JOURNAL
AND
PROCEEDINGS
OF THE
ROYAL SOCIETY
OF
NEW SOUTH WALES
FOR
1899.

(INCORPORATED 1881.)

VOL. XXXIII.

EDITED BY
THE HONORARY SECRETARIES.

FOUN. 1821. INC. 1881.

PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.
1899.

NOTICES.

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.

The Society's Journal for 1899, Vol. xxxiii., has been forwarded to the same Societies and Institutions as enumerated on the printed list in Vol. xxx. (viz. 400), with the addition of the Field Columbian Museum, Chicago; Royal Society of Sciences and Belles Lettres, Gothenburg; the Editor of *Science Abstracts*, London; Naturhistorische Gesellschaft, Nuremberg; British Medical Association (N.S.W. Branch); Mount Kosciusko Observatory, N.S.W.; Società Italiana di Fisica, Pisa; Bernice Pauahi Bishop Museum, Honolulu; Illinois Biological Station, Havana, Ill.; University of Chicago Press; Maryland Geological Survey, Baltimore; Philadelphia Commercial Museum, U.S.A.; Editor of the Mineral Industry, New York; American Institute of Electrical Engineers, New York.

It is requested that the volume may be acknowledged by returning the Form of Receipt (to be found stitched in the commencement of the volume) signed and dated in order that any delay or mis-delivery may be brought to notice.

Plates I. and II. illustrating the paper of Mr. R. A. Bastow, on "Red or Purple Marine Algæ," (pp. 45 – 47) may be had on application to the Hon. Secretaries.

TO AUTHORS.

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

ERRATA.

Page 109, last line, for "No. 3," read "*No. 2.*"
,, 114, line 5, for "No 3," read *No. 1.*"
,, 114, line 10, for "divisons," read "*divisions.*"
,, 125, line 14, for "an," read "*no.*"
,, 128, line 9, for "76," read "*7·6.*"
,, xvi., line 16, for "comfusing," read "*comprising.*"

PUBLICATIONS.

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

Vol.	I.	Transactions of the Royal Society, N.S.W.,	1867,	pp. 83,	,,
,,	II.	,, ,, ,, ,, ,,	1868,	,, 120,	,,
,,	III.	,, ,, ,, ,, ,,	1869,	,, 173,	,,
,,	IV.	,, ,, ,, ,, ,,	1870,	,, 106,	,,
,,	V.	,, ,, ,, ,, ,,	1871,	,, 72,	,,
,,	VI.	,, ,, ,, ,, ,,	1872,	,, 123,	,,
,,	VII.	,, ,, ,, ,, ,,	1873,	,, 182,	,,
,,	VIII.	,, ,, ,, ,, ,,	1874,	,, 116,	,,
,,	IX.	,, ,, ,, ,, ,,	1875,	,, 235,	,,
,,	X.	Journal and Proceedings ,, ,,	1876,	,, 333,	,,
,,	XI.	,, ,, ,, ,, ,,	1877,	,, 305,	,,
,,	XII.	,, ,, ,, ,, ,,	1878,	,, 324,	price 10s. 6d.
,,	XIII.	,, ,, ,, ,, ,,	1879,	,, 255,	,, 10s. 6d.
,,	XIV.	,, ,, ,, ,, ,,	1880,	,, 391,	,, 10s. 6d.
,,	XV.	,, ,, ,, ,, ,,	1881,	,, 440,	,, 10s. 6d.
,,	XVI.	,, ,, ,, ,, ,,	1882,	,, 327,	,, 10s. 6d.
,,	XVII.	,, ,, ,, ,, ,,	1883,	,, 324,	,, 10s. 6d.
,,	XVIII.	,, ,, ,, ,, ,,	1884,	,, 224,	,, 10s. 6d.
,,	XIX.	,, ,, ,, ,, ,,	1885,	,, 240,	,, 10s. 6d.
,,	XX.	,, ,, ,, ,, ,,	1886,	,, 396,	,, 10s. 6d.
,,	XXI.	,, ,, ,, ,, ,,	1887,	,, 296,	,, 10s. 6d.
,,	XXII.	,, ,, ,, ,, ,,	1888,	,, 390.	,, 10s. 6d.
,,	XXIII.	,, ,, ,, ,, ,,	1889,	,, 534,	,, 10s. 6d.
,,	XXIV.	,, ,, ,, ,, ,,	1890,	,, 290,	,, 10s. 6d.
,,	XXV.	,, ,, ,, ,, ,,	1891,	,, 348,	,, 10s. 6d.
,,	XXVI.	,, ,, ,, ