long drought, etc., etc."

Reference is again made to drought in 1823-4, and again in 1826, when he quotes Captain Sturt as follows :—

"This year commenced one of those fearful droughts to which we have reason to believe the climate of New South Wales is periodically subject. It continued the two following years with unabated severity."

I have dwelt in detail on this subject, for the purpose of showing to what straits the people, then numbering about 13,000, must have been in while depending on the Tank Stream and Blackwattle Swamp, and probably Farm Cove streams, and how anxiously they must have been looking forward to the completion of Busby's Bore.

The diagram shows that the ground water must have been very low in 1830, (after the long drought, extending probably with occasional relief from short spells of rain above the average, from the year 1820), when the tunnel, partially completed, began to supply water from the drainage coming from the surrounding rocks through which it was pierced.

In 1835 the colonists residing in Sydney must have been in a very bad way, as the diagram shows the curve to be drawn down to a very low point. In 1836 relief came by a rainfall for the year 22·22 inches above the mean, which no doubt, set the Tank Stream running again, and augmented the supply from the uncompleted tunnel. In June 1837 the tunnel was finished, thus tapping the Lachlan Swamps, and providing what seemed an assured supply of pure water.

Soon after the opening of the tunnel, Professor Smith says:—

"Then commenced a calamitous drought, the severest and most general of which we have any record. Contemporary accounts represent the Colony as reduced to great straits through the destruction of vegetation and live stock. One writer says, 'No words can express the miserable appearance of the country. There is neither food for man or beast. God knows what will become of us all, if some change does not take place very soon."

Professor Smith regrets that he cannot find any record of the rainfall at Sydney, or at any other part of the colony for the years 1838-9, during which the drought prevailed;

but in Captain Stokes' "Voyage of the Beagle," there is a distinct assertion of the total absence of rain for a period of perhaps eight or nine months. He says, "For some time previous to our former departure from Sydney, during the whole of our absence, and for several months subsequent to our return, not a drop of rain fell." Now the *Beagle* left Sydney on 11th November, 1838, and returned 10th March, 1839. The close of the above period must have been May 29, for he finds this record in the *Herald* of May 31: "It rained very hard in Sydney on Wednesday night, blowing a perfect gale of wind." It is usually stated, however, that the drought did not break up until October.

It will be seen in the diagram (1), that there is a gap in the record, no rainfall being given for 1839; but from the above account, it is probable that the curve would have been drawn down as low, if not lower, than in 1835.

"There is evidence," Professor Smith goes on to say, "that during this distressing period, the Tunnel never altogether stopped running, although the supply became scanty."

Even so early in the drought as 5th November 1838, he finds this statement in the *Herald*:—

"Great distress exists in Sydney especially at the northern end, in consequence of the scarcity of water. The stream from the pipes on the racecourse is very small, so small that the men cannot fill the watercarts without waiting four or five hours for a turn. Threepence per bucket is the price now asked, a heavy tax upon poor people. I have been assured by a gentleman who lived in the northern part of Sydney, at that time, that he had to pay as much as sixpence per bucket."

The increasing deficiency of water led the authorities to look about for some fresh source, and the dam at Cook's River was begun about that time, with a view of increasing the supply. Speaking of the disposal of some prisoners, the *Herald* of 13th May says,

"The men are to serve the probationary period at Cook's River stockade, where they will be employed at the dam, which is to supply Sydney with water."

This dam when constructed was not found to exclude the salt water, and no further steps were taken in that direction. Continuing, Professor Smith states that, "the great drought of 38-39 was succeeded by nine years of abundant rain and frequent floods." On reference to the diagram it will be seen that for six years the rainfall was all above the mean, the average being 61·07 inches, which must have raised the level of the ground water, so that although the two following years were a little below the mean, the streams were probably not much affected, and the next year, viz. 1848, the rainfall amounted to over 59 inches, which brought the level up again to what it stood at in 1845, consequently they were not far out in reckoning the wet period to be of 9 years' duration. Thereafter, to 1854, a very serious drought must have been experienced, every year being below the mean, the average being only 36·78 inches.

"During the wet period, the tunnel seems to have kept Sydney pretty well supplied," says Professor Smith, "at least I find no record of scarcity, nor of schemes for increasing the supply; but in the year 1849 there occurred a drought of considerable severity, and the water question again started into prominence. In that year the rainfall as measured at South Head was only 21½ inches, (the lowest ever recorded at Sydney), while the population of Sydney had increased to about 40,000, or double what it was when the Lachlan Swamp was first tapped. I find that in April 1849 the Water Committee of the City Council directed the City Surveyor (Mr. F. Clarke) to examine the Swamp and Tunnel, with the view of improving the supply. The surveyor sent in his report in December, recommending that a dam should be carried across the lower part of the swamp, so as to form a lake of 40 or 50 acres, with an average depth of 4 feet, and to construct a

reservoir of masonry near the east end of the tunnel, 25 feet higher than the lake, and capable of holding 10 million gallons; this reservoir to be filled by pumping from the lake. A commencement of the proposed dam was made, but it was soon abandoned, and the remaining part of the recommendation was neglected.

"The next movement was the appointmemt, in January 1850, of a special committee of the City Council, to inquire into and report on the best means of procuring a permanent supply of water to the city of Sydney. This committee did not close their labours until February 1852, when they sent in a large and carefully compiled report, the result evidently of a laborious investigation of the whole question.

This report gives the population of Sydney at nearly 50,000, (the census of 1851 gave about 45,000, and there was a large accession about that time in consequence of the discovery of gold), the number of houses 8,482, of which only 2,300 were supplied with water: the assessed annual value of city property £232,678, and the gross water revenue £3,493. In discussing the mode of improving the water supply temporarily, the report condemns the embankment proposed by Mr. F. Clarke, and recommends instead, that a trench should be dug at the lower part of Lachlan Swamp, and the water pumped from thence to a reservoir at Paddington, 207 feet above sea level.

"With regard to a permanent supply, the relative merits of George's River, Cook's River, the Nepean, and Lord's Dam, at the mouth of the stream draining the Lachlan and other swamps, are discussed, and the preference is given to the last named source.

"It is recommended, however, that this supply be supplemented by the drainage eastward as far as Bunnerong, and westwards to Shea's Creek, and Cook's River.

"Before any action could be taken on this report—before, indeed, it was handed in—the Governor, Sir Charles Fitz Roy, appointed in 1852, a board of five gentlemen to examine the

question afresh. Their report (remarkable chiefly for its length) was laid before the Legislature in August of the same year.

"They did not take up, as the City Committee had done, the merits of the different schemes, but restricted themselves to an examination of the Botany Swamps, as being undoubtedly the best available source; and they recommended that the stream flowing down from Lachlan Swamp should be intercepted at a point about a mile and a half above Lord's Dam, and the water pumped up to a reservoir at Paddington, capable of holding 12 million gallons. They held that a supply of about 20 gallons per head would be sufficient, while the City Committee assumed that 40 gallons ought to be provided.

Pumping from Botany, 1858 to 1889.—"On the 1st of January, 1854, the management of the city passed from the hands of an elective Council to three Commissioners appointed by the Governor, and this arrangement lasted for three years. The Commissioners took up zealously the question of water supply, and passed speedily from inquiry to action. In 1854 (a very dry year in Sydney) they erected a small pumping engine at the lower part of the Lachlan Swamp, for the purpose of throwing more water into the Tunnel, by this adding 150,000 gallons to the daily delivery, and at the same time, they entered on the necessary preliminaries for obtaining a new and more abundant supply from the lower end of the stream at Lord's Dam. It was not, however, until November 1858, that the pumping engines at Botany were set to work, and that system of supply commenced which we enjoy at the present time (October, 1868). Since then we have experienced some very dry seasons, and occasionally the pumps have not been fully served by the stream; but the Municipal Council has always been on the alert, and on the whole Sydney has been kept fairly supplied with water. Every dry season, however, has stimulated a fresh inquiry. In 1862 only 24 inches of rain fell, and a Select Committee of the Legislative Assembly was appointed to investigate the state of the Water Reserve. 1865-6 were rather dry (each year giving about 36

inches of rain) and the latter part of 1867 very dry, with only 9¼ inches in six months, which had the effect of starting inquiry once more. In September 1867, a Royal Commission was issued, appointing five gentlemen to take up the search for a more abundant and trustworthy supply of water."

On reference to the diagram, it will be seen that the ground water, which had been largely drawn upon during the period from 1848 to 1854, must have been at a very low level at the latter date, and the city was probably in a very bad way for want of water, the population being 40,000 in 1849, and over 50,000 in 1854, would hardly appreciate the small addition of 150,000 gallons per day, which was pumped up into the Tunnel. So that when the water works were completed at Botany, and the pumps were started at the latter part of 1858, the people were probably saved from absolute water famine, for the diagram shows that the drought extended for another year, 1859, which marks the termination of a dry period, second only to that of 1839, when probably all the sources of supply, upon which the city depended, would have been exhausted.

At the time the Royal Commission was appointed, in September, 1867, the state of the water supply was thus described by Professor Smith:—

"At Lord's Dam, the drainage of nearly seven square miles falls into Botany Bay. The pumping establishment then comprised three steam engines of 100 horse power each, two of which are generally kept going night and day. The total quantity pumped in 1866 was 956 million gallons. A 30 inch main about four miles long leads to two reservoirs, one at Crown Street, 139 feet above the sea, holding 3½ million gallons, and the other at Paddington, 214 feet above the sea, and holding 1½ million gallons. As these reservoirs contain less than two days' supply, and as the great defect of the system is the want of storage for

water in wet seasons, efforts have recently been made to form dams on the Botany stream, so as to preserve a surplus in wet seasons to make up the deficiency of dry. Six of these dams were constructed, but three were partially destroyed by heavy floods in the early part of this year. Had they remained efficient, they would have provided (along with the two ponds near the engine house) storage capacity for 250 million gallons. The total cost of the works for supplying Sydney (including the two Service Reservoirs, but excluding the cost of distribution) has been nearly £150,000. The cost of pumping up the water last year (1866) was £4,700, and if to this we add the interest on the cost of plant, we find that the total cost of supplying Sydney (still excluding the distribution) to be about £33 per day, or less than a farthing per head of the population supplied. The water is distributed through the whole of Sydney proper, together with the Municipalities of Glebe, Darlington, Redfern, and part of Paddington, by about 105 miles of piping.

"When the present system of supply was completed in 1858, the population of Sydney and Suburbs was about 87,000, at the present time (1867) it must be about 118,000. Of this number, about two-thirds share in the public supply of water; and adding the quantity delivered by the tunnel to that pumped from Botany, it appears that the distribution is at the rate of nearly 40 gallons per head. In a hot climate like this, there ought to be a superabundance of water, as well for public health and safety, as for personal comfort and convenience. Sydney, however, is not favorably situated for an abundant supply, and it cannot be procured without enormous outlay. The words of Sir Thomas Mitchell in his evidence before the City Committee, in 1850, are as true and forcible now as then. 'I cannot,' he said, 'but see that the weakest point in the character of this great city—for a great city it is likely to be—is the present insufficient supply of water. I should, therefore, desire a more certain source.'"

This terminates Professor Smith's most interesting historical sketch of the water supply of Sydney. I trust

I have not wearied you by quoting so fully from his paper, instead of condensing what I am sure you will all admit is an exceedingly valuable record.

Royal Commission of 1867.—The Royal Commission of 1867 consisted of the following gentlemen, viz.:—Professor J. Smith, M.D., Sydney University; Mr. E. O. Moriarty, M. Inst. C.E., Engineer-in-Chief for Harbours and Rivers; Mr. P. F. Adams, Surveyor-General; Mr. F. H. Grundy, C.E., and Mr. Thomas Woore. Mr. W. C. Bennett, M. Inst. C.E., Commissioner and Engineer for Roads and Bridges, was added to the Commission the following year.

In considering the question submitted to them, the Commissioners had to determine—

1.—The population to be supplied.

2.—The condition and prospects of the present scheme.

3.—New sources of supply.

They found that in 1826 the population was put down at 10,000, in 1836 at 20,000, so that it had doubled in the short space of ten years. In twelve or thirteen years more it had doubled again, but in consequence of the attractive force of gold, the next doubling was effected in six or seven years. After that the rate fell, and although thirteen years had elapsed since the population reached about 80,000, it had made only half as much more up to the time they were considering it, viz.:—1867. For the previous few years it had been increasing at the rate of over 4% per annum.

After careful consideration, they deemed it to be their duty to show how a population of, say a quarter of a million, could be liberally supplied, and decided upon 12 million gallons per day, being at the rate of 48 gallons per head per day, and that the scheme should be capable of expansion to at least double that amount.

Under the second head, they found that the then existing scheme from Botany could barely be made adequate to the wants of Sydney, and could not keep pace with the demands of an increasing population, that it should therefore be abandoned for another scheme, which they would hereafter describe, and that no more money should be spent in its improvement.

Under the third head, they made careful inquiry into various projects which had been brought forward from time to time, together with investigations of their own, viz.:—The Grose, Warragamba, and George's Rivers; the Upper and Lower Nepean River; Burralow and Wheeny Creeks; the Colo River and Couridjah Lagoons, and they ultimately recommended the scheme known as the Upper Nepean which they had originated.

Briefly, the general features of the scheme were, the intercepting of the drainage from 350 square miles of country lying at the head of the Nepean, Cordeaux, and Cataract Rivers, by small diversion weirs situated at the Pheasant's Nest—at the junction of the two former rivers—and at Broughton's Pass on the Cataract River, and connecting these points by a tunnel, through which the waters would pass, the combined stream at Broughton's Pass, at a level of 421 feet over sea, being conducted through another tunnel, emerging on the western slopes of the main dividing range, separating the waters of the Nepean from those of George's River. A conduit consisting principally of open canal, but tunnel through the hills, and wrought iron aqueducts across creeks and the railway, would lead the water to Prospect, over a total length of $41\frac{1}{2}$ miles from the Pheasant's Nest. At Prospect a reservoir was to be constructed, by throwing an earthern bank—$1\frac{1}{4}$ miles in length, and 80 feet at the deepest place—across a valley where the waters would be held up to a level of 195 ft.

above the sea, the total storage to be 10,635 million gallons, of which the upper 25 feet, amounting to 7,110 million gallons, would be available for distribution by gravitation. From this reservoir it was proposed to conduct the water by an open canal about $4\frac{3}{4}$ miles long, thence by an iron aqueduct about $1\frac{1}{2}$ miles in length, to a small reservoir capable of holding 400,000 gallons, from whence it would flow through a syphon pipe 48 inches diameter, crossing the valley of Duck Creek. From this point, the water to be conveyed through an open conduit about $1\frac{1}{4}$ miles long, to another small storage reservoir at Potts' Hill, where the water would have an elevation of 164 feet over sea level. The remaining 10 miles to Crown Street, would be covered by a 42 inch pipe, capable of delivering 12 million gallons per day. By this arrangement 84 million gallons daily could be delivered into Prospect Reservoir, and 29 million gallons to a point 14 miles from Sydney. The scheme provided for a reservoir at Petersham, to hold 800,000 gallons for the supply of that suburb. The total cost of these works was estimated at £755,029.

From the date of the report of the Commissioners being submitted to the Government in May 1869, nothing was done for several years, beyond making more complete surveys and investigations in connection with the scheme, especially with reference to the gauging of the streams upon the catchment area.

It will be seen on inspection of the diagram (1) of the Sydney rainfall, that with the exception of 1872, and 1875 and 1876, the rainfall was above the mean, right up to the year 1879. The residual mass curve shows an accumulated rise above the mean for the ten years from 1869, of 71·67 inches. This must have affected the level of the ground water. The Botany Catchment area being a vast sand bed must have received such stores of water, causing a sufficient

rise of the level of saturation, as to enable the supply to Sydney to be maintained by the pumps.

In 1872, however, there was considerable anxiety owing to the shortage of the rainfall, and again in 1875 and 1876, there was much difficulty in maintaining a sufficient supply for the citizens, for although the level of saturation in the sand was above that of the creek beds, the water did not drain out fast enough to feed the pumps.

In January 1875, the consumption of water in Sydney was 6½ million gallons per day, 5¼ millions being pumped from Botany, and 1¼ millions flowing by gravitation through Busby's Bore.

From August 1875 to April 1876, a very critical time occurred, when only 10 inches of rain fell during (about 8 months) 240 days. The supply from the Lachlan Swamp dwindled away from about a million gallons daily at the commencement, until it failed early in March; but the store in the sand enabled the pumps at Botany to still maintain a supply of from 3½ to 4 million gallons daily, right up to the end of the dry period. The population of Sydney at the time was 93,000, and in the suburbs 73,000, the total being 166,000, so that the rate per head was only 24 gallons.

The seriousness of the situation with regard to the water supply, experienced during the dry period of 1875 and 1876, caused public attention to be directed to the necessity of taking some immediate action to bring in an adequate supply. Since the Commissioners' report was received in 1869, several new proposals were formulated, notably one by Mr. James Manning, to obtain a high level gravitation supply from the Loddon and Madden Plains, supplemented by a further supply from Kangaloon and Wingecaribee. That gentleman had still a further proposal, to obtain a supply from Port Hacking, which was entirely separate

and distinct from the others. Papers on these schemes were read before the Royal Society in December 1874, and in August, September, and October 1875. It was also thought that several schemes inquired into by the Commissioners, had not received the consideration they deserved viz., the Warragamba scheme by Mr. Thomas Woore, R.N.; the Lower Nepean scheme by Mr. Macintosh, M.L.A.; two separate schemes from George's River by the Hon. Thomas Holt, M.L.C., and Mr. J. Lucas, M.L.A.

Enquiry by Mr. W. Clark, 1876.—To set the matter at rest, the Government decided to obtain, through the Agent General in England, the best expert advice obtainable, and Mr. William Clark, M. Inst. C.E., was selected, and on his arrival in the Colony on November 29, 1876, he immediately entered upon the duty of advising the Government on the subject of the water supply to the city, and made a most careful investigation of all the schemes proposed, including those already mentioned, and several submitted subsequently to his arrival, viz., a scheme to obtain a supply from Port Hacking, supplemented by an idea which suggested itself to him, (Mr. Clark) viz., to construct a low dam on the Woronora just above the influence of the tide, and thereby to force the water through a tunnel $2\frac{1}{2}$ miles in length, into the Port Hacking River; also a scheme from Erskine Valley, advocated by Drs. Fortescue and Spencer, and Mr. Grantly Fitzhardinge; a scheme to obtain water by means of tube wells sunk in the sands of the Lachlan Swamp, originated by Mr. F. Bell, City Engineer, in 1872, and brought under his notice by Mr. P. Wilshire; and a proposal by Mr. Richard Sadleir, R.N. in 1852, to obtain a supply by connecting the Nepean and George's Rivers with a tunnel three miles long near Appin.

On 15th May, 1877, Mr. Clark brought up his report recommending "with great confidence" the Upper Nepean

Scheme, for the future supply of the city, which he "considered to be much superior as a source of supply, and as a permanently secure work, and also to possess collateral capabilities of extended usefulness beyond that of supplying Sydney. Moreover, though equally cheap in supplying 12 million, when extended to 18 million gallons per day, the water will be furnished at a cheaper rate than by any of the other schemes."

The collateral advantages referred to by Mr. Clark were the utilization of the waste water from the rivers along the line of conduit for irrigation, pastoral, and manufacturing purposes. The Commissioner's scheme provided for works above Prospect Reservoir, capable of delivering 84 million gallons per day; but he thought it well worth further inquiry into the value of the surplus water before commencing the works, with a view to ascertain whether it be sufficient to warrant an increase in the sizes of the conduit and tunnels, to receive a large quantity of the water.

Prospect Scheme commenced 1880—This investigation was accordingly made, and the works were ultimately designed by Mr. Moriarty, to convey 150 million gallons per day as far as Prospect, and 50 million gallons per day for five miles beyond it. The surveys made by the Commissioners being for trial purposes only, it became necessary to re-survey the whole line, to enable the permanent staking out to be done, in order to prepare the work to be let by contract in sections, and it was not until Feb. 9th, 1880, that the first shot was fired at the Nepean Tunnel, which practically marked the commencement of the great works, which being completed, now stand as a monument to the founders, and minister to our health and comfort in the present day.

It is not my intention to go into any details in order to describe the construction of these works, and the difficulties

that were met with from time to time, although they are full of interest; but rather to sketch as concisely as the subject will permit, the leading events which many of you present are no doubt fully seized with. The years are passing swiftly away, and as no connected account has been written that I am aware of, it seems to me to be desirable that someone with a personal knowledge of all the circumstances should undertake the duty, and as I was very closely in touch with these works and those associated with them, as some of you may remember, perhaps it will not be considered out of place for me, with everything fresh in my mind, to put the leading facts on record, and I shall be glad to be corrected if any inaccuracies are noticed.

On reference to the diagram (1) once more, it will be observed that the works were commenced just when a very severe and protracted drought had set in, viz.—1880. The diagram shows that it lasted nine years, until the middle of 1889, every year being below the mean, except 1887, the average over the whole period being 40·70 inches or 7·65 inches below the mean. The residual mass curve shows the drought very clearly, the accumulated loss of rain for nine years amounting to 68·80 inches, or nearly a year and a half mean rainfall missing, and as the water from the Nepean was not turned on to Crown Street Reservoir until 20th November, 1886, and only then discharging about 3 million gallons per day, it can be well understood in what a sore strait the citizens were during the construction of the works, and what an anxious time was experienced by those responsible for the supply.

It was not long after the works were commenced that Mr. F. B. Gipps, who had been employed upon survey work in connection with them, brought forward a proposal to intercept the water at Kenny Hill, where the line of canal

crosses the road from Campbelltown to Camden, and store it in two reservoirs there, and to conduct it thence to Sydney by pipes direct, instead of by the conduit viâ Prospect as approved. Mr. Gipps' proposal being rejected by the authorities, and as the contracts for the various sections of the works had been let, within sight of the spot he proposed for his upper or service reservoir, he resigned his appointment under the Government, in order to develop his scheme, and within six weeks he read a paper before the Royal Society on 6th October, 1880, setting forth his views.

Kenny Hill Scheme Agitation for High Pressure Service.—As this proposal created a very large amount of interest at the time, and being strongly supported, not only when it was first introduced, but throughout the whole period during which the Prospect works were under construction—indeed the agitation did not cease, and the Kenny Hillites as they were termed, did not abandon all hope, until the middle of the year 1888—it will be doubtless of some interest to briefly describe its leading features. There were to be two reservoirs, the lower one called the storage reservoir, to contain 8,110 million gallons of water available by gravitation, the surface level to be 330 feet over sea, and the draw off level at 270 feet. The upper or service reservoir to impound 144 million gallons, the top water level being 372 feet over sea. The water from these reservoirs to be conducted by a double line of 36 inch cast iron pipes, through tunnels to be driven through the dividing ridge, and thence direct to Sydney, which would be capable of supplying daily, 2 millions to Waverley at 325 feet elevation, 1 million to Woollahra at 276 feet elevation, and 13 millions to Paddington at 214 feet, the estimated cost being £1,232,392.

It was claimed by Mr. Gipps that the scheme would be $12\frac{3}{4}$ miles shorter than Mr. Moriarty's, which would deliver

12 million gallons daily to Crown Street 141 feet above sea level, of which 1 million would be pumped to Paddington, and ½ million to Waverley, at an estimated cost of £1,562,268. He claimed high delivery to Waverley, Woollahra, and Paddington, with its attendant advantages of smaller mains and reticulating pipes, and fewer distributing reservoirs at North Shore and elsewhere in the suburbs, against low delivery to Crown Street, necessitating pumping stations at different smaller reservoirs, to reach the high levels of the city and suburbs, and also the use of large mains and reticulating pipes. A principal feature of his scheme was the great advantage to be derived for extinguishing fires; for the manufacturer and mechanic; for public fountains and hydraulic lifts and motors; and for flushing sewers.

On 11th January 1881, Mr. Moriarty's report was submitted to Parliament. He dealt trenchantly with the subject, showing that the upper reservoir on which Mr. Gipps relied to supply Waverley, Woollahra, Paddington, and St. Leonards, was not at sufficient elevation, and was too small, even if raised an additional ten feet—as was subsequently suggested by Mr. Gipps—to maintain the supply in dry seasons when it would be required most. He showed that the project would cost about £1,300,000 more than that of Prospect, and whenever it became necessary to expand the works to meet an increasing demand, the difference in cost between the Kenny Hill and Prospect schemes would increase in still greater ratio.

The leading peculiarity of the project was, that in a wet season at which time but little water would be required, the canal supplying the upper reservoir at Kenny Hill would be running full; but in a hot dry season when the canal would have ceased to run, or nearly so, a recourse would have to be made on the lower or storage reservoir, and the supply would then fall to about the quantity Sydney

was receiving from Botany during what may be almost called a water famine.

Mr. Moriarty's report had the effect of silencing the detractors of his scheme for the time, and the works were pushed on as rapidly as circumstances would permit, but the supporters of the Kenny Hill proposal, having modified it in order to reduce the estimate, by substituting one 44 inch cast iron pipe for the two 36 inch pipes, and dispensing with the service reservoir, sought advantage of the fact that the works were taking a longer time to complete than was anticipated, and that the cost was exceeding the original estimate—owing principally to the difficulties met with in tunnelling, and the necessity for lining those in shale throughout—and as the drought still continued, and dependence on the Botany stream was considered to be very precarious, they again strongly urged the acceptance of the Kenny Hill scheme, which they guaranteed would bring in the water in two years' less time than by the Prospect scheme, and at £200,000 less cost. A strong movement was made in March, 1882, to reopen the question, without success.

By December, 1882, work along the whole line of conduit, from Pheasant's Nest to Guilford, was being actively proceeded with, and operations in connection with the construction of Prospect Dam had commenced under contract, the time for completion being July 31st, 1887, it being considered that this important work should not be built too rapidly, as ample time should be allowed for settlement and consolidation of the bank. A line of 30 inch cast iron pipes, $1\frac{3}{4}$ miles long, was to be laid outside the Dam to connect the upper and lower canal.

During the first part of 1883 some useful rain had fallen, the gauge at Botany having registered $31\frac{1}{2}$ inches in five months, which, together with some rain that had fallen

during the latter part of 1882, was of some assistance, but did not go very far towards replenishing the sand beds at Botany, which had to withstand an exhaustive drain upon them for the previous three years, so that by January, 1884, fears were again entertained of a shortage of water, and an appeal was made by the City Engineer for economy in the use of it, as at the rate of consumption, then about 7 million gallons per day, the stock of water in the Botany dams would last only three months.

As it would be some years still before water through the permanent works could be delivered into Sydney, another movement was made by the Kenny Hill supporters, to bring in the waters as an auxiliary to the Prospect scheme, at a cost of £225,000, the scheme being modified by the exclusion of the storage reservoir, and the substitution of wrought for cast iron in the supply pipes, one only to be laid. The service reservoir to be increased in capacity to 400 million gallons, the works to be equal to a delivery of $10\frac{3}{4}$ million gallons to Paddington, or 14 millions to Crown Street in 24 hours, and to raise water from Paddington and Crown Street by Jonvals' low pressure turbines to Woollahra and Waverley. It was claimed that the scheme would provide sevenfold the delivery to Paddington, and over double the duty above it, than that estimated by Mr. Clark, and would provide a moderate high pressure throughout the city and suburbs. The scheme, however, was not entertained by the authorities, and the agitation simmered down again, the works being pushed on with all the expedition possible.

Nepean and Cataract Tunnels completed, 1885.—The Nepean tunnel was pierced through on 16th August, 1884, and the Cataract tunnel on 29th January, 1885, both tunnels being ready to deliver water about May 1885. By this time public attention—owing to the continuance of

the drought and the increasing difficulty of maintaining the supply from Botany and Busby's Bore—was directed to the absolute necessity of doing something immediately towards bringing in a supply by temporary works to augment that on which they were depending. When the Nepean scheme was projected, it was thought that the water from that source would be available about that time (1885); but contracts had to be transferred from one firm to another, and unforeseen difficulties had arisen which had necessitated grants of extension of time to different contractors. A consultation took place between the authorities of the Public Works Department and the City Council, with a view to determine whether some steps could not be taken to reduce the consumption from 25 gallons per head, which was then being delivered, to half that amount; by an effort to reduce waste, and otherwise to curtail the use of water wherever it could be done without inflicting hardship on the citizens. A scheme for temporarily bridging the creeks and railway with timber trestles to support sheet iron flumes, and laying about 12 miles of pipes, was also elaborated, and it was thought that if the Council could procure the latter, it might be possible to bring in the water in six months.

Intermittent Supply to the City.—The result of this conference was that an intermittent supply to the city was commenced, some districts in the city being absolutely shut off, and a programme was prepared which provided for all districts being similarly treated in rotation, and water was accordingly turned off every night, except in the lower part of the city. Consumers were especially enjoined to abolish the use of plunge baths, until the existing state of drought was passed. This action had an immediate effect on the water pumped from Botany, which was reduced from 5 million gallons per day to $3\frac{3}{4}$ millions; but great inconvenience and dissatisfaction were exhibited with

regard to the water supply, and the newspapers were flooded daily with schemes for augmenting the water at Botany. The City Council carried a resolution that application be made to the Government for the necessary power to bring in water from the Nepean at Penrith, to the engine pond at Botany, tenders to be invited by cable to England for 20 miles of 18 inch cast iron pipes, and local tenders to be invited for the requisite wooden flumes and cast iron pipes required at the creek crossings, and for pumping machinery required at Penrith, the whole to cost £100,000.

Hudson Brothers' Temporary Works.—The Government, however, had been considering a proposal from Messrs. Hudson Brothers, to bring in 3 million gallons per day from the Pheasant's Nest, by utilizing the existing works, connecting up the gaps, nine in number, across the various creeks, and the railway above Prospect, by timber trestles supporting 36 inch cast iron pipes to be provided by the Government; the valley, from the end of the canal near Guilford for two miles, to be spanned by wooden framework, supporting a galvanized iron trough; from thence to Pott's Hill, a distance of three miles, wrought iron pipes of 30 inches diameter to be laid excepting across the valley of Duck Creek, where the pipes would be subject to a head of about 110 feet, 36 inch cast iron pipes, to be provided by the Government would be required; from Potts' Hill to No. 4 Dam at Botany, a distance of 12 miles, to be covered by wrought iron pipes 20 inches diameter. All materials to be provided by the firm, excepting the 36 inch pipes. This enterprising firm lost no time in commencing the work, which was really of a much more formidable character than most people at the time were aware of. The creeks which had to be spanned were in out of the way places, difficult to approach, and exceedingly rugged and precipitous; the

timber trestles were over 60 feet high in some places, and the pipes which had to be hoisted and laid upon them weighed about two tons each. At Guilford, the flume two miles in length, was an imposing piece of work, the trestles and framework being of oregon and the trough of galvanized corrugated iron bent into a half circle, was for a considerable distance from 70 to 90 feet above the ground. Special machinery, at short notice, had to be provided for making the wrought iron pipes, which were in 20 feet lengths, made of sheet iron about $\frac{1}{10}$ of an inch thick, rivetted together, one end being tapered to make a telescopic joint of about 5 inches, each pipe being dipped in a composition of asphaltum and tar. At the crossing of Duck Creek, it had been arranged that the Government would supply the necessary 36 inch cast iron pipes, to cover that portion of the line where the pressure would be greatest; but as these were not forthcoming, Hudson Brothers at the last moment had to make 30 inch wrought iron pipes in substitution, and it was here that the greatest difficulty occurred in making the joints tight, which caused considerable delay in the completion of the work, and the water did not commence to flow into Botany until January 15th, 1886, or $2\frac{1}{2}$ months beyond the contract time.

Difficulty in Maintaining the Supply from Botany.—The completion of the temporary scheme gave considerable relief, as the rainfall had continued to be deficient, and the drought having lasted for six years, the greatest anxiety was experienced, the authorities being at their wits end to devise means to maintain the supply from Botany. In December 1885, in consequence of the delay in bringing in the water by the temporary scheme, extensive trenching operations were undertaken in the sand beds to augment the supply and lead it to the pumps, and the Bunnerong swamps were laid under contribution to the

extent of about 130,000 gallons per day. This, however, merely took the place of the water usually received through Busby's bore, where a serious falling off in the supply occurred owing to the drought. In order to relieve the pumps at Botany, which were now being taxed to their utmost capacity, arrangements had to be made to increase the supply through Busby's bore, by lifting the water from the lower levels of the Lachlan Swamp into the tunnel.

Shortly after the completion of Messrs. Hudson's temporary scheme, it was realized by the civic authorities, that notwithstanding the additional supply of 3 millions per day, it would have to be lifted by mechanical means for some considerable time, before the gravitation supply to Crown Street by the permanent works would be available, and it was decided to provide additional boilers and an auxiliary pump at Botany, in order to be able to raise another million gallons per day to Paddington.

Renewed Agitation for Kenny Hill Scheme.—Taking advantage of all the circumstances existing at the time the temporary water scheme was under construction, and especially of the delay in completing the permanent works and the fact that the estimate was being exceeded, the supporters of the Kenny Hill scheme commenced a very strong agitation again in August 1885. The scheme then proposed was to drop the large storage reservoir out of consideration and rely upon the upper reservoir with a dam 50 feet high, to impound 600 million gallons, and to lay a 36 inch wrought iron pipe to the Paddington reservoir, which would deliver 9 million gallons per day at a cost of £320,000. At a public meeting at the Town Hall, at which the mayor presided, the following resolutions were carried:—

"1. That the Government be petitioned to institute a searching and impartial investigation into the Prospect scheme now in progress.

2. That such investigation should extend to the proposed incorporation of the Kenny Hill high pressure scheme, as an auxiliary to the Prospect scheme.

3. That the future control of the water supply be placed in the hands of a board of works."

It was thought that as Sir John Coode was at the time in the colony reporting on the harbour works, his services might be obtained to inquire into and report on the matters in dispute concerning the water works. On October 27th, 1885, a request was made by the Government to that gentleman to undertake the duty, but he stated the question was of such magnitude and would require so much time, that on the ground of time alone, he would be obliged to decline the proposal; but suggested that a statement should be prepared by each party in this matter, and forwarded to Mr. Hawksley in London for his opinion. This, however, was not accepted by the supporters of the Kenny Hill project, who thought that the question should be submitted to three engineers instead of one. This proposal does not appear to have met with acceptance, and the matter remained in abeyance until February 1886, when advantage was taken by the Government of the presence of Sir John Fowler in Sydney, to obtain his opinion on the stability of Prospect Dam, and the works immediately connected therewith. It was thought by the Kenny Hill supporters that the occasion was opportune to get him to extend his investigation to the whole of the permanent works, and also of the proposal to incorporate the Kenny Hill scheme with them, as an auxiliary. This, however, on account of the shortness of his visit to the colony, prevented Sir John Fowler from complying with. No further action appears to have been taken, but the Kenny Hill people were by no means disheartened and simply bided their time, waiting for any chance that might present itself to renew the agitation.

Water Flowing into Crown-street Reservoir by Gravitation.—The year 1886 continued to be very dry, and in May, notwithstanding the rapid increase of population, and extensions of the reticulation which had been proceeded with in anticipation of an additional supply by the Prospect works, the total quantity of water from all sources supplied to the citizens, was only a little over 6½ million gallons per day. It can readily be understood, therefore, with what feelings of relief the announcement was received, on 20th November, 1886, that the water viâ the permanent works was turned into Crown Street reservoir, through the 48 inch and 42 inch pipes from Potts' Hill, discharging, however, only at the rate of 3 million gallons per day.

At this time the water in Prospect reservoir had not attained sufficient height to feed the canal, and the supply was therefore coming through the 30 inch pipes, which had been laid outside the dam, connecting the upper and lower canal. The amount of water available for Sydney was therefore still depending upon the daily flow of the rivers, and the capacity of the 30 inch pipe across the dam at Prospect to deliver it. As the year 1887 was wet, 60 inches having fallen in the 12 months at Sydney and about the same at the heads of the rivers, no inconvenience was felt in Sydney, and the citizens were beginning to hope that the drought had passed away; but the following year was one of the driest on record, 23 inches only being registered in Sydney, and for 11 months to end of November, only 21½ inches fell at the heads of the rivers. Prospect reservoir, however, had been conserving the surplus water during 1887, and by the end of the year 1888 the water there had reached the level whence it could flow by gravitation into the canal. On January 26th, 1888, the storage above gravitation level amounted to 1,356 million gallons. Had it not been for this, there can be no doubt

that the situation in Sydney would have been most serious, as the daily flow from the rivers up to the end of November, 1888, was exceedingly small, and the Botany catchment had been almost depleted of its water.

Tunnels reported to be collapsing.—The authorities, however, were given no rest, and public attention was again directed, by a section of the press, to the alleged unsafe condition of the works, and an alarm was raised that the tunnels were collapsing, and that Sydney's supply was in danger of being cut off by the blocking up of the Nepean and Cataract Tunnels, through the roof falling in.

It may be explained that during the construction of these tunnels, the contractors claimed that those portions where the rock appeared to be unsound, or where shale occurred in the crown, necessitating the use of timber supports, should be bricked; but Mr. Moriarty always strenuously opposed the application, being of opinion that after the loose rock was pulled away no support of any kind was required, and as a matter of fact, no bricking whatever was done. The floor of the tunnels was concreted, and a line of rails embedded in it, so that any falls which might occur from time to time might be readily removed.

Alleged Instability of Prospect Dam.—The alarm raised in 1888 was quite uncalled for, as an investigation showed that the quantity of rock which had fallen over the $6\frac{1}{4}$ miles of tunnel was insignificant, and only what had been anticipated and provided for. Time has since proved the correctness of Mr. Moriarty's judgment. The detractors of the scheme were, however, not to be foiled, and they commenced an agitation about the alleged instability of the dam at Prospect. What gave rise to the rumours was, that in April, 1888, a settlement at one portion of the bank had been noticed, which at first gave little uneasiness; but as the subsidence increased beyond what was considered

reasonable in a large bank of that character, reports from Messrs. Moriarty, Whitton, and Bennett were called for, and the opinion of Mr. F. A. Bishop, an hydraulic engineer then resident in the colony, were obtained. These reports were received in the middle of June, and they all agreed that there was nothing in the settlement which had taken place, that should raise doubt as to the stability or safety of the dam. As the trouble still continued, these gentlemen, after further investigation, advised the weighting of the toe of the bank with stone, which was done. In November, a second slip having occurred, Messrs. Whitton, Bennett and Hickson advised that further weighting of stone at the toe be carried out. This treatment was proceeded with, the action taken being endorsed by Messrs. G. Gordon, and R. L. Mestayer, who were requested to report upon the matter, and it was ultimately successful in arresting further movement, and the bank gave no more trouble for about nine years.

Report on the Kenny Hill Scheme.—Taking advantage of the difficulties which were being experienced in connection with Prospect Dam, and the fact that it was proposed as part of the permanent works, to commence the construction of a balance reservoir at Potts' Hill—in order to maintain the supply to the city, in the event of any accident occurring to the conduit below Prospect, necessitating extensive repairs—the supporters of the Kenny Hill scheme began another agitation in favour of their proposal, which they considered would obviate the necessity for so large an expenditure as £120,000 for a work they thought was unnecessary, and would provide a service at a higher level. The Government decided to obtain a report from a Commission of three engineers, and Messrs. F. A. Bishop, E. E. Sawyer, and R. L. Mestayer, were appointed to undertake the duty. Their report, submitted on 26 June, 1888, was unfavourable, and they concluded it in the following terms:

"Were the source of supply totally different from the present one, and the supply itself unlimited, or sufficiently ample to allow of extension or duplication, it might be well worth while to spend the much larger sum in carrying out such a scheme. These two vital points are however wanting, and considering the great additional cost required, which in our estimates it has been our endeavour to minimise as much as possible, we are of opinion that further investigation would only establish a greater difference than the one we have shown, without any corresponding advantages."

The agitation in connection with this scheme gradually died out, and nothing more was heard of it, the public becoming reconciled to that which brought a large body of water close to the city, at a moderate elevation by gravitation combined with a system of pumping to the highest required levels. This, being the cheaper, it was contended by Mr. Moriarty that no sensible man would throw away the money of the ratepayers, in order to attain some imaginary but certainly not real advantage from a uniform system of gravitation alone.

Board of Water Supply and Sewerage constituted, and retirement of Mr. Moriarty.—On 22nd March, 1888, the Board of Water Supply and Sewerage constituted by Acts of Parliament assented to on 10th June, 1880 and 1st March, 1888, came into existence, and took over the control of the works already completed; those remaining incomplete being still carried on by the constructing authority, the Minister for Public Works. On 1st January, 1889, Mr. Moriarty, after seeing his scheme practically finished and in operation, retired from the Public Service. His health for a considerable time previous to his retirement had been failing, having been undermined by the continual strain put upon it by his arduous duties in the conduct of a big department, which together with the heavy load entailed during the construction of the water works,

and the defence of his scheme against the constant and bitter attacks upon it and himself personally, imposed a burden which few men could have carried so long and so successfully. Broken in health he sought rest in the old country, but he never regained strength, and died at Southsea in England, on 18th September, 1896. This great public officer to whom we owe the conception, design, and successful construction of the Prospect scheme, is now almost forgotten. There is not, along the whole long line of the works, even a simple name plate to his memory. Certainly there stands in a dusty niche, high up in a dark corner of the basement of the Public Works Office, a marble bust—with an inscription on a bracket which it is almost impossible to read—which is recognised by a few of his old staff, as the presentment of their chief. Some day perhaps it may be brought out into the light and given a post of honour.

The Board of Water Supply and Sewerage were fortunate in not having a deficiency of rainfall to contend with after assuming control of the works. On reference to the Sydney diagram (1) it will be seen, that for the five years following 1888, the rainfall was all above the mean. For the five years after 1893, however, a serious shortage of rain occurred. Fortunately for the consumers, the supply was not depending on the Botany catchment, or the situation might have been serious. The rainfall on the catchment from which the Prospect works derive their supply was however good, with the exception of 1895-6, as will be seen if the diagram (2) of the Cordeaux River be referred to, consequently there was no inconvenience. A comparison of the two diagrams will be of interest as showing the value of the more elevated gathering ground. The good seasons, however came to end in 1900, and for the three following years a remarkable falling off occurred.

The average during this period was only 44·19 inches, being 9·19 inches below the mean, amounting to an accumulated loss of 45·58 inches below the mean. This had the effect of drawing Prospect reservoir down rapidly, and early in March, 1902, the water was within 9 feet of the gravitation level, and in view of the prospect of a continuance of the drought, arrangements were made to establish a pumping plant, in order to raise the water into the canal when it reached the gravitation limit. Temporary weirs were also constructed across the Nepean River at Penrith and Menangle, and machinery and pipes procured for pumping the impounded water from Menangle into the upper canal, and from Penrith into the Prospect reservoir.

Royal Commission of 1902.—The situation being considered very serious, the Government appointed a Royal Commission on March 12th, 1902, to inquire into the Sydney water supply. The most important question engaging their attention was that of the storage, and the capacity of the catchment area to supply the wants of a rapidly increasing population. They found that the population supplied in 1888 was 296,246, and the consumption of water averaged 8,144,000 gallons per day, equal to 27·5 gallons per head. In 1901 the population supplied was 491,000, and the average consumption was 21,538,000 gallons per day, equal to 44 gallons per head. This average was the quantity reported to have been actually passed for use down the lower canal, and did not include loss by evaporation from the surface of the reservoir itself. If this amount be added, the total average quantity abstracted from Prospect reservoir, under the conditions then existing of population and consumption, in round numbers was 25,000,000 gallons per day, or 9,125 million gallons per annum. The increased consumption per head from 27·5 gallons in 1888, to 44 gallons in 1901, might be attributed to a variety of causes,

such as increased use of water for baths, especially plunge baths, gardens and manufactories.

As experience in other cities has shown that the consumption per head may still further increase beyond the 41 gallons referred to, the Commissioners were of opinion that, in providing for the future requirements of Sydney, a consumption per head of 60 gallons should be allowed. On this assumption, the estimated requirements of Sydney and Suburbs in ten years with a population of 594,300 would be 36 million gallons per day, and taking loss by evaporation into consideration, the actual quantity which would have to be provided, would be 40 million gallons per day, or 14,600 million gallons per year.

Cataract Dam.—The Commissioners therefore considered that the present storage should be supplemented by a dam to be erected on the Cataract River to impound 7,000 million gallons, which, together with the storage of Prospect Reservoir, would meet the requirements of the population up to 1912, or for at least ten years. This proposal was referred to the Parliamentary Standing Committee on Public Works, who, on 12th July, 1902, recommended the construction of a dam 160 feet high, to impound 18,200 million gallons of water, at a cost not exceeding £217,500. This work was commenced at the latter end of 1902, and was completed by the end of January 1908, although the water commenced to be stored in September 1906. At the present time, May 1908, the storage amounts to 5,000 million gallons, about two months ago it was 2,000 millions more, or about what the Royal Commission of 1902 thought was sufficient for the requirements of Sydney. The full capacity of the reservoir has been ascertained to be 21,411 million gallons, the increase on what was recommended by the Public Works Committee resulting from an error in the original survey. As the catchment area relied upon to fill it is only

50 square miles, with a mean rainfall of probably not more than about 53 inches, it is considered doubtful in some quarters whether the reservoir will ever be filled. A study of this very interesting question, with the help of the Cordeaux River rainfall diagram, will I think convince any unprejudiced person, that the right step has been taken in building the dam up to the full capacity of the catchment area to fill it during wet seasons, so that it may be ready to assist us to contend with dry seasons for a longer time than would otherwise be the case.

With the knowledge we now possess of the quantity of rain which runs off this catchment area, few people will doubt that had the smaller dam been constructed, an immense quantity of water would have been wasting to the sea, during a period such as was experienced from 1888 to 1900, while during a dry period similar to that from 1900 to 1907, it would have been empty the greater part of the time, assuming that it was being drawn upon to the extent of supplying the complement of 40 or 50 million gallons per day, which the city will soon be demanding, and Prospect reservoir would also have been drawn upon to exhaustion. The history of the Sydney water supply is full of interest, showing that provision not having been made during good seasons to improve the supply, and to prepare for the shortage which must eventually take place over an extended period of drought, the citizens have entered upon the dry seasons, badly equipped with the means of contending against them, and towards the end of the drought, which we know may last as long as 14 years, they have more than once been face to face with a water famine.

It is not my intention to go further into the history of the building of the Cataract Dam, than to place on record the fact, that in addition to the inquiries already mentioned which took place before the work commenced, it became

necessary to submit questions relating to the amount of storage which should be provided, affecting the height to which the dam should be raised, and also the cost of the structure, to two separate Royal Commissions while the work was proceeding, and it will suffice to say, that the great dam as it stands completed to-day, is the materialization of the views held by the present Lord Mayor of Sydney, The Right Hon. Thomas Hughes, and myself as expressed in the minority report of the Royal Commission of 1902. The justification of the position then taken up, and the strenuous efforts subsequently put forward on behalf of the citizens, by the advocates for the larger and more generous provision which that dam is capable of affording them, have yet to be consummated.

We are now at the termination of one of the longest droughts of which we have any record, and the pendulum of the seasons is just on the point of swinging the other way. Let us hope, therefore, that the demonstration will be complete, and that it will not be long deferred. The storage now available at the Cataract reservoir, has set at rest the anxiety which has always been experienced whenever the exigencies of the water supply to the Metropolis has necessitated the drawing down of the water in Prospect reservoir below the level where the movements in the embankment have been observed, and it will now be possible to adjust the withdrawals of water from that reservoir, in such a manner as to avoid all risk to the structure, while leaving room in it for the freshets of the Upper Nepean and Cordeaux Rivers, which otherwise would waste to the sea, if Prospect were always to be kept full.

Melbourne Water Supply.—Melbourne affords a striking example of the hand to mouth policy in connection with water supply. There they depend largely on the daily flow of the

streams, draining from a catchment area of about 97 square miles, or 250 square miles less than we have to rely upon. The geological formation of the area, however, enables the ground to absorb and retain the rainfall as in a vast sponge, and the stream flow is therefore larger and more constant than from such a formation as the Hawkesbury Sandstone. Having so good a supply from the streams, they provided only a storage amounting to about 6,400 million gallons, or a little more than half Prospect. This reservoir was built about the year 1850, and if the Melbourne rainfall diagram (3) be consulted, it will be seen that the season of drought had then been passed, and good rains had been experienced for several years, thus raising the level of the ground water, which was maintained without much fluctuation until 1875, when a slow, but persistent decline in the rainfall commenced and extended for 23 years, so that in 1898, the accumulated loss of rain, as shown by the residual mass curve, amounted to 47·49 inches. This must have affected the level of the ground water, and consequently of the stream flow, which was probably reduced to what it stood at in 1843. During the following six years up to 1904, a slight rise of only 8·15 inches occurred; but the next three years up to 1907 have reduced it again to what it stood at in 1898.

The situation, with regard to the water supply in Melbourne must therefore be regarded as most serious, in view of the fact that the reservoir is now at a very low level, the main dependence being upon the daily flow of the streams, whose source, viz., the ground water, is shown by the diagram to be probably at the minimum, or very close to it. With this example before us, it is obvious that no dependence should be placed upon the stream flow in this country, and that large storage is absolutely necessary, in order to supplement the supply derivable therefrom, during periods of drought.

Storage Available in Prospect and Cataract Reservoirs.—The Stuart Murray Royal Commission of 1905, was of opinion that 6 feet below top water level in Prospect reservoir, should be considered to be the maximum limit to which it should be depleted, except under great emergency. Under this arrangement, the storage permissible would be 2,000 million gallons, in addition to the storage at Cataract reservoir, or a total of 23,000 million gallons with an emergency storage below the 6 feet limit at Prospect, of 9,000 million gallons. It should be the duty therefore, of the authorities, to avoid recourse to the extreme measure of drawing upon the latter storage, by exercising prevision in making further conservation of water, when the consumption shall have reached the point making this step requisite.

With such magnificent storage room as we at present possess, there is danger of the people being lulled into a sense of false security. No doubt the general opinion is that it should serve for a considerable number of years; but Sydney is increasing by leaps and bounds, and the citizens who have been looking anxiously forward to the time when they may have unrestricted use of water, will naturally avail themselves of the present opportunity, and demand to be served with as much as they require. And why should they not have it? They have always been willing to pay for it. In a hot climate like this, a liberal water supply is indispensable, yet Sydney up to the present time has always been compelled to exercise self denial in that respect. It has the smallest consumption per head of any of the Australasian cities. Hobart, Adelaide, Melbourne, and Dunedin range from 60 to 64 gallons per head, Brisbane even has 54, and Auckland 44 gallons per head, while Sydney has only 40. The citizens will never again suffer the restrictions they have so long been subjected to.

If we are wise, therefore, we should not rest satisfied with Cataract Reservoir, large as it is ; but endeavour to forecast requirements, and ascertain what our position will be in the near future.

Forecast of the Seasons.—The diagram of the Sydney rainfall is the record of our experiences of the weather during the last 76 years. If we consult it we shall see that there have been two periods of 14 years accumulated loss of rain below the mean, and one of 9 years. It is true that in the period from 1893 to 1907, there was a break of two years, viz., 1899 and 1900, when the rain was above the mean; but all the other years were below the mean, and the accumulated loss of rain over the whole period of 14 years was greater by 8·67 inches than during the 14 years period from 1845 to 1859, when breaks occurred in 1848, 1855, and 1857, these years being above the mean, and all the others below it. During the drought of 9 years from 1879 to 1888, only one year, viz., 1887 was above the mean. We may reasonably anticipate therefore, that we have reached the minimum, and may look forward to five or six years of rainfall above the mean, such as we had following the termination of the droughts in 1839 and 1888. It is possible, of course, that instead of a run of wet years similar to these, we may be about to experience weather such as we had from 1859 to 1872, when after two years of good rainfall above the mean, there were two below it, followed by three periods in succession of one year above the mean, followed by two years below it.

Estimate of Population and Consumption of Water.—Assuming however, that we have a run of five years of good rainfall above the mean, let us see what our position would be during that time, and at the end of the wet period. The reservoirs, after the first heavy rainfall, will be full, and would practically remain so until 1912-13. If the rate

of increase in the population for 10 years from 1896-7 to 1906-7, viz., from 418,512 to 603,910, be taken, it will have increased in 1912-13 to 715,000; but the rate of increase for four years from 1902-3 to 1906-7 has been more rapid, viz., from 523,000 to 603,910, and if this be continued, the population supplied with water in 1912-13 will have increased to 725,000. The present rate of consumption per head per day is about 40 gallons, which is low, owing to the necessity for economy in the use of water during the long drought, but the restrictions having been removed there can be little doubt that the consumption will increase very rapidly, and at the end of the good seasons in 1912-13, it would not be unreasonable to assume that it will have increased to at least 60 gallons per head per day. The population then being probably 725,000 will require an average supply daily of 43½ million gallons. If there is anything in periodicity of rainfall, and I think most people will now admit that there is something in it, then the year 1913-14 will mark the first year of a long period of declining rainfall, and the diagram shows that the first year is usually exceedingly low. The supply would then depend almost wholly upon the storage in the reservoirs.

Behaviour of Reservoirs during Wet and Dry Seasons.— Let us see how they will be likely to stand the drain about to be made upon them. Assuming the rate of increase in the population to be maintained, and the consumption to be 60 gallons per head, the figures will be, population 745,000 and consumption 44¾ million gallons per day in 1913-14. To the latter must be added the loss by evaporation from the surface of the two reservoirs which will cause the draft upon them to amount to 52¾ million gallons per day. If we assume for the moment that no addition to the storage is made, the entire quantity of 21,000 million gallons in Cataract and 11,000 million gallons in Prospect reservoirs or a total of 32,000 million gallons

would be exhausted in 1·66 years. If the storage at Prospect be considered to be available only to gravitation level the total supply would last only 1·37 years; but we know by experience that Prospect reservoir should not be drawn upon to a greater extent than 3,000 million gallons, except under great emergency, this being 1,000 million gallons more than the Stuart Murray Commission considered safe, so that the permissible storage should not be regarded as being more than 24,000 million gallons, which would last only fifteen months.

Although it is very unlikely that such a length of time as stated would occur without rain falling and making some addition to the storage, we do know, however, that during the droughts the percentage of the rain which finds its way into the river channels is exceedingly small, and gaugings have shown that periods of eight and nine months sometimes occur when only $\frac{1}{20}$ of the water which fell as rain was available for storage purposes. The figures showing the time the storage would last under the conditions stated are useful to enable us to realise what the situation would be after a year of exceedingly low rainfall, with the following five or six years much below the mean, the population rapidly increasing, and the daily loss from the reservoirs exceeding 50 million gallons per day. Even with the strictest economy and large reduction in the consumption the situation would be very serious. It is obviously unnecessary for me to further enlarge upon the position of the city with reference to the water supply under such circumstances.

Let us now take the other case, and assume that on the termination of the drought in 1907, the weather conditions will be similar to those experienced after the end of the drought in 1859. The diagram (2) of the Cordeaux River rainfall does not go back far enough to show the curve at

that time, but the Sydney diagram (1) can be relied upon to show the general character of the rainfall. On an inspection of it, it will be seen that the rainfall for the two first years was well above the mean, viz.:—82·81 inches in 1860, and 58·36 inches in 1861, and the rainfall on the catchment area would probably have been greater than this. It takes the whole of the rainfall equal to 29 inches falling off an area of 50 square miles to fill the Cataract reservoir, and if we assume that it was empty in 1859, and Prospect reservoir was drawn down to its safety limit also, then with the rainfall above stated, allowing say 40% run-off, both reservoirs would have been filled to overflowing, and would have remained so probably to the end of 1861.

During 1862 the Sydney diagram shows a rainfall of only 23·98 inches, and although the rainfall on the catchment area would probably have been a little more, the run-off would have been inappreciable. In 1863, 47·08 inches fell, and being close to the mean, some contribution to the storage might be expected. The rainfall having been below the mean, however, for the two years would have resulted in a continual draft upon the reservoirs, but not to a serious extent. The following year, 1864, had a rainfall of 69·12 inches at Sydney, and probably more than that on the catchment area and the reservoirs would have been filled again; but it must not be forgotten that the population and rate of consumption would probably have increased to 705,000 and 42¼ million gallons respectively, and allowing for loss by evaporation over the surface of the two reservoirs, the daily loss therefrom would probably have amounted to 51 million gallons. Under these conditions, and the rate of increase still going on, the next two years have to be faced, during which the rainfall at Sydney was only a little over 36 inches per year, denoting very dry seasons on the catchment area, when there

would be little addition to the storage. It cannot be doubted, therefore, that the reservoirs, notwithstanding restrictions which the citizens would have had to submit to by the end of 1865 would have been severely taxed, and by the end of 1866, the reserve storage at Prospect would have probably been drawn upon. In 1867, the rainfall at Sydney was 59·68 inches, only a little above the average and although the rainfall on the catchment area may have been greater it would probably have been insufficient to fill the reservoirs, and the population having increased probably to 785,500 in 1868 and nearly 806,000 in 1869, with a rainfall below the mean, the situation can better be imagined than described. The correctness of this estimate depends upon the rate assumed for increase of population supplied with water, and of the daily consumption per head. No doubt my figures will be challenged, but I certainly think it prudent to adopt the rate of increase during the last four or five years in order to estimate the population for a similar period ahead, than to adopt the rate of increase over say ten years back. It will be remembered that all previous estimates have been exceeded. Even the Royal Commission's estimate, so recently as 1902, was much too low. They adopted the rate of increase from 1888 to 1901 in order to estimate the population in 1912, which they put down at 594,300, whereas we know that these figures were reached early last year or in half the time. In view of these facts it will, I think, be admitted to be safer to adopt the figures I have chosen. If an error be made it is better to be on the high than on the low side in future.

Reasons for Anticipating a Large Increase in the Consumption of Water.—With reference to the estimate of the daily consumption per head, I have already given some reasons why we should assume that in 1912-13 it will have risen to 60 gallons per head. An abundant supply for street

watering, plunge baths, lawn and garden sprinklers, sanitary flushing of the street gutters, and public conveniences, fire brigade practice, and public swimming baths, will be demanded by the citizens, and must be provided for. All these services have been for a long time very severely reduced, which, together with the necessity for frequent caution to the ratepayers to enconomise even in domestic services, have resulted in keeping down the rate of consumption to the very low figure of less than 40 gallons daily per head. It is a reproach to the city that the supply should be so constantly stinted in the use of water for these purposes, which may all be regarded as absolute necessities in this climate. If the city is to be made beautiful as it is admitted on all hands it should be, a liberal supply must be provided for the public parks and gardens where restrictions have been so long enforced. Public fountains should be established in all the parks and domains, the overflow from which could be applied to the maintenance of ornamental ponds, and the watering of the flower beds. From what I have said it will be easy to account for the exceedingly moderate supply of 60 gallons per head in 1912-13, which is already enjoyed by nearly all the Australasian cities. In America the consumption of water is much greater. In New York at the present time, the Boroughs of Manhattan and the Bronx, where the population is over $2\frac{1}{4}$ millions, have a gravitation supply providing water at the daily rate of 110 British gallons per head, which has been found to be insufficient, and provision is now being made to increase it to 125 gallons per head in the future, by the construction of additional works.

Need of More Storage.—These two pictures I have drawn, showing the operation of the water system under weather conditions, one or other of which we may reasonably anticipate, and with the population and rate of consumption

increasing to the figures I have assumed, which will probably be proved to be not an incorrect estimate, should be sufficient to arouse public interest on the state of the water supply, and the absolute necessity of making immediate provision for the future. It must now be obvious that Sydney cannot any longer place any dependence upon the daily flow of the streams supplemented by storage, unless the storage is regularly and systematically provided for as the demand for water increases. Even Melbourne, with its splendid stream flow from the mountain slopes, has been rudely awakened to the necessity for greater storage.

Cataract Dam was commenced five years ago, and has only just been completed. I have shown from the records of past rainfall, that in five or six years we shall be in urgent need of more storage than we at present possess, in order to maintain the rate of consumption which I have assumed will be reached by that time, otherwise the citizens may expect to be called upon to submit to restrictions again. If we are prudent, therefore, we should lose not a moment in deciding where such storage should be made, and commencing the works in connection therewith.

Sites Available for Reservoirs on the Existing Catchment Area.—It is well known that on the Cordeaux, Upper Nepean, Avon, and Bourke rivers, within the catchment area supplying the present water system, there are several good sites for reservoirs, three of which were actually surveyed by the Royal Commission of 1902, and estimated to impound 27,000 million gallons, so that all that would be necessary would be to select one of them, and set about building the dam. When completed, say in five years' time, it would be ready to supplement the storage at Cataract, the water from it being made available in the same manner as at Cataract, by allowing it to run from the dam into the river channel, ultimately to find its way into the existing conduit which supplies Prospect reservoir.

In the future when further storage is required, another of these dams can be built, and so on until the utmost use has been made of the catchment area. Under this system of increasing the storage, which no doubt would serve Sydney for a very long time, the water would continue to be delivered by gravitation to Crown Street at 141 feet above sea level, and to Ryde at 97 feet, being thereafter raised by pumping to the higher levels. The quantity of water at present pumped from these stations is 60% of the total supply, and as time goes on, no doubt this will increase considerably.

Advantages of a High Pressure Gravitation Supply.—The advantages to be derived by the delivery of water by gravitation, at a sufficient level to enable pumping to be dispensed with are so great, that, as we have already seen, strenuous efforts were for a long time made by the supporters of the Kenny Hill project to gain it. As that scheme was not an independent one, and did not add anything to the existing supply by increasing the catchment area, and moreover was limited in its delivery to a level insufficient to satisfy the fast growing settlement on the higher parts of the city, and as it was not thought possible to obtain these advantages of high pressure, without very great expense in bringing in the water from the mountain streams, such as the Warragamba, Colo, and Grose rivers, the citizens have accepted the situation, and have been content with the present system of gravitation with pumping.

A scheme has however, now been evolved which will fulfil all the requirements, viz., it will provide an entirely independent supply of additional water, derived from a gathering ground separate and distinct from the present catchment area, and at a sufficient pressure to dispense almost entirely with pumping. It is capable of expansion

up to 50 million gallons per day, and when delivering that quantity, the cost per million gallons at Bankstown will be about the same as by the existing works; but to the higher levels of Stanmore, Ashfield, and Penshurst, which are depending on pumped water, the cost per million gallons would range from half to a quarter of what it is at present. If a separate fire service be laid throughout the city, the pressure would be sufficient to enable the water to be thrown over the highest buildings ever likely to be constructed without the aid of fire engines.

The Woronora Scheme.—Briefly the scheme is to construct a dam capable of impounding 7,500 million gallons, just below the junction of the Waratah rivulet with the Woronora river, the top water level being 510 feet above sea level. The catchment area above the dam is 29 square miles. The country being of a similar character to that of the Cataract, and with a rainfall at least equal to it, if not superior. Assuming the average rainfall to be only 50 inches per annum with 35% run off, the reservoir would be filled in 12 months. A steel pipe to be laid from the dam through a tunnel into George's River valley, and thence along the flats of the Holdsworthy Estate opposite Liverpool, crossing George's River near its junction with Prospect Creek, and thence along the main road to Bankstown, which would be the main distributing centre. To supplement the storage at Woronora and double the catchment area, a tunnel about 4½ miles long can be constructed from the Woronora reservoir to the junction of O'Hare's and Stokes' Creek, where a second dam can be built impounding 2,000 million gallons, having a top water level of 654 feet above the sea level. The catchment area is 30 square miles, of similar country to that of the Woronora, and almost wholly unoccupied.

Ultimately, when the city requires more water at high pressure than the scheme can afford, a tunnel about 3½

miles long can be made into the Cataract reservoir, which would release all the water there if required above the 900 feet contour, amounting to 18,000 million gallons, thus converting the water impounded there from low to high pressure. The water would pass from a valve tower in the dam at the intake of the tunnel into O'Hare's Creek, and run down into the reservoir there, to be passed on as required into the Woronora reservoir. Supplemented thus by the water from Cataract reservoir, the high pressure scheme can be depended on to supply 50 million gallons per day if necessary, the tunnels being made large enough in the first instance to convey the maximum quantity, and the pipes to be duplicated when the necessity arises for the increased supply. The head of water derived from the Woronora reservoir will be sufficient to serve all the high levels about Bankstown, also the zone at present served by the Centennial Park reservoir, the heights of Canterbury, and the Illawarra suburbs. Should a greater pressure be required for a fire service, it can be obtained by extending the pipe from the Woronora dam to the outlet of the tunnel from O'Hare's reservoir, and making connection there, when an additional head of 144 feet above the top water level of Woronora reservoir, viz. 654 feet above sea level can be obtained.

Alternative Scheme.—An alternative scheme provides for the diversion of the water from the Woronora and O'Hare's Creek reservoirs, into the existing canal just below the drop at the Sugarloaf, by means of a tunnel about 10 miles in length, which would intercept the drainage from about 84 square miles of country, being about 25 square miles more than by the first scheme. The levels admit of the water being drawn off from the Woronora reservoir, at an elevation of 410 feet over sea, through the tunnel having a fall throughout of $2\frac{1}{2}$ feet per mile, and a delivering capacity of 50 million

gallons per day. Where the beds of the creeks are above the tunnel, the water would be diverted into it down the nearest shaft. From a pipe head reservoir at the junction with the canal, the water would be conveyed through a steel pipe laid along the main road passing through Campbelltown and Liverpool to the proposed distributing reservoir at Bankstown, having a pressure at that place of 302 feet above high water. When delivering 25 million gallons per day, the cost per million gallons would be practically the same at Bankstown as by the first scheme, but it would be about 17s. per million gallons less when delivering 50 million gallons per day, as the expense of tunnelling into the Cataract reservoir would be unnecessary, the water therefrom being conveyed to Sugarloaf by the existing works.

The only advantage this scheme has over the first one, would be in its adding a larger area to the existing catchment, the surplus water during freshets, over what would be required at Bankstown, being passed on down to Prospect reservoir for storage. The 25 square miles additional catchment area beyond that of the first scheme, is no doubt of very great value in assisting to maintain the storage at Prospect, but it is a matter for careful consideration, whether this outweighs the advantages which the other scheme possesses, of being able to convert 18,000 million gallons of the water impounded at Cataract reservoir, into water having a pressure if required for fire fighting purposes, due to the head of 654 feet at O'Hare's Creek reservoir.

It is strange that in all the investigations that have been made from time to time, the scheme for the high pressure service from the Woronora and O'Hare's Creek should have been missed. I have gone to some trouble to look up the old reports, but in none can I find any reference to it. It

is true that the prospect of obtaining a supply by erecting dams in the lower reaches of the Woronora and Port Hacking Rivers, connecting the reservoirs by a tunnel, was inquired into by Mr. Clark, and the Royal Commission of 1869 devoted some attention to this aspect of the question and also to a proposal to obtain a supply from the lower reaches of George's River, but the idea of erecting dams in the upper portion of these streams and connecting them by tunnelling, does not appear to have occurred to them. The advantages of an independent gravitation service, capable of expansion to the collection and delivery of so large a supply of additional water at high pressure as 50 million gallons per day, at less cost per million gallons than by the existing works, are so great, that it must now be clear that had Mr. Gipps been in possession of the facts at the time he was urging the Kenny Hill scheme, he would have succeeded, and the Woronora water would have been in circulation about the higher areas of the city to day. In view of our present knowledge it is fortunate that his proposal was not adopted, otherwise we would now be in possession of an inferior supply.

The survey of the schemes from the Woronora River were made on my recommendation, by the Metropolitan Board of Water Supply and Sewerage, on which the preliminary plans and estimates have been prepared, and as the surveys of the sites and estimates of the cost of the dams on the Cordeaux and Nepean Rivers were made by the Royal Commission of 1902, there is nothing more required to enable the Public Works Committee to arrive at a conclusion as to the source from which the additional water supply should be derived, whenever the question may be referred to them.

Disposal of the Waste Water for Irrigation Purposes.—Before concluding this history of the Sydney water

supply from the days of its infancy to the present time, there is one other matter to which I would direct your attention, and that is to the use of the waste water from the rivers for irrigation purposes. This question has remained in abeyance until now, owing to the storage having always been insufficient to permit of a small quantity being used to supplement the waste water from the rivers, during dry seasons. Should the necessary works to provide additional storage be shortly commenced, there is no reason the irrigation proposal should not be given effect to without further delay, and thereby bring in a large revenue which would go a long way towards paying the interest on the cost of the new works.

HYDRO ELECTRIC INSTALLATIONS.

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(Communicated by F. M. Gummow, M.C.E.)

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Introduction.—The subject of this paper is an exceedingly wide one and it is perhaps the most interesting line of work which an engineer can take up, because he has to co-ordinate a large proportion of the following:—

Preliminary surveys, frequently over difficult and mountainous country, deciding upon positions for head works, pipe line, power house, and transmission lines; arranging

for access by roads, rope ways etc. Measurement of water power, evaporation and seepage; position and design of forebays, sand boxes, dams, flume and tail race. Provision of cranes, hauling engines, wire rope ways; design of pipe line, valves, turbine or impulse wheel and governing gear, etc. Layout of power house, substations, and houses for men engaged on construction etc.; questions *re* suitable building material and methods of getting same on to site. Providing for light and power during construction; deciding as to system, voltage periodicity; size and detailed design of main generators, exciters, transformers, and switch gear. Calculation of transmission lines, type and number of poles, sizes of insulators and pins; provision against lightning, and for safety where transmission lines cross roads, railways, etc.; design and equipment of substations.

There is also miscellaneous work such as arranging for agreements about water and fishing rights and rights of way for transmission lines. Negotiations with the authorities *re* crossing roads and railways and non interference with telegraphs and telephones. The engineer may also have to arrange for the commissariat during construction, to conduct preliminary negotiations for sale of power etc., etc.

The slides shown are those of the Snowdon transmission of the North Wales Power and Traction Co., for which the writer acted as advisory electrical engineer before coming to Australia in 1905. As will be seen from Table I and the Schedule, it is a 8,000 HP plant, working on a fall of 1,140 feet, and it may be taken as typical of what is required at Barron Falls if ever that installation be carried out.

Table I.	Horse Power Trans-mitted-	Distance of Trans-mission.	Voltage.	Size of Transmiss-ion Wire.	Height of Fall in feet.	Revs. of genera-ting unit	Output of each alter-nator. Kw.
North Wales Great Britain	10000	Several totalling about 100 miles	10000	Several circuits of No. 2 S.W.G.	1140	500	1500
Launceston, Tasmania.	1300	5 miles	5000	2 circuits 19/14	112	500	300
Waipori, Dunedin, N. Zealand.	3300	12 and 15 miles	2400 to 35000	2 circuits Nos. 2, 3, B. & S.G.	670	430	1000
Hillgrove, N. S. Wales.	250	19⅓ miles	550 to 23000	1 circuit 7/18	300	750	160

NOTE.—The system of transmission in each case is three phase, the periodicity 50 cycles per second, and the transmission wires of copper.

Schedule of particulars of Snowdon Transmission of North Wales, of which a series of slides was exhibited.

Water taken from Lake Lldaw, on east side of Snowdon, 120 acres in extent, at 30 feet below surface, through two steel pipes 1¼ miles long.

Each pipe 30 inches diameter by $\frac{5}{16}$ inch thick, rivetted, at upper level and increasing in thickness to ¾ inch thick and 27 in. diameter welded, at power house 1,140 feet below.

Pipes in 18 feet lengths, carried on 10 × 7 inch wood sleepers 10 feet long, spaced 8 feet apart. On steep slopes each pipe length anchored to concrete block, 8 feet × 3 feet × 4½ feet.

Catchment area limited by the Snowdon ridge, but rainfall averages over 190 inches per annum, the heaviest being in August. Snow lying on the catchment helps to average up the supply of water in spring.

Power house 145 feet by 45 feet, containing four 1,500 Kw. generating units, each having a twin Pelton wheel. The alternators by Bruce Peebles, give 3 phase current at 10,000 volts 50 cycles when running at 500 revolutions.

Switch board by Ferranti with oil switches, feeder panels at back of generator panels and a room between. Lightning arresters of horn and water jet types.

Transmission lines in three directions—to Dinorwic, Pen-y-Orsedd, Oakeley quarry centres—of copper wires on wooden poles set 40 to the mile; some are lattice poles.

The Oakeley quarries at Blacnan Festiniog employ 2,000 men, and the installation consists of two substations containing 500 Kw oil cooled transformers, stepping down to 520 volts, supplying current to 37 motors aggregating 1900 HP.

Considering that Australia is such a large continent it is singularly lacking in natural water power, yet particulars of two successful plants already at work, namely at Launceston and Hillgrove are given in the table. Barron Falls is one of the largest water powers not yet harnessed, and according to Mr. Corin this Fall will develop 3,500 electrical horse power at the generator terminals for all the year with a minimum of 50 feet per second on a head of 818 feet. From records taken weekly from June 1899 to January 1901 and thus including the exceptional drought year of 1900, the flow varied from 684 to 41 cube feet per second, and only for three months of the above period was it below 100 cube feet per second. With water storage, therefore, Barron Falls should easily give 5,000 HP. and possibly nearly double that.

It will be noticed that the power depends mainly on the high head, and it is just possible that if search were made, several insignificant looking falls would be found which could be made to give a head of over 1,000 feet at the power house with only a moderate length of pipe. As will

be seen later these extra high head falls present many advantages over those of low head.

Trawool Dam and Power.—Though lacking natural water power there are few countries in which large bodies can be so cheaply conserved by dams other than Australia. Some four years ago Messrs. J. M. and H. E. Coane, of Melbourne, asked the writer to join them in a scheme for building a large dam at Trawool on the Goulburn River with a view to conserving water for irrigation and at the same time to develop electric power. Flying surveys showed that with a dam about 1800 feet long and 180 feet high 60,000 to 70,000 million cubic feet of water could be impounded; that is to say, about double the amount conserved by the Assouan Dam or Barren Jack. A large amount of data was got together, including estimates of the electric power that could be developed at the second, sixth, and tenth year of working with power factors of 30, 40, and 50%, and the project was submitted to the Victorian Government. Some engineers have stated that power cannot be economically generated from such irrigation dams; and on the other hand, there are some who hold extravagant ideas of what can be done. The truth lies somewhere between, and certainly so far as *Trawool is concerned the writer is convinced that such an amount of power can be developed* all the year round as to make it well worth while laying down an installation. It is also likely that other irrigation dams could be made to develop power if well engineered and balance reservoirs were provided. When in Victoria, Mr. C. H. Merz was given particulars of Trawool, and it is interesting to note that one of the main conclusions in his Electrification of Railways Report reads :—

"At a later stage when the demand for power has developed still further, additional power should be obtained from a water power station at Trawool."

Value of Water.—Since the proposal of Messrs. Coane and the writer was placed before the Government a distinguished American expert on irrigation, Mr. Elwood Mead, has been appointed Chairman of State Rivers and Water Supply, and he has stated that the construction of the dam at Trawool will enable 750,000 acres to be irrigated against the 50,000 which can be irrigated at present, and he gives the annual value of the Goulburn River for use in irrigation when Trawool is completed, at not less than £375,000 per annum. In addition there would be much better regulation of the river in time of flood. Regarding the power side of the proposition he says that :—

"10,000 HP. can be generated continuously, and 20,000 HP. for perhaps six months in the year without the loss of one gallon of water for use in irrigation. . . . . . During the six irrigation months all the water needed to generate 10,000 HP. can be stored in Waranga Basin and drawn from there in the succeeding summer months. He estimates the value of the electric power at £50,000 per annum."

He has informed the writer that the above estimate of the values of power was based on a 24 hours run, and the price at which it could probably be marketed in the mines of Bendigo and at Melbourne. If transmitted to these centres a good deal of the power would not be used right through the 24 hours, and so the figures for maximum horse power output from the dam might be increased. In any case, however, a revenue of £50,000 will go a fair way towards reducing the cost of irrigation water to the farmers, and this is a most important matter if irrigation is to be successful.

It will be evident from the above figures that *water stored on a large scale is almost as good as a gold reserve in the bank*, and the writer considers that the community is greatly indebted to those who first showed how such

a gold mine could be tapped. Although the possibilities of Trawool have been staring everyone in the face for generations, for the railway runs close by, nothing was done until Messrs. Coane and the writer came forward with a detailed scheme and data to back it. Now having fathered the scheme the Victorian Government will probably build the dam, for detailed surveys are in hand, but whether the power side will be given to a company to develop remains to be seen. It need hardly be pointed out that if the Trawool proposition is carried through it may have important and far reaching results, for there are many valleys in New South Wales which could be easily dammed up and from which power could be obtained, some of these valleys being also well situated for irrigation.

It should be mentioned that the idea of building a large *dam for power purposes only, is common enough in other countries.* Thus at the Spier Falls on the Hudson River there is a dam 1820 feet long and 155 feet high above bedrock, which is simply for the purpose of developing electric power. Note, this dam is about the size of the one we proposed at Trawool, yet the amount of water which it impounds is a mere fraction. If, therefore, it pays other countries to build such dams for power only, so much the more should it pay Australia to build much more effective dams for both irrigation and power. Tables II and III give particulars of some of the largest dams in other countries, and it is of interest to compare them with those in Australia and with the proposed dam at Trawool. The latter is easily first for storage capacity with minimum size of wall even if the conservative estimate of 60,000 millions of cubic feet is taken.

TABLE II.

Name.	Country.	Catchment area, acres.	Height of dam above river bed in feet.	Reservoir area, acres.	Storage capacity in million gals.	Average rainfall inches.
Cataract ...	N.S. Wales	32,000	154	2,145	21,410	45
Barren Jack	,,	3,200,000	200	12,740	208,630	30
Coolgardie	W. Austral.	364,160	100	800	4,600	26
Beetaloo ...	S. Australia	...	118	...	...	130
Birmingham,	England	45,560	128	1,499	18,000	69
L. Thirlmere	(Manchester) England	11,000	52	793	8,130	85
L. Vyrnwy	(Liverpool) Wales	23,500	85	1,115	12,000	68
Bombay ...	India	33,000	118	3,520	16,070	102

TABLE III.

Name.	Egypt. Assuan.	In United States. Roosevelt.	Shoshone.	Pathfinder.
Length in feet	6,562	1,080	175	226
Maximum height in feet	141	284	326	215
Maximum water depth in feet ...	107	242	243	195
Crest width feet	36	16	10	10
Down-stream batter	3·2	3·2	4·1	4·1
Up-stream batter...	18·1	20·1	20·3	20·3
Volume, cubic yards	790,000	340,000	69,000	53,000
Gates...	140—6½′ × 23′ 40—6½′ × 11½′	3—4½′ × 10′	3—3′2″ × 7′	4—3′2″ × 7′
Storage, acre feet	1,860,000	1,284,000	456,000	1,025,000
Material	granite rubble	sandstone rubble	concrete masonry	granite rubble

NOTE —The Assouan dam is now being raised from its original maximum height of 118 to 141 feet.

In order to continue to develop power from an irrigation dam when the water is low and at the same time not lose the use of it for irrigation purposes *a balance reservoir must be arranged at a lower level.* In the Trawool scheme this is already provided for by the Waranga Basin which has a capacity of 9,000 million cubic feet, and which can be nearly doubled by raising the wall another 10 feet. To obtain power from Barren Jack all the year round similar provision would have to be made. The varying height of water behind the irrigation dam which at Trawool would be from say 140 down to 60 feet presents a difficulty, but it can be overcome by providing special turbines. For example, they might be made to work in series on the higher and in parallel on the lower heads.

When flooding a large valley it may be necessary to inundate cultivated land and possibly buildings, etc. therefore ample compensation must be allowed on the estimates and the interest on this will be a constant charge against irrigation and power. In the case of Trawool, for example, it will be necessary to relay a section of railway line and remove a part of Yea township, but even allowing £300,000 for this, the scheme is financially sound. All the State Governments would do well to at once reserve all valleys that are likely to be wanted for water conservation.

Uses of Electric Power.—It is a mistake to assume, as some do, that given the possibility of developing electric power from conservation dams, it must necessarily be transmitted over long distances in order to find a market. Electro chemical and electro metallurgical works are often situated near to the power plant as has happened at Niagara and Rheinfelden, and in Scandinavia. The writer had some professional work in Norway in connection with a 3,000 HP plant, situated about 70 miles inland from Trondtheim, and very much out of the way. It would have been easy to have generated at high voltage and transmited to a more accessible factory site, but on the contrary, it was thought advisable to have the factory near the water power. It does not follow, therefore, that when Trawool is harnessed, all the power need be transmitted 60 miles or so to Melbourne, Bendigo etc. One great advantage in giving a supply to factories situated near to the power is that special time contracts can be entered into, by which if there should be a shortage of water the output of the factories can be temporarily reduced. In cold countries shortage is usually in midwinter, due to the small streams freezing, and factories frequently ease up at such times. In Australia the shortage would be in midsummer.

Assuming that there will be a drought every ten or fifteen years necessitating a reduction in power delivered

to factories, this is a risk which most manufacturers would take if they could get power at the specially low rates which are possible from water power. In this connection it is interesting to mention that the Yorkshire Electric Power Co. has made arrangements to supply current at a specially low rate to a carbide of calcium factory which shuts down each day at the time of the peak-load. Hydro electric plants in this country would have an advantage over those of, say Canada, in that there would be no trouble *with anchor or frasil ice.* This substance is of a soft jelly nature and it is liable to stick to the strainers and passages of the turbine at certain times of the year.

Copper—One can suggest many uses for electric power in locally situated factories. For example, all the copper mined in this country should be treated here electrolytically. Fifty per cent of the world's output is so treated. There is a small electrolytic works at Lithgow and another is being built at Port Kembla, but even these together will only treat a small fraction of what is mined in this State. Copper is treated electrolytically because it gives great purity, and enables all the gold and silver to be removed. In time, electric smelting may also take the place of the present system. Caustic soda and potash, bleaching powder, which are imported to a value of over £80,000 per annum, also aluminium and phosphorus are produced by electricity, and given cheap power could be made here.

Manures.—The ideal kind of factory, however, would be one turning out artificial manure by the direct fixation of nitrogen process or else as cyanamide from carbide of calcium. Both these manures are being made in rapidly increasing quantites and time is all in favour of the electrical method, because Chili nitrates are being worked out. In 1906 the imports of Chilian nitrate to the Commonwealth were valued at £36,000, the price being about £10 a ton.

It is certainly a neat idea that the *same water which irrigates the land should also be used for making artificial nitrate manures*, and who knows but what this may be realised first in Australia. Huge plants are being put down in Europe for the manufacture of these artificial manures, and the President of the Acetylene Association stated in February 1907, that over one million sterling was at that time being invested in equipping water powers and factories for the manufacture of cyanamide.

Carbide of Calcium.—A promising scheme was got out some time ago for a carbide of calcium factory at Cairns, the current to be supplied from Barron Falls, and such factory is quite justified, because the present Australasian consumption is well over 5,000 tons per annum and increasing rapidly every year. In a report which the writer prepared in connection with this matter he showed that about one and a third tons of carbide could be produced from one horse power year, so that the 5,000 electrical horsepower which the Queensland Government contracted to supply, would produce about 6,000 tons, at a cost under £8 a ton. The selling price is more than double that figure.

Cost of Current.—Power was to be generated at 12,000 volts and delivered at Cairns 12 miles away, for £2 15s. per EHP year. At 300 days and 24 hours a day, this works out at about $\frac{1}{8}$d. per B.O.T. unit, whereas the lowest price charged by the Sydney City Council is one penny. Of course a lighting or power load having a load factor of 25% is very different from an electric metallurgical plant running right through the 24 hours and giving a load factor of nearly 100%. At Niagara the charge per E.H.P. year is £3 19s, and at Lachine Rapids, Canada, £3 11s. 9d. At Meran in Austria and at Sarpsfos in Norway it is £2 7s. 6d., but there are still cheaper rates at some of the Scandinavian water powers. As an example of what can be done from a fuel

driven station the charges which are proposed by the London and District Electrical Supply Company may be cited; there is to be a yearly charge of £3 per kilowatt and a running charge of a farthing per unit, supplied so that if the customer uses full current for say a quarter of the total hours in the year or has what is called a 25% load factor, then he will pay at the rate of $\frac{9}{16}$ths of a penny per unit.

It should be noted that it is more important to have a high load factor for a water power plant than for a fuel power station, because a natural water flow is only controllable to a certain extent, whereas a fuel supply can be controlled to any degree. In practically all water power plants some water must run away uselessly, and the amount will vary according to the number of and the height of the peaks as compared with the steady all day load. It might be thought that the difficulty could be got over by electric storage, but hydro electric stations are unsuitable places for storage batteries and in any case there would be considerable loss of energy in changing from direct current to alternating. In several hydro electric plants situated on rivers, special water storage reservoirs are provided. At Zurich for example, water is delivered from the river to a reservoir by turbine pumps which run when the main generators are not fully loaded. Then, when the power of the river gets low the reservoir can be drawn upon.

Power House.—The power house and hydraulic works for a high head, such for example as Barron Falls, differs considerably from what would be required at the Trawool dam with a head of say 100 feet. The amount of water to be dealt with is very much smaller, and it would be brought to the power house through a steel pipeline of comparatively small cross-section, whereas at Trawool the power house would practically form part of the dam and the water be lead direct into a turbine chamber and away through a

tail race of considerable dimensions. But even for low head falls where the hydraulic works have to be on a considerable scale to deal with a large volume of water, the hydro electric power house is immensely superior to a steam power station, as there is no chimney, boiler house, coal store, pump room, etc. The building is merely a simple shell of considerable length compared with the width. The Oakland power house for example is 275 feet long by 40 feet wide, and that for the Snowdon transmission 145 feet by 40 feet.

The switchboard is usually situated in a room midway along one side, and it has over it the tower from which the transmission lines lead away. Step up transformers are sometimes placed underneath the switchroom, but it is well to locate them in an entirely separate building because of the oil. At Niagara a canal divides the transformers from the power house.

The attendance required in a hydro electric station is remarkably low, an average of many stations giving it at less than one fourth of what is necessary with steam. As the combined cost of fuel and labour in a steam station is $\frac{3}{4}$lbs. of the total, it will be seen what a great saving water gives.

Water Wheels.—In a general way it may be said that impulse wheels are used for heads of over 400 feet, and turbines for under that. The Pelton or impulse wheel in which the water impinges against a part only of the periphery has *the advantage over a turbine of being very cheap; indeed it is the cheapest form of prime mover.* It is also able to work with any head; in one case in Mexico over 2000 feet being employed. With such high heads the buckets wear out quickly, and it is necessary to go to the trouble of building forebays, etc., to allow sand and other solid matters to settle.

Governing is generally arranged by slightly deflecting the nozzle so that more or less of the water is effective, but in one form—the Cassell—the wheel is in two halves which open slightly under the action of a governor and let some of the water through. With a low head fall the guides, wheel and draught tube of the turbine must be kept full of water and so the turbine has to be within say 12 feet of the tail race level.

Occasionally the tail water will, in flood time, bank up nearly this amount, and therefore it is common practice to have a vertical spindle turbine with the alternator above. With very high heads the water missing the bucket is destructive, and it is usual to provide a pool in the tail race for it to strike into, as was done at the Snowdon power house. But for this fact, the power house on a high head fall could be situated well above tail water level.

Alternators.—From the electric generator point of view, *a high head means a great saving of expense because the speed can be high.* For example, at Barron Falls, with a head of 800 feet, the Pelton wheels could run at say 500 revolutions, but at Trawool, where the average head would be 100 feet, the turbines would have to run at say 100 revolutions. Assuming the same output of generator in each, the cost at 100 revolutions would be several times greater than for the higher speed.

Rivers giving a head of only 15 feet or so are frequently harnessed, but it is only at great expense; in some cases several turbines being coupled to one generator in order to get a reasonable speed for the latter. The highest pressure for which alternators have been wound is 15000 volts, but there are many running at 13,000 volts., and 10,000 to 12,000 volts. is quite common. Where the distance of transmission does not exceed, say 25 miles, the alternators could therefore be wound for say 15,000 volts. and step up

transformers dispensed with, but for higher transmission line voltages the pressure or the alternator should be say 5000 and the voltage stepped up. Generating at high pressure is liable to cause nitric acid to form by silent discharge.

Transmission Line.—The longest transmission in the world is from Colgate to San Francisco via Mission San Jose, a distance of 220 miles, or say a little more than from Orange to Sydney. The Colgate power house develops 15000 horse power. The next is 154 miles, from Electra power house to the same city, and there are a great many above 100 miles, including the Cauvary Falls, India. It will therefore be seen that *a transmission of 60 miles from Trawool to Melbourne, or Barren Jack to Sydney, is quite a simple matter.* In California eight power houses are linked together by transmission lines, and although put down originally as independent plants, they now run in parallel almost as easily as if all the generating units were under one roof. The total length of transmission lines on this system is well over 1000 miles. When transmitting power over long distances, it is necessary to run as straight as possible, which frequently means purchasing the right of way. In this respect expense in Australia would be small, and it is probable that many transmissions could be run along the railway lines. The writer looks forward to the day when *coal fuel power stations as Newcastle, Sydney, Lithgow, and on the South Coast will be linked up with several water power stations at* Barren Jack, the Grose Valley, the Colo River, etc., and the bulk of the railway system this side of the mountains worked electrically.

Voltage.—The voltage of transmission is limited by (*a*) leakage or discharge losses between the conductors; (*b*) difficulty in obtaining porcelain insulators to withstand

high pressure; (*c*) unfavourable atmospheric conditions, sea air and dust. Sixty thousand volts is the highest pressure at present in use, and it has been found that with the wires $6\frac{1}{2}$ feet apart the discharge losses can be kept down to a reasonable amount. It is now proposed, however, to employ 100,000 volts, and the Muskegan Power Co. of Michigan are changing over one of their lines.

The highest voltages at present employed in Australasia are 23,000 volts at Hillgrove to 35,000 volts at Dunedin, but except on the coastline belt almost any pressure could be used, because the air is so dry. Deciding upon a voltage and periodicity is almost as important as deciding upon a railway gauge, and it would be well to have such matters settled.

Size of Wire.—The size of wire depends partly on how many hours each day it carries the maximum load; if only a few hours the voltage drop at full load can be say 15% otherwise 10% is the rule. The actual size employed is generally just about $\frac{7}{16}$ inch diameter, if of solid copper, and about $\frac{5}{8}$ if of stranded aluminium. The latter metal is preferred for long lines because it is cheaper. *Thus for equal conductivity 48 lbs. aluminium is equal to 100 lbs. of copper, so that if aluminium is being sold in the standard form at say £100 a ton (in ingot it is £80) then copper wire must be £48 (in ingots it is about £55 at the present time) in order to compete.* Of course aluminium presents a greater surface to the wind and for ice and snow to form upon, but these are not difficulties likely to be met with in Australia as they are in Canada and some parts of Europe. It should be noted that when branch lines have to carry small currents the size of a copper or aluminium conductor would be too small mechanically, say below No. 4 S.W.G., and in such cases iron wire is frequently used.

Poles.—In a country which produces splendid hardwoods it seems sacrilege to suggest that steel lattice towers should be used, but the tendency in other countries is all in that direction. Steel towers or lattice poles spaced 10 to the mile are not much more expensive than wooden poles 40 to the mile, taking into account the shorter life of the wood and the greater number of insulators and pins. Wooden towers could be used, but white ants and bush fires are against the use of wood. Long transmission lines have to be efficiently patrolled, and in this respect *Australia is more favourably situated than in countries like South Africa and India, were mischievous or hostile natives may give trouble.* In the Cauvery Falls to Kolar gold fields line in southern India, the natives found that the voltage on the telephone wire was not dangerous, and stole it, until the engineer hit upon the plan of putting high pressure on the line during the night time.

Insulators.—To insure that there shall be no internal defect, large porcelain insulators are usually made in two or three parts cemented together, and sometimes one part is of glass. The petticoats are usually about the same diameter, arranged one above the other so as to give necessary axial length. The break down test is made at double the working pressure, and carried out by placing the insulator in an inverted position in brine. The pin hole is also filled with brine and the pressure applied between the two. The test for non-absorbent quality of the porcelain is to break the insulator into small pieces and weigh after drying at 212° Fah. The pieces are then steeped in water for 24 hours, weighed again and if there be any difference in weight the batch of insulators is rejected.

Iron pins cost more than wood, but the total cost of pins is only a small percentage of the total cost of a transmission

line. The pins on the Waipori to Dunedin transmission are of galvanised iron 2 inch diameter sagged down where they enter the brownware insulator. Portland cement mixed with water to a thick liquid is usually employed to fasten the iron pins to the insulator, but sulphur and litharge and glycerine have also been used. Brownware is preferred to white because the insulators are not such a tempting target. For pressures above 60,000 volts the pin supported insulator is not suitable, as it becomes too tall for mechanical strength. An entirely new type has therefore been developed in which the wire is suspended from the under side of the cross arm by several porcelain dish-shaped disks, held together by steel wire loops which pass through eyes in the insulator.

Of the various methods of taking care of lightning, the water jet arrester seems to be the most certain. The horn arrester is much used, and the objection that the time taken for the arc to break is enough to set up dangerous surgings, can now be met by arranging aluminum cells in the earth circuit. These cells have the property of shutting off one half of the alternate current wave, and thus the current is broken instantly.

Summary.—In conclusion, the writer would like to emphasize the following points:—

(*a*) There is some natural water power in Australia, and the Barron Falls installation is one that should be worth carrying out. The Queensland Government should either do it or let a company get to work.

(*b*) In no other country can large bodies of water be so cheaply conserved and for the peculiar conditions of Australia such conserved water would be almost as good as a gold reserve.

(*c*) With a proper provision of balance reservoirs, the water from irrigation dams could be made to develop quite respectable amounts of power all the year round.

(*d*) By such development of electric power the price of water to the irrigationist would be reduced, and this is an important matter if irrigation is really to be successful.

(*e*) In other countries it has paid to build large dams merely for electric power, and therefore expenditure on dams which provide water for irrigation as well as power would appear to be still more justified.

(*f*) When the Trawool dam in Victoria is built, it will be easily first amongst the reservoirs of the world, for the amount of water stored as compared with the size of wall.

(*g*) At a conservative estimate it will develop at least 10,000 HP. all the year round, without in any way interfering with the use of the water for irrigation.

(*h*) In order to enable water from irrigation dams to be used for power a balance reservoir at a lower level is necessary to catch the water passing over the main dam when it is not required for irrigation.

(*j*) To reduce the amount which may have to be paid in compensation in the future, Governments would do well to reserve all valleys which are at all likely to be required for water conservation.

(*k*) Given a supply of electricity from a hydro electric station it does not follow that it need be transmitted over long distances in order to find a market.

(*l*) Some of the largest water powers such as Niagara and Rheinfelden have electro chemical and metallurgical factories near the power house. They give an ideal load, so the price of power can be very low.

(*m*) Refining of copper electrolytically and the manufacture of carbide of calcimum are two processes which could at the present time absorb a great deal of electric power.

(*n*) The ideal use, however, would be to manufacture artificial nitrate manures with the same water that goes to irrigate the land.

(*o*) The consumption of such manures produced by electricity is bound to rapidly increase as more and more land is put under cultivation and the Chilian nitrate deposits become worked out. The limit of the latter is said to be another 30 years.

(*p*) Power at £2 15s. per electrical horse power year, which is the price suggested by the Queensland Government, for current from the Barron Falls is equal to about $\frac{1}{8}$ of a penny per B.O.T. unit if used right through the day.

(*q*) A high load factor is more a necessity for hydro electric plants than for steam, and in case there are peaks they are better cared for by water storage than by electric storage.

(*r*) Hydro-electric power houses are immensely superior to steam plants, because of the simplicity of the building and the attendance being about one-fourth, whilst fuel, which is the biggest item in a steam plant, entirely disappears.

(*s*) The Pelton wheel is the cheapest form of prime mover there is, and it would be the type employed at Barron Falls. It works efficiently on heads of over 2000 feet.

(*t*) High head falls are preferable to low heads, because the speed of the water wheel is higher and this cheapens the electric generators. The cost of hydraulic works is also lower.

(*u*) There are many electric power transmissions over 100 miles in length and one over 200 miles, so that transmissions of say 70 miles from Trawool to Melbourne

or Bendigo, or from Barren Jack to Sydney, would be a a simple matter.

(*v*) In the future, coal fuel power stations at Newcastle, Sydney, Lithgow, and on the South Coast may be linked up with hydro electric stations at say Barren Jack, the Grose Valley, the Colo River, etc., just as power houses hundreds of miles apart are linked together by transmission lines in California.

(*w*) As compared with long distance transmissions in other countries, Australia presents several advantages :— There is be no trouble with anchor ice in turbines; no breaking down of transmission lines on account of ice and snow; as the air is very dry, except on the coastal belt, practically any voltage can be used. There would be very little to pay for rights of way, transmission lines and straight runs would be possible; the patrolling and maintainance of such lines would be easy.

SOME NOTES ON THE STATE OF THE MELBOURNE WATER SUPPLY.

By T. W. KEELE, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 15, 1908.*]

IN view of the present very serious situation at Melbourne in regard to the water supply, it will doubtless be of some interest to members of the Engineering Section of the Royal Society to know from whence the water is derived and what is the reason for the present shortage.

Melbourne is served by (1) The Yan Yean, (2) The Maroondah, two separate systems which deliver the water into a distributing Reservoir at Preston, which is about 7 miles in a direct line from the G.P.O., and is at an elevation of 328 feet above sea level. Its capacity is 16 million gallons or 2 millions less than our Centennial Park Reservoir.

The Yan Yean System derives its supply from the drainage of the coastal range of mountains, the summit of which at this part is 2,630 feet above sea level, and about 29 miles in a direct line from the G.P.O. Here the River Plenty, Wallaby Creek, and Silver Creek take their rise, the former flows to the South of the range, and the two latter to the north. Small weirs intercept the drainage from the Wallaby and Silver Creek catchments, whose combined watersheds amount to 11,500 acres or 18 square miles, and divert it into an aqueduct which conveys it to a low place on the crest of the main dividing range, where the elevation is 1694 feet above the sea. From this point the water drops a height of 633 feet in a length of 683 feet through a series of shoots and artificial falls lined with

granite, discharging into Jack's Creek, which is one of the branches of the Plenty River. It then follows the bed of this creek for 3 miles and enters the Tooroorong Reservoir, which receives the combined waters of the Eastern Plenty, Jack's, Silver and Wallaby Creeks, from a total catchment area of 22,000 acres or 34·37 square miles.

The dam of this reservoir is 15 chains long with a puddle wall; the inner slope is protected with granite pitchers. The area is 36 acres, and the storage capacity 60 million gallons. The water from the reservoir is conveyed by a "clear water channel," $4\frac{3}{4}$ miles in length, lined with granite pitchers, having a carrying capacity of 120 million gallons per day, and discharges into the "old Plenty Aqueduct," which connected the Plenty River with the Yan Yean Reservoir. The Yan Yean Reservoir is formed by the construction of an earthen bank, 49 chains long, 30 feet high, 20 feet wide on top, inside slopes of 3 to 1, outer slope of 2 to 1. The by-wash is 5 feet below the top of the bank and is at a level of 602 feet above low water at Hobson's Bay. When full the water covers an area of 1,360 acres, with an average depth of 18 feet and maximum depth of 26 feet. The total capacity being 6,400 million gallons, of which 5,400 million gallons are available for consumption. From the reservoir the water enters an open aqueduct 7 miles long, which delivers into a small reservoir 14 feet deep and holding 3 million gallons, which serves as a pipe head, and is at an elevation of 485 feet over sea. The delivering capacity of the aqueduct to this point is 33 million gallons per day. From the pipe head reservoir three large mains viz., a 27 inch and two 30 inches lead the water to Preston Reservoir a distance of 7 miles. This reservoir as before stated, is 328 feet above sea level and holds 16 million gallons. This system served Melbourne for a considerable time, but the increasing population and

demand for water requiring an additional supply resulted in the selection of the Maroondah or Watts' system being brought into operation in the year 1891.

Maroondah System.—The water from this system is obtained from the tributaries of the Yarra arising from the flanks of Mount Juliet, Mount Monda and Mount Riddell, whose altitudes are 3,651, 2,974, and ——[1] feet respectively. The completed Maroondah scheme includes a storage reservoir with a dam 105 feet high, calculated to store 2,000 million gallons. This dam has not yet been constructed, as up to the present the natural flow of the creeks with the storage in the Yan Yean reservoirs have proved quite capable of providing all the water at present required for Melbourne, equal to about 44 million gallons per day summer service. The watershed of the Maroondah system embraces an area of 35,500 acres or 55·46 square miles.

A temporary weir has been constructed of Portland cement concrete across the Watts' River, from which the water is led in an aqueduct 41 miles long to the Preston Reservoir. On this length there are 25½ miles of open contour channels, 12 tunnels aggregating 6½ miles, three of which are about one mile long, and 14 inverted syphons totalling 9¼ miles. The open conduit is lined with cement concrete or brickwork in cement, the cross section being a quadrant of 3 feet 10 inches radius, with 1 to 1 slopes, and a fall of 1 foot per mile. The channel as now completed, is capable of delivering 25 million gallons per day, while the tunnels are of this capacity lined where necessary with brickwork or cement concrete.

The valleys are crossed by wrought iron syphons 50 to 53 inches diameter, with falls of 7½ or 4 feet per mile respectively. These syphon pipes are ¼ inch or ⅜ inch wrought iron plate, in some places carrying a pressure of 100 lbs. per square inch. With the exception of the Plenty

[1] This height cannot be supplied.

River, which is crossed on a wrought iron girder bridge, all the syphons are laid under the beds of the streams. At each of the charging and discharging basins, provision is made for connecting a duplicate syphon. Each of the syphons is provided with a scour pipe large enough to take the full flow of the aqueduct, enabling the water to be directed down any of the natural water courses when it becomes necessary to empty any lengths of aqueduct for cleansing and repairs. The tunnels are constructed to carry 50 million gallons per day, but the aqueducts and syphons are only now arranged for 25 million gallons, but by constructiug the duplicate syphons, and raising the side slopes of the open channels the necessary increase to 50 millions can be readily obtained.

Preston Reservoir.—Both the Yan Yean and Maroondah systems unite in the Preston Reservoir where the water is distributed to the central parts of the Metropolis. This reservoir is constructed partly in excavation, partly in bank, and is lined with bluestone pitchers, the side slopes being $1\frac{1}{2}$ to 1. It is 20 feet deep, and holds 16 million gallons.

The Yan Yean reservoir with a by-wash level of 602 feet governs the whole Metropolitan area by gravitation. The Maroondah system only delivers into Preston reservoir at 328 feet.

Average daily consumption for each month from 1891 to 1903:

	January.	February.	March.	April.	May.	June.
Average	33093436	34666704	30185718	25211126	22520842	21287286
Maximum	37821998	41630304	33610839	28562900	27147129	25689700
Minimum	28306891	28498814	25008731	21280987	19412690	17036021
	July.	**August.**	**September.**	**October.**	**November.**	**December.**
Average	21321399	22127792	22664674	25067122	29339076	33101834
Maximum	34349226	26580548	27135736	29047355	34956667	38276258
Minimum	17273423	18110390	19534740	21836103	25177922	28575041

The demand for water increased from 32 gallons per head in 1877 to 41 in 1887, but as soon as the Maroondah system became available the use of water rapidly increased. In 1888 it was 49, rising in 1894 to 61, then dropping to 52 in 1896, rising to 61 in 1898.

The total quantity of water that can be sent into Melbourne by the existing works is—

Yan Yean system	33	million	gallons	per day
Maroondah	25	,,	,,	,,
High level main	9	,,	,,	,,
Total possible daily supply ...	67	,,	,,	,,

NOTE.—The above description of the Melbourne Water Supply is extracted from the Engineer-in-Chief's Report of 1903.

It will be seen from what has been stated, that Melbourne is supplied practically from the daily flow of the streams, and the quantity received from these sources has been so good that it is only on occasions when the rainfall is considerably below the average, when the demand for water is in excess of the combined stream flow that the Yan Yean reservoir has been called upon to make up the deficiency. Owing to the long continued drought the draft upon the reservoir has been so continuous as to reduce it to a level never previously experienced, and very great anxiety is felt as to the result should the dry spell continue.

It will be remembered that I drew attention in my address on May 20th, 1908, to the fact that there had been a persistent decline in the rainfall from the year 1875 to 1898 as shown by the Melbourne residual mass curve diagram, and that although a slight rise had occurred for the six years following to 1904, another persistent decline had set in which has continued to the present time when the ground water would probably be found to be at a lower level than it had ever attained before.

That the conditions which have existed since the year 1875 are having the effect I anticipated may be judged from the following extract from a report by Mr. E. G. Ritchie, the Melbourne Engineer for Water Supply, published on July 1st, 1908. The report is as follows:—

"Lest too much reliance be placed upon the results from the rainfall of the past few days, and the warning of the drought be soon forgotten," Mr. Ritchie points out, "From 19th to 24th inst., we have had the splendid rainfall of 516 points at Wallaby Creek, making 736 points for the month up to 24th. This is a record of total rainfall for June which during the past 18 years has been exceeded only upon five occasions. Nevertheless, the total intake to Yan Yean reservoir has not exceeded a rate of 30 million gallons per day. Under normal conditions of saturation I should have expected nearly three times the rate of intake from such a rainfall as that of the past few days showing how great have been the demands from the absorbent soil. I might mention that the carrying capacity of the intake channel is 120 million gallons per day. The net gain in depth of the Yan Yean reservoir from this rainfall has only been about 8 inches to date. There is no doubt of course that the daily volume of the streams will be fortified for some time, but the fact remains that the larger portion of this splendid rainfall has gone to make good the losses incurred by the failure of the last autumn rains. The results may be further improved by phenomenal rainfalls, but I do not think we are at all justified in expecting such. The possible exhaustion of the reservoir which I have predicted may be to some extent averted by further drastic economies, which will amount—possibly to restriction—at least to greatly reduced pressure. Even if the latter course only be resorted to, it must mean deprivation to the residents of the Metropolis, less water for gardens and a great loss in revenue to the board which can ill be faced. Further it will mean increased peril by fire."

The Engineer-in-Chief Mr. Oliver, in his covering minute refers to the

" Remarkable and unexampled falling off in the streams supplying the Yan Yean for such a long period has reduced the stored water to a dangerous point. The fears expressed he adds are not based on mere conjecture, but on absolute results of intake and output."

The President of the Board, Mr. W. J. Carre-Riddell, in his report says :—

"Although there is only a possibility of the Yan Yean being completely exhausted during next summer (which is unpleasant to contemplate) there is a great probability of that reservoir being then reduced to such a dangerously low level that the supply for the following years may prove insufficient for domestic and sanitary purposes. It is therefore of the utmost importance that immediate steps be taken to prevent the exhaustion of the Yan Yean, and the only means available are the diversion of the Coranderrk Creek and the Acheron River. The former work will be put in hand at once, and the latter should be carried on simultaneously so that both streams may be contributing their waters to the supply of Melbourne early in the new year at the latest, when the supplies from the Watts' River begin to fall off. The work of raising the sides of the Maroondah aqueduct is rapidly progressing and will be completed towards the end of this year, so that it will be in readiness to receive and deliver the waters of the Acheron into Melbourne on the completion of the work of diverting that stream. Upon the completion of the Coranderrk and Acheron diversions all will have been done that is possible to secure a supply of water to the metropolis during the interval which must elapse before the O'Shanassy scheme is completed. Even with the aid of the Coranderrk and Acheron it will require the greatest care and economy in the use of water to tide over the time required to carry out the O'Shanassy works. In reference to the Acheron diversion it is proposed to construct an earthern channel capable of delivering 7 million gallons per day, but there is no intention to take that amount of water all the year round. For the greater part of the year the Watts' River and Coranderrk Creek will

suffice for the requirements of the lower levels, but when the daily consumption of water exceeds the supply from those sources the waters of the Acheron will be availed of to make up the deficiency. It is estimated that the full amount of 7 million gallons per day will only have to be availed of during periods of high consumption, and that during a considerable part of the year there will not be any necessity to take any water at all from the Acheron. In the summer provision can be made by means of compensation water to secure ample supplies for domestic purposes for those dependent on the Acheron."

The Coranderrk Creek drains an area of about 7 square miles to the south of the Watts' River watershed. It is proposed to divert the water from this area amounting to about 3 million gallons per day, by a pipe conduit 4 miles in length delivering into the Maroondah aqueduct. The walls of this aqueduct are now being raised and strengthened to enable it to carry from 28 to 30 million gallons per day. As the lowest parts have been raised first, the aqueduct now brings about 1½ million gallons more water daily to the Preston reservoir than ever before. The result is that up to 24 million gallons of water have come from the Maroondah system to meet the daily demands of the metropolis, and it has been necessary therefore to draw upon the Yan Yean reservoir to only a very slight extent. Recently the water flowing down the Maroondah aqueduct has been within two inches of the top of the bank.

The Acheron River takes its rise in the mountains north of the Watts' River and the stream ultimately finds its way into the Goulburn River. The mountains here attain an elevation of over 3,000 feet. It is proposed to divert the water of this river from an area of about 9 square miles, and lead it round to a low saddle in the dividing range separating the Acheron from the Watt's River catchment area where the altitude is 1,628 feet. The water being

discharged on the southern slope of the dividing range would thus find its way into one of the tributaries of the Watts' River and ultimately into the Maroondah aqueduct.

The O'Shanassy scheme referred to in the reports proposes to intercept the water draining from an area of about 59 square miles of mountainous country lying to the east of the Watts' River about 6 miles, and to lead the water by a channel to carry 25 million gallons per day at present, to a pipe head near Woori Yallock, from which point pipes 42 inches and 50 inches diameter would be laid to a storage reservoir near Mitcham. The estimated cost of the scheme is £675,000.

It will be seen from the extracts from the official reports which have been published, that the situation in Melbourne with reference to water supply is very disquieting. It will take at least three years to bring in the water from the O'Shanassy River, and in the mean time it is absolutely necessary to augment the present supply from the Yan Yean and Maroondah systems in the manner described. No objection seems to be raised to the diversion of the Coranderrk Creek into the existing aqueduct, but there is very strong opposition by the residents on the Acheron and Goulburn Rivers to the head waters of the former stream being tapped for the supply of Melbourne.

The Minister for Water Supply Mr. Swinburne, says:—

"I am very strong in my attitude, and I will never give way on this point, that the waters of the Acheron belong to the northern areas. The northern people must not have taken from them water they require in order to save the Melbourne people expense. What the Board wants is equal to $\frac{1}{50}$ of the total summer flow of the Goulburn, and the Acheron waters are among the most assured sources of supply."

The Cabinet has arrived at the following conclusions as published in the press of 11 July :—

"The Cabinet recognising that the water of the Acheron is part of the Goulburn system and is required for the development of agriculture in the northern areas where the supply of water is already inadequate, is extremely reluctant to even temporarily divert any flow that will affect those localities, and the more so as assured and ample water supply for the metropolis can be obtained from other sources. In view, however, of the Board's contention that danger of the most serious character to the inhabitants of the metropolis, may arise, unless the Board has during the next three years the opportunity of supplementing its water supply by a diversion from the river, the Cabinet is prepared to grant the concession on the following general conditions, which if approved by the Board will be later incorporated in an agreement :

(*a*) That the Board guarantee to the satisfaction of the Minister of Water Supply, that it will proceed with and complete within three years from the date of the signing of the agreement, an adequate scheme for the improvement of the water supply of the metropolis from the O'Shanassy River, or some other source than a tributary of the Goulburn.

"(*b*) That the works necessary for the temporary diversion be designed and constructed to the satisfaction of the State Rivers and Water Supply Commission which may itself either carry out the whole or part of the works, or may require the Board to do so. The Board in either case is to pay the total cost of the works, and also all the subsequent cost of maintenance and management.

"(*c*) That while the various districts dependent on the Goulburn system of water supply have received the quantities of water at present, or that may from time to time be allotted to them, the commission may apportion, divert, and supply to the Board from the available remainder, such quantities as the Commission may decide.

"(*d*) That the Board pay to the Commission for the water so diverted by the consent of the Commission at the rate of 1d per 1,000 gallons, such payments to be made every three months."

The press states that this communication will be considered at a meeting of the Water Supply Committee, and it will probably come before the Board at the meeting to be held on Tuesday week. In the meantime members of the Board are being confirmed in their opinion that it is not equitable for them to be called upon to pay for the water at its source, in view of the fact that about £36,000 worth is given to the Government free every year for use in Government departments. That sum does not include either water for flushing channels, watering the streets, supplying gardens under the control of the Government, nor what is used in extinguishing fires, for all of which no charge is levied.

* * *

It will be seen that these conditions are very stringent, even at one million gallons per day so diverted from the Acheron into the Watts' River watershed, the cost will be for the necessary works £6,000, and for water at 1d per 1,000 gallons £4 3s. 4d. Very little is known about the Acheron, and as to what quantity is available. The area above the point of interception of the water is only about nine square miles, and the long continued drought has no doubt affected that stream in a similar manner to the Wallaby and Silver Creeks, which Mr. Ritchie has already stated are diminishing quickly. In view also of the ground water in the Watts' River catchment area being at a lower level now than ever before, since records have been made of the rainfall, it appears to me that only a small proportion of the Acheron water discharged over the mountain side will find its way to the aqueduct situated at the lower levels. The probability is that a considerable part of the water will be absorbed on the way down, and although it will not be actually lost inasmuch as it will be stored underground to ultimately assist in feeding the stream, it will take a long time to gravitate to the point where it is now so much needed.

Seeing that there is such opposition to the diversion of water from the Acheron River, and that if proceeded with it will be exceedingly costly for the small amount of water likely to be derived thereby, which also may be seriously diminished before it reaches the intake to the aqueduct by losses such as I have described, it will be well to consider whether the money proposed to be expended on the Acheron scheme would not be more advantageously applied to the extraction of the additional water required from the saturated beds adjacent to the streams on the Watt's River watershed, and at the same time commencing works for the development of that system, by conserving as much as possible the underground water.

Notwithstanding the protracted drought the Maroondah catchment area appears to yield still a very large quantity of water, I think something like 17 million gallons daily is now flowing into the aqueduct for the needs of Melbourne. How long it would continue to discharge at this rate if the dry season continues it is impossible to say. The stream fluctuates of course with the rainfall. Every shower that falls upon the area contributes its quota to the stream and also to the underground supply or water table. If the water table is low, the immediate "run off" will be very much diminished as has been already proved on the Wallaby and Silver Creeks. That portion of the rainfall which is absorbed by the soil and goes down below the limit of evaporation (which is estimated by competent authorities at 2 feet) continues to sink until it joins the water table.

If the rainfall is sufficient in quantity and rate of fall to maintain the level of the water table, the hydraulic gradient underground will remain constant, and the streams will continue to flow in undiminished volume. We know, however, in the case of the catchment areas on which Melbourne relies for its supply, that the stream flow has very

seriously fallen off, and must therefore conclude that the water table must be low and is still falling.

The Melbourne rainfall diagram (*Plate 3*) shows that there has been an accumulated loss of rain below the mean at that place since the year 1875, amounting to 47·94 inches, or 1·8 years mean rainfall, and although a much higher rainfall is experienced on the catchment areas (probably nearly double that of Melbourne) it is reasonable to suppose that the same influences which have resulted in the decline at Melbourne, have affected those areas in a similar manner and the water table there is in all probability at a lower level than ever previously known.

In view, however, of the large quantity of water still running from a comparatively small area like the Watts' River catchment, viz., 55½ square miles, it is evident that there must be an enormous underground storage, either in the upper or lower portions of the area, probably in the latter. It would thus appear to be feasible, in order to maintain the supply in the aqueduct, or to augment it if necessary, to drain the water out from the saturated beds by making cuttings or trenches into the hill sides, or by constructing drains to be laid in trenches and parallel to the creek beds, properly protected with broken stone surrounding the pipes in order to arrest the sand while permitting the water to enter the joints or perforations. In this manner no doubt as much water as may be required could be liberated from the saturated ground by extending the drains. While this system would no doubt be very effective in keeping up the supply, it would assist in lowering the level of the water table in those areas where the operations were carried on, and it would therefore be necessary to construct works in suitable places in the upper portions of the catchment area to impound water resulting from heavy rains, which would exceed the discharging capacity of the aqueduct and would consequently run to waste.

Dams of the "rock fill" class could be quickly and economically built in the beds of the principal streams, or crib dams of rough timber logs could be erected, which would retard the flow of water during freshets and pass it off slowly. The water could also be diverted from the creek beds and conveyed by shallow channels contouring the hill sides, distributing the water in such places where there are thick deposits in which it would be quickly absorbed, thus artificially irrigating the soil for the purpose of storing up the water underground.

The building of the Maroondah dam should not be neglected any longer. It should certainly form part of the scheme for conserving the water, *by preventing the escape of the underground water, and impounding it*, together with the surplus water of freshets beyond the capacity of the aqueduct. This reservoir is estimated to contain 2,000 million gallons of surface water, but the dam being over 100 feet high would raise the level of the ground water at the back and sides over a very considerable area, thus conserving a very large underground supply.

Enough has been said to show how the scheme for conserving water above, and underground, could be developed to such an extent that a very large proportion of the water which fell as rain would be stored, and if the same treatment be extended to the Yan Yean system it would probably be sufficient to obviate the necessity for going further afield in search of new sources of supply for very many years. Silting up in the retarding reservoirs would probably take place in time, but it should be remembered that this can not be regarded as a total loss, for the reason that even if they filled up completely with sand they would still conserve in the interstices between the grains of sand about one third of their mass in water which would drain off slowly. Being of such cheap construction, others could be built

readily to replace them. The silting up of the Maroondah dam would be deferred indefinitely by the construction of these retarding dams on the upper part of the catchment area, but the débris carried down by storms from the thickly wooded area would be arrested and prevented from passing into the aqueduct, and the water having undergone a process of sedimentation in the big reservoir would be supplied to Melbourne of better quality than at present.

DISCUSSION.

The WATER SUPPLY of SYDNEY, PAST, PRESENT and FUTURE.

By T. W. Keele, M. Inst. C.E.

17th June, 1908.

Mr. Norman Selfe said, in the first paragraph of Mr. Keele's most interesting paper he states that the subject will no doubt afford ample scope for discussion. While it is not the general rule to discuss the addresses of retiring chairmen, it was certainly true that in the present case, the author had opened up a subject on which there was very much in addition to be said and in danger of being forgotten. He therefore, proposed rather to supplement than to discuss if the meeting was agreeable. As the paper opened with the history of the tanks and Tank Stream he (Mr. Selfe) thought it might not be generally known that among the many pictures of early Sydney, there was one published in London, at the beginning of the last century, which actually showed these tanks, and he had intended to bring it in to the meeting, so that members

who desired might inspect it; it could however be seen at the Conversazione of the Historical Society in the same room in a few days time. There was a proposal in the very early days to dam the tank stream at about Bridge-street, with the view of getting power for working a water wheel, but the futility of the idea with such a small watershed, was probably soon seen through. Mr. Keele makes no reference to the great number of public and private pumps from wells which supplemented the tank stream supply in early days, but many references to them appear in the records of those times which present startling contrasts to present day conditions.

On the 9th August, 1825, a committee of the Council—in a report with regard to the Carter's Barracks (the buildings lately removed to make way for the Central Station)—said, "The boys should be separated from the carters, and instructed in the trades of carpenters, wheelwrights, tanners, block makers, and *pump borers*," thus showing that the use of pumps was so very common at the time as to constitute work for a trade to make them from the native trees. In the *Gazette* of 7th January, 1810, there is an account of £36 paid to Jas. Bowler for a pump in the gaol yard, while others stood in the streets, one at the corner of George and Barrack Street was objected to as so hard to work that animal power was desired to work it. There was a fine spring which supplied water to the public at the rear of the present Education Office, then the Colonial Secretary's, over which Isaac Peyton erected a beautiful little fountain in 1812, designed by Governor Macquarie's architect Mr. Greenway. This is perpetuated in the name of Spring Street. One of the vandalistic acts of Sydney's custodians was the destruction of this structure when the space was needed, instead of carefully taking it down and re-erecting it in one of the parks. (An illustra-

tion of this fountain in water colour was exhibited). There was another fountain in Macquarie Place, erected also in Governor Macquarie's time; the temple over it was removed to make room for the Mort Statue. This fountain was illustrated in Fowle's "Sydney in 1848."

On page VII, of his address, Mr. Keele mentions that in 1854 a small pumping engine was erected by the City Commissioners at the Lachlan Swamp to raise more water into the tunnel, he (Mr. Selfe) had long been of opinion that such engine was part of the work of the old Corporation, and that the credit of its establishment was due to Mr. Daniel Egan the mayor of the City in 1852. In the *Illustrated Sydney News* of that period there is a portrait of Mr. Egan, and an account of certain improvements in the water supply carried out on his initiation, with the dam and machinery "now on the eve of completion," being due to this gentleman. It is however possible that this work may not have been put into operation until after the dissolution of the Corporation and the advent of the three City Commissioners, who were superseded by the Hon. George Thornton as mayor in 1857. There are a great many interesting circumstances connected with the Botany Waterworks, and the task of getting the heavy machinery there which are brought to mind by the address. One at least of the large boilers was towed round to Botany Bay by the "Washington" tug and parbuckled ashore, owing to the heavy traction on the sandy road. With these engines a stand pipe originally came out from home, but air vessels were afterwards adopted and the stand pipe was never erected. One gentleman who used to write to the newspapers of the day was wont to attribute all the troubles in connection with the water supply to the non-erection of this appliance; cuttings still preserved show that there was much amusing controversy over the matter.

Mr. Keele necessarily passes very briefly over the report of the Royal Commission of 1867, but there is much instructive matter to be gleaned from that great document in the light of contemporary and present experience. We have now a body of trained engineers in the public service, but at that time there was not one member of the Water Commission (although they were all men of attainments) who was qualified to make the estimates for a water supply scheme. The late Mr. Bennett was the most competent civil engineer no doubt, but it is curious to read now how greatly the cost of favoured projects was then under estimated, and how those schemes not presenting such attractions to the members were over estimated. On page 40 of the report the estimated cost of the Upper Nepean scheme is put down at £790,029, but in the interval between 1869 and 1877 it rose to £863,525. Then Mr. Clarke came out from England to report on it, and from the data supplied to him (see Report p. 16, 1877) made it £1,086,763. But the Hon. John Lucas writing to the press of the day in letters, subsequently printed at the Government Printing Office in 1876, p. 6, made his estimate £2,600,000, taking Mr. Moriarty's quantities and Mr. Whitton's prices. Which of these was the nearest need not be stated as it is known to all present. Mr. Clarke estimated the cost of water by the Upper Nepean scheme supply with 12 millions daily 3·327 pence, with 18 millions daily 2·45 pence per 1000 gallons, and specially favoured the scheme because the system was so elastic that the charges per 1000 gallons would come down with every increase in the supply. The price is still at a shilling.

With regard to Mr. James Manning's far seeing proposals and his persistent advocacy of high level storage and gravitation, Mr. Keele has not been able in the space at his disposal, to do that gentleman justice. Mr. Manning,

however, was—like many other men—thirty years ahead of Mr. Moriarty, and the truth of all his disinterested representations as to the advantages to Sydney of a high pressure supply by gravitation is now being realised. Mr. Clarke's estimate (in his report) of the amount of water which would require to be pumped above Crown Street, was absurdly small even at the time it was made, but perhaps the mistake was quite excusable in a stranger, whom there was no necessity to send for. Mr. Keele has since done yeoman's work for the community in pointing out where and how water in the future can be found and impounded at high levels, thus not only doing away with the expense of pumping it up again—after as now, allowing it to fall hundreds of feet to Crown Street level—but also securing supplementary channels of supply to reduce the risk of a water famine through accidents. It is very nice to read Mr. Keele's championship of his old chief Mr. E. O. Moriarty in connection with the controversies which he had with Mr. Gipps and other rivals; nothing else should be possible under the circumstances, and on the principle of *De mortuis nil nisi bonum*, it will not be attempted now to traverse the pros and cons of the rival proposals to which Mr. Keele refers, or dig up the controversies and paper warfare which extended over years in connection with the Sydney water supply; but as a matter of strict historical accuracy, it should be remembered that while Mr. Moriarty entered the Government service with a college education, it was only as an assistant surveyor, not as an engineer at all, and that if the Government thrust great engineering responsibilities upon him which thus brought him into constant conflict with public opinion through the scrutiny his proposals received, he was more to be pitied than blamed. Peace to his ashes. He (Mr. Selfe) had been brought very much into contact with Mr. Moriarty half a century ago and afterwards, and had nothing but kindly feelings for him

as an individual and gentleman, but he looked upon him as the greatest living proof he had ever met that a round peg however true and handsome, will not fill the ugly corners of a square hole.

Mr. Keele's account of the needless scares which have been raised in the public mind on several occasions as to the instability of the Prospect dam, and its present condition, is very satisfactory and reassuring, but it would be additionally interesting if he would state what was the total cost of that dam to day, and how it compares with the original estimate. With regard to the Cataract Dam, there is no doubt that Mr. Keele's actions in connection with that great work have received unanimous public approval, and that it is fortunate for the citizens that the Government finally acceded to the proposition for the greater height; only those who regularly look ahead can properly appreciate the requirements of the Sydney of the future. The tonnage of our shipping has doubled since the beginning of this present century, the city and suburbs are expanding at an ever increasing rate, the tram traffic for the population is extraordinary, and the demand and uses for water are being multiplied daily on every side. Mr. Keele has pointed out, what has long been known, that there are suitable sites for additional dams on the Cordeaux, Upper Nepean, Avon and Bourke rivers within the present watershed, but he has also made particularly his own, a proposition for a reservoir or reservoirs on the Woronora and Waratah gathering grounds. In the wisdom of the Government, his valuable services have now been transferred to another sphere, and he will indeed have achieved a double fame, if he can make so distinguished a mark in connection with the control of the harbour, as the public already credit him with in connection with the Sydney Water Supply. Apart however, from this aspect of the

case, the amount of information now collected in his recent address will constitute a permanent record in connection with the most important public service in which the metropolitan community is interested—its water supply.

Mr. J. H. CARDEW said, our late Chairman, in choosing the subject of the water supply of Sydney for his annual address, could not have selected one more appropriate to the occasion, or of greater interest to his hearers. So many years of his life have been devoted to the accomplishment of this great work, from its very inception until now, that he is the person best fitted to perform the task of recording its successive stages, and we may congratulate him upon compiling not only an able and instructive address but the best history extant of the undertaking, and a valuable contribution to the Society's Journal. The first part is of an historic character, but the latter part affords plenty of matter for discussion. The allusion to the great services of the late Mr. E. O. Moriarty was a graceful and pathetic tribute to the genius of an old chief, it is indeed sad to think that the services of this public officer in connection with the water supply of Sydney should be almost totally forgotten and not even recorded on any part of the works that his genius evolved, and it is a true commentary on the fate of most engineers in the Public Service. If this great work had been designed and carried out by an independent engineer from abroad, it would have brought him great fame and much emolument, but "a prophet is not without honour except in his own country." Surely it is not too late even now to erect on the works, some memorial of their eminent designer. With regard to the "run off" from the catchment area of the Cataract in connection with the behaviour of the reservoir, it appears to me that 40% is rather a high percentage of the rainfall to rely upon. The percentage discharged from other catchments is not nearly

so high as this. On the impermeable catchments of Great Britain the run off averages only 20%, and in the permeable catchments only 7½%. Mr. R. T. McKay, in his paper read before this Society in September 1906, gives the run off of various catchments from 15 years observation as follows:—The Murrumbidgee at Gundagai 21·6%; the Goulburn at Murchison 33%; the Ovens 28%. The above catchments may be classed as impermeable. It was found when constructing the reservoir for the Lloyd Copper Co. at Burraga, on impermeable slate country, that the amount of rainfall conserved was only 21½%. On permeable catchment such as the Murray at Morgan, in flood years the run off was 9%, and in drought years only 1%. The Darling at Wilcannia shews a mean run off of only 0·65%.

The author's reasons for anticipating a large increase in consumption of water are perfectly sound. Amongst the causes likely to increase consumption is the development of manufactures which have only just begun to expand under the Federal tariff. The amount of water consumed by a city is some indication of its refinement and civilization, and the climate of Sydney is such as to encourage a large use of water, if it can be obtained in unlimited quantity at a reasonable price. Given the latter conditions and the consumption might easily go to 120 gallons a day per head.

Not the least interesting part of the address was the analysis of rainfall and its effect on the reservoirs, but I am of the opinion that the data regarding the rainfall does not extend over a sufficient number of years to make it reliable for forecasting. I am prepared to admit the cycle theory, but so far we have no proof of the extent or periodicity of the cycles, and possibly it may require the meteorological study of hundreds of years to arrive at a solution of that question. Attention might be directed to ascertaining the greatest number of years that the rainfall is above and

below mean respectively, and the total amount of rainfall for various periods above and below mean in order to determine the periods of greatest plenty and greatest scarcity. The Sydney records seems to show a proportion of 41% of the whole above, and 59% of the whole below the mean. This disparity is greater in Australia than on the continent of Europe, India, or Africa. In Europe the range is about 45% to 55% respectively; in India 48% to 52%; and in Africa 46% to 53%. The subject is such a complex one that it is difficult to discuss it off hand, but it is one that requires to be continually watched and studied by the authorities. It is greatly to be deplored that such an expert as Mr. Keele should have been removed from a sphere of usefulness where technical knowledge and vigilant administration are so valuable to the public, and where he would have brought his professional experience to bear on the question of providing Sydney with an extended supply of high pressure water.

I am not at all satisfied that the method adopted by our late Chairman of presenting the aspect of the rainfall by the residual mass curve is the best for the engineer to adopt for a study of the question. It appears to me that the varying accumulations of rainfall over a long period of years as shewn by the residual mass curve, except on such a catchment as Botany or Long Island, might be deceptive, without some knowledge of the maximum and minimum and the intensity of the rainfall. Another element in the question is the nature of the catchment and its capacity for holding the accumulation of rainfall over a series of years. Its physical features may be such that the surplus rainfall might flow rapidly off, and after filling the reservoirs the balance would escape to the sea, leaving little or no accumulation in the ground for future delivery. On the other hand the catchment may be of such an absorptive

character as to hold all the accumulation and to give it up gradually to the rivers. The intensity of rainfall on the former class of catchment would have an important bearing, and it is quite possible that an evenly distributed rainfall much below the average for a series of years, might be more advantageous to the reservoirs than a series of bounteous years with a rainfall far above the average, but which fell at a high rate of intensity. I think it will be found that it is not the accumulation of rainfall as disclosed by the residual mass curve which is the factor engineers have to look for, but the run off and above all the fluctuations of the run off. Perhaps the residual mass curve may be of service for indicating the state of saturation of the ground and the periods when a greater or less run off may be anticipated, but I think the plotting of the rainfall itself would shew the same thing in a less deceptive manner. I think the plan adopted by Sir Alexander Binnie in a paper read before the Institute of Civil Engineers in 1892 is a better one for studying the effect of rainfall. The method adopted is to reduce the rainfalls for each year to a percentage or ratio of the average rainfall and then plot them from one common datum, the average rainfall being taken as unity. The method consists in dividing the rainfall for each year by the average rainfall thus—

$$\frac{49 \cdot 06}{48 \cdot 35} = 1 \cdot 015$$

shewing the fall for that year to be $1\frac{1}{2}\%$ above the average, or again—

$$\frac{35 \cdot 14}{48 \cdot 35} = 0 \cdot 727$$

that is the fall for the year was a little more than 72% of the average, or fell short thereof by 28%.

I have prepared a diagram (*Plate 49*) of the Sydney rainfall on this principle. It will be seen that all negative quantities are avoided, and when all the years in the series are so treated, if the average has been accurately ascer-

tained, the sum total of all the ratios will be equal to the number of years of observation. The principal question the engineer has to consider is the fluctuation of rainfall in order that he may design his works to equalize the years of bounty and scarcity, and this diagram presents at once to the eye the salient facts of the case. Let us take the wettest and driest years, and it will be found that the mean falls very close to the average rainfall or unity, thus

$$\frac{\overset{(1860)}{1{\cdot}713} + \overset{(1849)}{0{\cdot}444}}{2} = 1{\cdot}078 \text{ or } 7{\cdot}8\% \text{ above the average;}$$

here the wettest is 71% above the average, and the driest is 56% below the average. Take the average of 2 wettest and 2 driest consecutive years

$$\frac{(\overset{(1860)}{1{\cdot}713} + \overset{(1861)}{1{\cdot}207}) + (\overset{(1908)}{0{\cdot}659} + \overset{(1907)}{0{\cdot}648})}{4} = 1{\cdot}057 \text{ or } 5{\cdot}7\% \text{ above the}$$

average. Here the mean of the 2 wettest is 46% above the average and the mean of the 2 driest is 35% below the average. Take the average of 3 wettest and 3 driest consecutive years

$$\frac{(\overset{(1890)}{1{\cdot}684} + \overset{(1891)}{1{\cdot}144} + \overset{(1892)}{1{\cdot}430}) + (\overset{(1905)}{0{\cdot}724} + \overset{(1906)}{0{\cdot}659} + \overset{(1907)}{0{\cdot}648})}{6} = 1{\cdot}048$$

or 48% above the average; here the average of the 3 wettest is 42% above the average, and the average of the 3 driest is 32% below the average. A study of the averages of 6 wettest years 1840-5 and of 7 driest years 1901-7 shews a ratio of 1·035 or 3½% above the average; whilst the average of the 6 wettest years is 31% above the average and of the 7 driest is 23% below the average. This discloses the fact that the shorter the period under review the greater the fluctuation in extremes of rainfall. Now if 29 inches are required to flow off the catchment to fill the Cataract dam, and 40% is allowed as the run off, we shall require a rainfall of 72½ inches, which is 50% above the average. But if 25%

is to be allowed for run off, which I think a fair average all the year round, we shall require a rainfall of 116 inches, which is 140% above the average, and is more than the sum of all the rainfall for 1905-6-7. In the latter case the rainfall of the wettest year in the record (1860) would not fill the dam, if no water were drawn off, but the combined rainfalls of the two consecutive wettest years (1860-1) would do so. An interesting feature of the diagram are the three dry periods, the first 1880 – 1886 seven consecutive years; the second 1894 – 1898, five consecutive years; and the third 1901 – 1907, seven consecutive years; the previous years of the record of 75 years shewing nothing similar.

Mr. H. Deane dealt specially with the population and rate of increase:

The Statistician's figures for 1901 were	491,222
Mr. Keele's figures	496,960
Difference	5,742
Statistician's figures for 1902	516,540
1903	521,000
	1,037,540
Mean	518,770
Mr. Keele's figures 1902-3	523,000
Difference	4,230
Statistician's figures 1906	556,830
1907	577,180
	1,134,010
Mean	567,005
Mr. Keele's figures for 1906-7 ...	603,910
Difference	36,905

Statistician's figures—	1900-1,	increase	9,000
	1901-2,	,,	19,500
	1902-3,	,,	4,200
	1903-4,	,,	6,600
	1904-5,	,,	5,300
	1905-6,	,,	23,500
	1906-7,	,,	20,300

He would like the disparity explained. In referring to the work of the Royal Commission of 1902 he would like to say that he was prepared to admit now that the best thing had been done in building the dam to impound the larger quantity of water.

Mr. T. H. HOUGHTON was of opinion that some consideration should be given to the riparian rights of the people on the lower rivers. The drainage from the upper portions of the rivers should not be taken away wholly in the manner it had been done in the past, and was now proposed from the heads of the Woronora and O'Hare's Creeks. Assuming the population of Sydney at $1\frac{1}{4}$ millions in 30 years' time, and allowing 60 gallons per head, it would be necessary to store 6 inches of the whole catchment or 15% of the total rainfall, this would leave no flow for the lower rivers. He considered a large city like Sydney should look to sources further afield than the proposal. The future source of supply in his opinion should be from the other side of the Nepean, such as the Grose, Warragamba, or Colo Rivers, rather than from small extensions of the present catchment area.

Dr. STOKES dealt with the estimate of water likely to be required. A low estimate should not be taken. He agreed with Mr. Cardew that 60 gallons should not be considered the limit of supply. We would certainly be using large quantities of water in the near future.

Mr. J. M. SMAIL said he was pleased that the retiring address of our late Chairman has taken the form of an

account of the metropolitan water supply, past, present and future, as there does not exist to my knowledge any connected account of the development of the system—if we exclude that by the late Dr. Smith, referred to by the Chairman, written some 40 years ago. My connection with the old Sydney water supply dates from 1866, where as a young pupil in the engineering profession I had an opportunity of dragging a chain over the watershed or dressed in dungarees descended into the pump well to take measurements for alterations or repairs. The paper by Dr. Smith, quoted by the Chairman, will form a valuable link in the chain of developments of the water supply to the city of Sydney and suburbs. I have a distinct recollection of having to take charge of a gang of men about 1868 to tap the hills surrounding the Botany swamps to increase the flow into the engine pond reservoir, and although it was stated that the supply of water would give out in a few months, the engines maintained a supply of between 4 and 5 millions per diem to Crown Street—the supply from Busby's bore being limited to the soakage en route, as no water passed into the inlet. The whole of the watershed from Randwick and Waverley to the engine pond reservoir being one vast sandy sponge, the depth of sand being in some places 100 feet deep, would account for the shortage in storage when the surface water disappeared. About 1873, large tube wells were experimented with in the Lachlan Swamp area near the inlet of Busby's bore, under direction of Francis Bell, C.E., then City Engineer; although the inflow was all that was anticipated at first, the system had to be abandoned on account of the fine sand choking the bottom. It became evident that if water was to be conserved in the Lachlan Swamps it could only be by constructing dams as in the case lower down in the Botany Swamps. The rapid development of the suburbs near to Sydney, and to which the Botany system was gradually

extended, was as much the cause of shortage to the city proper as shortage in rainfall. This was, however, a blessing in disguise, as it lead up to the appointment of the commission referred to by the Chairman, which culminated in the present supply known as the Prospect supply.

The Chairman has referred to the Kenny Hill agitation for a high pressure supply as against the proposed scheme to gravitate the water to a large impounding reservoir at Prospect, thence by gravitation to Crown Street, from whence it was to be pumped to the higher zones. I need not refer to the controversy which took place at the time, as a very warm newspaper warfare was waged, and it was only through the statesmanlike attitude of the then Premier, Sir Henry Parkes, that the scheme was passed by the Legislature and assumed practical form. I have a distinct recollection of discussing the merits of the two schemes with my late respected chief W. C. Bennett, M. Inst. C.E., during a visit of inspection to the main drainage works, when he informed me that grounds for adopting the Nepean Prospect supply was a question of quantity *v.* pressure. I think it will be conceded that judging by the experience of the past, the foresight of Mr. Moriarty and his colleagues has been amply justified.

I might here refer to the old city supply again. The pumps at Botany, installed about 1857, had a full capacity of 5 millions per diem, the reticulated area was restricted to a low level zone served from Crown Street reservoir, and what was then termed, the high level zone served from Paddington reservoir. The fittings were the usual type of the period, viz., instead of the more modern ball hydrant, they consisted of wooden plugs, which had to be withdrawn very carefully by the turncock, if he did not want to have a shower bath ; very often passing pedestrians participated in the douche. A description of the engines installed at

Botany was given in a report by Norman Selfe, M. Inst. C.E., in 1880—which has no doubt been given to the members by that gentleman—so that it is not necessary to refer to them any further than that they performed their duty well, but were anything but economical as compared with later types of engines.

Coming to the year 1902, which tested the capacity of the Nepean-Prospect system, owing to the long dry spell which occurred, the water level in the storage reservoir was drawn down to about 9 feet from gravitation level; as there was no prospect of the reservoir being repleted, the Board took action by installing a powerful pumping plant in duplicate, the capacity in the aggregate being 50 millions per day; other steps were taken to augment the supply at Menangle and Penrith—the latter was not brought into requisition—and the Prospect pumping plant was only required to work for a short time, as the reservoir commenced to be repleted by copious rains on the watershed. The Prospect Dam has given trouble at different times, but owing to judicious weighting of the toe of the bank and careful attention to the dam, no fear of further movement is anticipated, although the water has been drawn down lower than 6 feet below top water level. The outcome of the Royal Commission of 1902 was the construction of the storage dam at Cataract. This has been described in the Chairman's address, but I would like to state here that the consumers in the metropolitan area are indebted to the Chairman when President of the Water and Sewerage Board for his exertions in obtaining against many obstacles such a magnificent asset in connection with the metropolitan supply. The value of his advocacy for a high dam will be fully justified in the future, in maintaining a sufficient supply to the metropolis. The existence of the Cataract reservoir as a means of storage during favourable rains

enables the authorities responsible for maintaining the supply to provide the ratepayers with all reasonable requirements in proportion to the quantity conserved. As it will naturally take time to fill the reservoir, and in this respect Sydney is not different to other large cities, the value of the reservoir cannot well be tested until it arrives at its fullest extent.

I do not agree with the statement that it is not advisable to draw down Prospect below 6 feet, although at one time I was of the opinion, for considerations of stability, that it would be inadvisable to do so, but later experience has amply demonstrated that the bank would be quite safe if drawn much lower; consequently, if necessity demanded it, the water could be used to the fullest extent, supposing that Cataract dam was empty. I quite agree with the Chairman that it would be unwise of the authorities to lull its constituents into a false state of security; I am quite certain that it will not be the question of expenditure which will deter the authorities from making the necessary provision to provide for the future. There is no doubt that the consumption per head of the population supplied is low as compared with other Australian cities, taking the supply per head when no restrictions were placed upon consumers; the maximum was 43·95 gallons per head in 1901, compared with Melbourne and Adelaide with from 60 to 64 gallons per head respectively. In the case of each of these cities they have had to face shortage. The question of consumption per capita depends in a measure on the method of measurement and prevention of waste. During the year ending June 1907, the consumption per capita was 37·92 gallons per head; the figures for 1908 have not yet been worked out, but I do not anticipate any material increase in the quantity, although restriction has been placed on the reasonable use of water from the Board's mains for sanitary purposes.

I am quite in accord with the Chairman's remark that the future requirements should be forecasted, so as not to leave a narrow margin to execute the necessary storage reservoirs. In connection with this, the investigations made by the Chairman will form a valuable guide; this opinion I formed while having the advantage of seeing the results during the investigation. I do not know of another instance, at any rate in any of the States, where such valuable information has been collated, from which the question of periodicity of rainfall can be deduced.

In estimating for future requirements, the prospective population to be served and existing storage has to be considered. Taking the population supplied in 1906-7 as compared with 1907-8, the increase is about 12,500 or about 2%, but taking the population for a decade, June 1898 to 1908, the average increase per annum is about 4%; taking this annual increase as a basis, the estimated population in 1912 is 690,710, and assuming that the consumption is 50 gallons per capita, which is a very liberal estimate in view of the present consumption, the quantity which would be drawn daily from Prospect would be about 39½ millions per diem, allowing for evaporation. Taking the storage at Cataract, assuming it full at 21,411 million gallons, and only 2,700 millions available at Prospect, would give a storage equal to 610 days. I am only assuming that 2,700 million gallons are available at Prospect, whereas the quantity available to gravitation level is 5,503 million gallons. I think that it will be admitted that as far as storage capacity is concerned the metropolis is in a safe position for some years to come, somewhat different prior to the 1902 drought. Unfortunately we have heavy rains in the metropolitan area with very poor result on the watershed, while the rain reduces the consumption in the metropolis it adds very little to the storage, and hence the value of the high dam to store the rain when it does fall.

From my experience of some of the larger American cities, it cannot be gainsaid that there is an enormous amount of waste, in some instances it is calculated that from 40 to 50% of the water passing from the mains is wasted, and the water authorities in America are awakening to this fact, and every effort is being made in the direction of checking the waste. In New York city the administration of water distribution is not of the soundest, as the City Hall dominates the same and Tammany dominates the administration. There is no doubt that if the legitimate consumption ever reaches that of New York, the present catchment area would be far too small to cope with such demands. The value of high pressure water is not so great as at what might be termed the Kenny Hill period. At that time the supply of power for commercial purposes by gas or oil engines, electrical, or hydraulic power was not to any extent known, and it can be quite understood the value power would have obtained from high pressure mains.

With regard to fire fighting, the trend of opinion in America where the cities abut on harbours and rivers, is to lay force mains along the levels with branches along the principal fire zones, and pump the water by pumps in sections on land or fire-floats. I do not think it would be economical to bring pressure water from a long distance for fire fighting purposes in the city, where any pressure could be obtained by the method referred to.

The scheme outlined by the Chairman when President of the Metropolitan Board of Water Supply and Sewerage forms a valuable adjunct to the metropolitan system and the area should be added to the existing watershed—there is no doubt that the expansion of the metropolitan supply will necessitate this being done—and it is to be hoped that although reserved from alienation, it should be made a substantive part of the metropolitan system.

Mr. KEELE proposed that the debate be adjourned as the hour was late, and he had many points requiring replies to which reference had been made by various speakers.

ADJOURNED DISCUSSION.

15th July, 1908.

Professor KERNOT said—The address contains much valuable historical and statistical matter as to the Sydney Water Supply, but would have been much clearer and more intelligible, had a plan even on a very small scale and a longitudinal section with figured levels, been added. The facts stated about the Prospect Reservoir somewhat surprise me. Its enormous cost—its very low level causing the lower two-thirds of its depth to be unavailable without pumping—the unfortunate, I think I may say, lamentable fact that only 2,000, or as elsewhere stated 3,000 million gallons can safely be be drawn from it, and—the fact that the Cataract Reservoir, having practically seven times the reliable capacity has been constructed for a comparatively moderate cost, provoke the question, as to why the Prospect Reservoir was ever made at all. Then the serious failure of the embankment, which I personally witnessed, and which was very similar to that which took place at the only Victorian dam of equal height, namely that at Durdidwarrah on the Geelong Water Works, has raised in my mind a confirmed aversion to earthen dams of more than 50 feet in height. It seems to me that in the light of present knowledge, a reservoir should have been made at Cataract in the first instance and the money spent on Prospect saved.

The residual mass curve is new to me. I have carefully studied the curves given by Mr. Keele, and fail to see that they give the information he claims. Take the simplest, that at Cordeaux River. It starts quite arbitrarily at a

low level in 1872, and follows on, from that by simple addition and subtraction, of the excess or defect, above or below the mean annual rainfall. But suppose the years before 1872 at Cordeaux to have been similar to those at Sydney, the curve would have started at a far higher level and would have been proportionately raised all along. The fallacy it seems to me is, that the effect on the curve of the rainfall of any given year goes on for ever, whereas in reality such effect is transient. A year of heavy rainfall increases its own stream discharge, and perhaps helps the next year a little, but has no appreciable effect on the third or subsequent years. The year 1876 at Sydney had a rainfall very nearly up to the mean of 76 years, while the residual mass curve was decidedly high, higher in fact than it had been for a quarter of a century, and yet a little peculiarity in the distribution of the rainfall during the months of that year caused the absolute stoppage of one system of water supply, the Lachlan, and the serious falling off of the other. The serious shortage of water in 1902, which came under my personal observation during a visit to Sydney, occurs under a high part of the curve, and shortly following the abundant rainfalls of 1899 and 1900. These are my objections to the method. All my experience of flood discharge and run off, which I have to some extent made a special study, leads me to reject this curve as a guide to estimate the probable discharge of springs and streams. The paragraph on the Melbourne Water Supply I do not agree with, especially do I object to its closing sentence, but the question is too large to discuss here. Melbourne has had for the past half century, and has now an abundant supply of wholesome water. The suburbs are however rapidly growing, and a supplementary scheme is being rapidly pushed on which will give an enormous increase of supply all through the year without any storage reservoir being needed.

Mr. G. R. Cowdery made a few remarks on the financial aspect of the water supply of Sydney.

Mr. R. T. McKay dealt with the general question of rainfall and 'run off' in the States of New South Wales and Victoria on the Murray, Murrumbidgee, Goulburn and Ovens rivers.

Mr. Keele in reply said—Mr. Norman Selfe made some remarks on the historical side of the water supply question.

"There was much to be gleaned from the report of the Royal Commission of 1867. The truth of Mr. Moriarty's contentions as to the necessity of a high level gravitation scheme was being proved by recent developments. He would like to know to what extent the estimate for the Prospect scheme was exceeded, and the reason for the excess cost?"

In reply I would like to say that the principal reason for the excess cost was owing to the scheme being enlarged throughout, to convey 150 million gallons per day instead of 80 millions as originally designed; more brick lining was required in the tunnels than was at first thought necessary. Hudson's temporary scheme, and the difficulties met with in connection with the Prospect dam construction also added considerably to the cost; the balance reservoir at Potts Hill was a necessary but expensive addition to the scheme. Mr. Selfe said—

"He had the highest personal respect for Mr. Moriarty, but it should be remembered that his case was an instance of the inability of a round peg to fit a square hole. The Government thrust responsibility upon him. He thought that none of the engineers composing the Royal Commission of 1867 were competent to get out a water supply."

In reply I would say, that the facts do not by any means bear out Mr. Selfe's statements. The results of Mr. Moriarty's life's work have been a distinct gain and benefit to the public. The Prospect scheme was well conceived,

designed, and carried out by him under greater difficulties than fall to the lot of most men, and it received the endorsement of one of the leading hydraulic engineers of that time Mr. W. Clark. Next to the scheme for supplying water to Sydney from Prospect, came the design of the main system of sewerage for Sydney. This great work was the joint production of Mr. Moriarty and W. Bennett, and when submitted to Mr. W. Clark, was adopted by him with very slight amendment. I am in a position to know that the work in connection with the evolution of these two great schemes, occupied a very large share of his time, and when it is considered that in addition, he had to shoulder the responsibility in the conduct of a big department, the verdict of posterity will be that although he may have failed in some minor respects, the sum total of his services to the community was a distinct and lasting benefit, for which he should be gratefully remembered.

Mr. Cardew made complimentary references to Mr. Moriarty and myself, for the work done in connection with the Sydney Water Supply, for which I thank him. He was of opinion that a tablet should be erected somewhere to the memory of Mr. Moriarty. I think it would be a graceful act on the part of this Section of the Royal Society, if they were to draw the attention of the Council to the fact that no such tablet is in existence, with a request that they would make representation to the Board of Water Supply and Sewerage, with a suggestion that they repair the omission at an early date.

He thought we had not sufficient data to go on in forecasting the recurrence of dry and rainy periods. Mr. Russell thought he had discovered a 19 years cycle, but the 76 years record was insufficient to go upon. I would say that it is to be regretted we have not a longer record, but we have to do the best we can with what we have,

and, although the record does not allow of the determination of a cycle, if such exists, it has undoubtedly shown periodicity, in the accumulated loss and gain of rain with respect to the averages, which demonstrates a run of dry and wet years, however irregular the periods may at present appear to be. "He thought my figures as to the run off were too great. I was too optimistic in expecting 40% from the catchment area; that percentage was not got elsewhere. Mr. McKay in his investigation of the run off from the Murrumbidgee adopted 21·6%. He (Mr. Cardew) found in looking into the Sydney rainfall figures that the percentage above the average was 48%, and below the average 59% in the 76 years rainfall."

With reference to Mr. Cardew's statements about the run off, I may say that the last rain over the catchment area of the Cataract reservoir, has resulted in over 50% being impounded by the dam. Although we have not as many rainfall stations there as might be desired, there are sufficient to arrive at a fair estimate of the average fall over the catchment area, and the contour survey of the reservoir admits of a pretty close approximation of the amount of storage as the water rises. The result of the rainfall mentioned is as I have stated, which Mr. Cardew can verify if he will take the trouble to go into it. The result rather surprised me, in view of the fact that the fall took place over a ground surface not previously saturated, but at the end of a very long dry season. The average rainfall over the 50 square miles of catchment area was $12\frac{1}{4}$ inches, and the storage during that time was 4,500 million gallons. This is by no means an exceptional fall in this locality, and if it had occurred during the wet season, when the ground had been previously saturated, or even partially so, the percentage of run off would have been very much greater. Who can doubt therefore, that 40% run off

would be attained in such years as those from 1890 to 1894 when the rainfall ranged from 67·62 inches to 104·17 inches annually, or 20 inches annually above the average. The reason for so high a percentage of run off as has been shown to result from a catchment area like that of Cataract, is mainly on account of the reservoir being situated in the heart of it, and that the rain is received upon a surface with very steep slopes everywhere towards the reservoir, the rock having very little cover, and the distance from the watershed or boundary of the catchment area to the margin of the reservoir being nowhere more than 3½ miles, the average being under 2 miles.

Mr. Deane dealt specially with the population and rate of increase, and quoted figures from the Government Statistician's report to show that my figures were too high, and he would like the disparity explained. I said at the time that the Statistician's figures could not be accepted, as they only referred to the metropolitan area, which on the west was bounded by a line passing through Strathfield, whereas the Board supplied water to all the areas beyond that up to Parramatta, which would soon have to take its supply wholly from Prospect, instead of depending on the drainage from its own small catchment, which was caught in a shallow reservoir, and the quality of the water was unsatisfactory, and likely to remain so, if it did not become worse. In addition to the large settled area up to Parramatta, there was the large area watered by the Board's mains running down to Ryde, Liverpool, Fairfield, Campbelltown and Camden, and all the district round about them was supplied from the canal, and if the irrigation project was gone on with, a large additional settlement requiring water would spring up. If the Statist's figures were adopted, it would be seen we would be a long way out in the estimate, and this was shown clearly in the estimate

prepared from his figures in 1902, for calculating the increase up to 1912, the figures given in 1902 Commission's report having been reached last year. Water authorities usually adopted the plan of taking the number of houses supplied with water and multiplying by 5; this gave satisfactory figures upon which better dependence could be placed. It might appear to be a crude method; but what was wanted was the population served with water each year, and it was evident from what I have said that this could not be arrived at by the figures supplied by the Statistician, which only applied to the metropolitan area; but the Board delivers water to consumers far beyond that area.

Mr. Deane, in referring to the work of the Royal Commission of 1902, said he was prepared to admit now that the best thing had been done in building the Cataract dam to impound the larger quantity of water. In view of the position taken up by my colleagues on the Royal Commission of 1902, and subsequently during the controversy on the height to which the dam should be raised, whether to impound 7,000 million or 21,000 million gallons, I must take this opportunity of thanking Mr. Deane for his admission, which I cannot but regard as a compliment to myself, and I must congratulate him on his magnanimity, and on his showing that he has the courage of his opinions. I would jocularly remind those who are still reticent about the matter, that there is some truth in the adage, that "It is a good thing to know when to come in out of the wet."

Mr. Houghton was of opinion that "some consideration should be given to the riparian rights of the people on the lower rivers. The drainage from this upper portion of the rivers should not be taken away wholly in the manner it had been done in the past, and was now proposed from the heads of the Woronora and O'Hare's Creeks." To this I would reply that the matter received the earnest consideration of the Commission in 1869, and they recommended

that the diversion weirs at the Pheasant's Nest and Broughton's Pass be so constructed as to allow of any quantity up to 10 million gallons to pass down the rivers, and that none be drawn away by the tunnels, until the discharge exceeds that quantity up to 80 million gallons. When the matter came to be investigated by Mr. W. Clark, he advised that the works be designed, to take all the water coming down, up to 150 million gallons daily from the Nepean and Cataract rivers, and that provision be made to impound water in the lower reaches of the river, to compensate for the loss of water diverted for the supply of Sydney. With the exception of a small concrete weir on the rocks just below Menangle Bridge, I am not aware that anything has been done in the direction suggested by Mr. Clark; but the people are undoubtedly entitled to this provision.

In the case of the proposal to obtain an additional supply for Sydney from the Woronora and O'Hare's Creek, Mr. Houghton is in error when he states that it is proposed to take all the water. It is proposed to allow a sufficient quantity, equal to the dry weather flow of the streams, to pass down the rivers, and to construct low weirs in suitable places to hold up the water, and prevent it from running to waste to the sea during freshets. Under this arrangement, the people would be better off than they are now, inasmuch as they would have an assured supply, which they have not at present. There are occasions when the streams practically cease to run during extreme droughts.

Mr. Houghton considered "that a large city like Sydney should look to sources further afield than the Woronora-O'Hare's Creek proposal. The future source of supply in his opinion should come from the other side of the Nepean, such as the Grose, Warragamba, or Colo rivers, rather than from small extensions of the present catchment area." To

this I would reply, that I am quite sure if Mr. Houghton will give this matter the cosideration that I have done, he will find that he could not possibly obtain the necessary elevation to supply even Crown Street reservoir, let alone the higher levels of the city by gravitation, without going a very long way back from the junctions of either of these streams with the Nepean River. Both the Royal Commission of 1869, and Mr. W. Clark, fully inquired into these sources of supply, but owing to the long length of piping required in each case, ranging from 50 to 60 miles, they were discarded. The whole matter resolves itself into one of cost, to obtain an adequate additional supply, to command the highest levels of Sydney by gravitation, and I can assure Mr. Houghton that having studied the question very closely, I now rest quite satisfied, that when the question of additional supply comes to be inquired into by the proper tribunal, the Woronora scheme can be depended upon to hold its own.

Dr. Stokes dealt with the estimate of water likely to be required. "He was of opinion that a low estimate should not be taken. He agreed with Mr. Cardew that 60 gallons should not be considered the limit of supply. We would be using larger quantities of water in the near future." In reply, I would say, that I dealt with this matter fully in my address, and my reasons are clearly stated for anticipating a quick rise from the present rate of consumption per head, about 38 gallons per day, to 60 gallons, and I concur with Mr. Cardew, that if manufacturing industries become established, as may be anticipated under the Federal Tariff, the rate of 60 gallons per head may very soon be found much too low. Dr. Stokes thought that "quantity and quality should go hand in hand. It was a question whether it was wise to count upon water being entirely satisfactory as caught and stored in reservoirs

from such catchments as the present one, without filtration or treatment of some kind. In his opinion, we were drawing near the time when some treatment of the water more than it at present received, would be required, and this should not be lost sight of in preparing estimates." In reply, I would say that I think the Doctor is justified in directing attention to the necessity of preserving the purity of the supply. In these days it is difficult for the water authorities to obtain complete control of catchment areas. Our experiences are being repeated at Melbourne at the present time, where they have been compelled within the last few weeks, to accept a gathering ground for their additional supply, on terms that are far from satisfactory. The Board at Melbourne desire to obtain complete control over the catchment area of the O'Shanassy River, but have only been given the right to a narrow strip on each side of the river and its tributaries, the Government reserving to itself the right to cut timber, and occupy for that purpose the whole of the remaining area. Under such circumstances it will be impossible to preserve the purity of the water, and the consumers may look forward to additional expense on account of the necessity for filtering it. On our own catchment area the Board has had a hard struggle in the past, to prevent occupation, and as coal mining extends under the area, their constant vigilance will be necessary to avoid contamination of the streams. It was hoped that the catchment areas for the proposed additional supply from the Woronora could be preserved solely for gathering water; but a difficulty has already arisen, which it is perhaps undesirable to enlarge upon at this stage, but the difficulty still remains notwithstanding the warning which has been given, and to all appearance it is likely to cause trouble in the future. The Doctor has pointed out that such difficulties may be overcome by filtration—but at what cost! Only those who are aware of the

enormous cost of filtration works for the supply of pure water to populations exceeding ½ a million, and rapidly increasing, can supply an answer to that question.

Replying to Professor Kernot, Mr. Keele said that the Professor is not in agreement with the President of the Water Board and his professional officers Messrs. Oliver and Ritchie, who had expressed themselves in no uncertain terms in their reports as published in the press of July 1st, on the present condition of the Melbourne Water Supply. On the one hand it is stated that " there has been for the last half century, *and is now*, an abundant supply," and on the other that "there is a probability of the Yan Yean reservoir being reduced to such a dangerously low level that the supply for the following years may prove insufficient for domestic and sanitary purposes"; that "the records of the past point most unmistakeably to four successive years of average and low rainfall as now due before a return of high rainfall"; and that "with the *last resort* and *absolute necessity* we are *clearly face to face* with, the time has arrived when the Acheron diversion should be carried out if we are to prevent *disaster* in Melbourne and metropolis. The *remarkable and unexampled falling off in the streams* supplying the Yan Yean for such a long period has reduced the stored water to a *dangerous point.*" Now which of these statements are we to accept?

The Board's responsible officers arrived at their conclusions from an intimate knowledge of local conditions, and as Mr. Oliver remarks, "their fears expressed are not based on mere conjecture, but on absolute results of intake and output." I had no personal knowledge of the Melbourne water supply, or of its present condition, but arrived at my conclusions from a study of the rainfall and particularly of the residual mass curve as deduced therefrom, which Professor Kernot utterly condemns and rejects as a guide "to estimate the probable discharge of springs and streams."

With all due respect to the Professor, I may be permitted to say that, he appears to have entirely failed to grasp the importance of the water table, or level of the saturated zone in the soil, which varies greatly in depth below the ground surface, and governs the flow of streams in the absence of rain, and taken in conjunction with the amount of evaporation, degree of porosity of the soil, and the slope of the ground surface, controls the surface "run off." As the water table is affected directly by the excess or deficiency of rain, the only way by which to determine the exact position of the water table, is of course, by ascertaining its level in tubes or wells sunk in suitable places. In the absence of these measurements there is no other way of approximately estimating the rise or fall of the water table, than by ascertaining the *accumulated* rise or fall of rain above or below the mean over a long term of years. The residual mass curve shows in the best possible way the cumulative effect of the rainfall in excess or deficiency in relation to the mean.

The Professor says that this method is new to him, and because the curve as derived from the rainfall at one place, does not agree with another, or that a drought is shown in a high part of the curve, following abundant rainfall a few years previously, he objects to the method. He does not seem to realise that, each place is a "law unto itself." The comparison of the curves constructed from the rainfall returns at all the long record stations in Australasia, show clearly that each place has its own peculiar periods, according to its elevation above the sea level, and its geographical position, especially with reference to the distance from the coast, and proximity to the mountain range. If he will construct a residual mass curve from the Hobart record, and compare it with the Melbourne one, he will find that the periods are exactly the reverse of Melbourne. If

observations of the rainfall had been continued sufficiently long on the Melbourne catchment areas, viz: the Watts' River, or Wallaby and Silver Creeks, the curves constructed therefrom, would no doubt be found not to compare any closer than those of Sydney and the Cordeaux; but the distance between them is so short, being not greater than 30 miles or so, it is reasonable to assume that, the drought which has affected Melbourne since 1875, resulting from the persistent decline in the rainfall for the following 23 years, which has brought the curve down to day lower than ever previously experienced, will be found to show a somewhat similar decline on the catchment areas named. That this is not an incorrect assumption, is shown by the returns published by Mr. Ritchie on July 1st.

While making an investigation of the Australian rainfall, the necessity of taking into consideration the cumulative effect of the rainfall was impressed upon me, and my views were confirmed on reading the report of the Commission on Additional Water Supply for the City of New York (1904) in which I found that Mr. Walter E. Spear, one of the Department Engineers, had proved that the fluctuations of the water table agreed with the mass curve. The following is an extract from his report:—

"Since the height of the water table—on which depends the delivery of the ground water on Long Island—represents the cumulative effect of the rainfall for many years, it was appreciated that the ordinary method of considering the maximum delivery of a watershed, to depend upon the rainfall during the dryest season or during the dryest year, would not necessarily give the lowest yield; for if the season or year of drought followed a period of heavy rainfall, the water table, having been raised during the rainy years, would still deliver during the period of drought, a large amount of water that had fallen during the previous years. Consequently the residual mass curves were worked up. The general agreement between these mass curves and the fluctuations in the elevations of the ground water justify their computations."

DISCUSSION ON A PAPER—HYDRO-ELECTRIC INSTALLATIONS.—(See p. LI.)

By E. KILBURN SCOTT, Assoc. M.C.E., M.I.E.E.

Mr. NORMAN SELFE said Mr. Kilburn Scott's paper is so comprehensive that it suggests quite a number of points for consideration under both the hydraulic and the electrical aspects; leaving the latter to specialists, the only point to which reference will now be made is the possibility of utilising some of the immense amount of energy that is now or may in the future be lost in the operations of the present water supply of Sydney. The statement of the author of the paper that under the suggested Trawool scheme "10,000 HP. could be generated continuously the year round on a 24 hours' run," presents such extraordinary attractions to the engineer that one naturally wonders whether or not some sort of improvement is possible, under modern conditions, in our own water supply. Under the existing conditions the water is nearly all gathered at considerable elevation, and then wastes its latent energies in descending by open channels through several hundred feet of elevation to low level reservoir at Crown Street at 141 feet, after which, in very large proportion, it is raised again by steam pumping to the other service reservoirs. The records show us that the original engineer of our present supply adopted "gravitation in open channels" as his motto, and that those who opposed him received very short shift at his hands (possibly deservedly at the time) in the discussion of their projects. Thirty years ago Mr. James Manning—who was largely inspired by the reports of Colonel Mendell, the engineer of the Water Commission of San Francisco—advocated the conservation of the Sydney water supply at high levels, and the use of steel tubular conduits, while Mr. F. B. Gipps proposed to store it at a much higher level than the Government proposal adopted.

Admitting that the conditions existing at that remote period, with the imperfect knowledge available to those then in authority warranted, the open conduit and loss of head which has been adopted, it by no means follows that the whole matter is not worth reconsideration in view of the facts set forth by Mr. Kilburn Scott and later experience. The construction of the Cataract dam to its full height—notwithstanding the influence which was exercised to keep it down—seems now to be fully justified, and as it is probably the most all round successful engineering work yet constructed by the Government of the State, it opens up in connection with the paper before the Society the following queries:—

1. What would be the length, diameter, and cost of the smallest main necessary to deliver the given supply direct to Potts' Hill while utilising the whole head for friction?

2. What would be the extra cost of larger and stronger main, to give say, a 250 or 500 feet head at Potts' Hill with average delivery?

3. Given a 500 feet head at Potts' Hill, what horse power would be available from the supply at average delivery?

4. What would the power cost per horse power year in the form of electrical energy with the most modern appliances of hydraulic motors and electric generators?

There are many other questions which suggest themselves in this connection which might well occupy the attention of our student members; for instance, there is the supply of the higher levels of Sydney and the comparison of direct supply from such pressure main to local reservoirs above Crown Street. For instance, given a 500 feet head at Potts' Hill, would it be more economical to supply direct to a service reservoir at 250 feet with friction, and thus lose one-half of the available head, or to utilise the head of the whole quantity for power, and by turbine pumps, or motor pumps re-raise the high level supply?

It is very unfortunate that although the literature of the Sydney water supply is very voluminous and comprehensive there does not seem to be any *vade mecum* to give one the elevations of the various dams, capacity of channels, and volumes of delivery for handy reference. The very instructive and masterly paper of Mr. Keele, read before this Association recently, gives the top level of water under the Woronora scheme as 510 feet, and at O'Hare's Creek as 654 feet; also the level of Crown Street 141 feet is mentioned, but otherwise no heights appear to be given with regard to either the Cataract dam as built, or the three other dams on the upper waters of the catchment area which have been surveyed and planned.

When the Royal Commission on Sydney Water Supply in the "Seventies" considered the Warragamba and the Grose schemes, only earthen dams were entertained by the members, and especially with regard to the Warragamba, the estimated cost was enormous. Mr. Thomas Woore who was the author of the scheme, wrote a pamphlet on the subject, and on the 19th October, 1876, the writer read a paper in which he contrasted the Commissioners' dam with one of masonry. With the success of the Cataract scheme and the practically assured success of the Barren Jack, the Warragamba proposal, dismissed in so summary a way by the officials of 34 years ago, might be worth looking up again. If one were a prophet he would say exactly how long it would be necessary to live in order to see that great work carried out. Although the available head might be only moderate, the watershed of the Warragamba is so large that it would be a mighty scheme, and as the writer has known the river in a flood to rise 90 feet at the junction with the Nepean, the scheme also would be a bold one, apart from either the Warragamba or the Grose, and the power which might be obtained from them.

Mr. Keele has shown how the future requirements of Sydney may be met for some years to come at least, and now Mr. Kilburn Scott suggests that great economic use may be made of the surplus head from those upper reaches. Had the data just referred to been readily available these remarks might have been supplemented by some calculations and estimates. As it is they must be taken as an appreciative acknowledgment of the very valuable paper of Mr. Kilburn Scott which has suggested them.

Mr. Cardew advocated combining irrigation schemes and hydro electric installations. He gave some interesting details of Waipori (Dunedin) hydro electric installation, and in connection with some mistakes made there, he pointed out the necessity for obtaining skilled advice in every one of the many branches of engineering involved in a great scheme. He gave details of cost of various power plants and showed that steam plants in large units in Lancashire were able to compete with hydro electric plants. He also quoted the figures of Mr. Rooke concerning the steam generated electric power in Sydney.

Mr. Shirra drew attention to the work that can be done by a comparatively small quantity of water at high pressure. He strongly advocated large power stations outside the city.

Mr. Corin quoted 55/- per E.H.P. at Barron Falls as the price actually paid by the Queensland Government. At this rate carbide of calcium ought to be produced at great profit, as 130,000 ℔s. were imported by the Commonwealth last year. He said that 3,500 HP. might to be developed at Barron Falls. Production of aluminium from bauxite ought to be taken up also, especially as aluminium conductors might with advantage be used. He thought Barren Jack, being primarily an irrigation scheme, must be a great

success as it also possessed great possibilities as a hydro electric installation.

Mr. HOUGHTON said, the profession of engineering consists of "the art of directing the great sources of power in nature for the use and convenience of man," and in bringing before us his paper on "Hydro Electric Installations," Mr. Scott has described cases in which the great source of power provided by the sum in raising water from a lower to a higher level has been used with manifest advantage to mankind. Unfortunately the water supply of Australia has so far only in one instance been successfully utilized for the generation of electricity for sale, except in Tasmania which is blessed with a more copious rainfall than the mainland, and in that one instance, Hillgrove, I believe that the vagaries of our uncertain rainfall have interfered considerably with its usefulness. As to the many advantages to be obtained by using hydraulic power for the generation of electricity I have nothing to say, but I take exception to Mr. Scott's somewhat optimistic view of the prospects of so utilizing the scanty rainfall of the interior. He speaks of providing a balance reservoir to hold the water from Barren Jack during the period of the year that it will not be required for irrigation, has he considered the cost of such a reservoir? I understand that the dam of Barren Jack will cost £800,000, which is low compared with the volume of water that can be impounded, but what will be the cost of a low level dam to hold water for six months that has been used for the generation of the electric current; it would require to retain about 13,000,000,000 million cubic feet to hold 1,000 cubic feet per second flowing through the wheel or turbine for 150 days a year. Would not the interest on the cost of such a reservoir do away with all the profit to be derived from supplying electric power from this source? Again,

although the discharge from Barren Jack will be 1,500 cubic feet per second during the time that irrigation water is required and there is water to discharge, yet in the evidence given before the Parliamentary Inquiry Committee it is stated that should seasons like some of those we have experienced occur again, there will only be the water necessary for maintaining the flood in the river, 500 cubic feet per second, available for nearly nine months, so that during that period no electric current could be generated. What then would become of the industries established on the basis of cheap motive power, must they provide a steam plant capable of carrying on their works, or shut down the former? The interest and depreciation on the electrical and steam machinery would take all or nearly all of the savings, for both plants must be installed.

According to Professor Unwin, interest, maintenance and depreciation account for 60% to 40% of the cost of a horse power dependent upon whether the engine works 1,000 or 3,000 hours per annum at full power, so that Mr. Scott's estimate of only 25% for those items appears low, and consequently where, as in many parts of this State, coal can be obtained at a very low price, there is no justification for the large expenditure involved in constructing a large dam and bringing current a considerable distance, where either a steam or gas driven plant can be more conveniently established near a port or large city. It must not be thought that I am of opinion that hydro electric installations are not possible in this State, for there are many local applications of water as a source of power that can be utilized, and in other States there are large sources of power which will no doubt be fully developed. We cannot hope for the development which has taken place in other parts of the world where the conditions are very different, but I think that Mr. Scott is too optimistic, and

has given the prestige of his name to ideas that are not practicable and may mislead. It would be more satisfactory if Mr. Scott gave some details of the capital cost of his suggested schemes, so that a comparison could be made with steam or gas driven plants, and then it could be seen whether the stoppage of supply during drought, to which he refers as being of apparently only of small importance, would be more than compensated for by the great saving that would result from cheaper power.

In the above remarks I may have taken a very conservative view, but that does not lessen my appreciation of the work done by those who have proposed these big schemes of harnessing water, which would otherwise flow to waste to the machines in a factory a long distance away, and our thanks are due to Mr. Scott for bringing the subject before us.

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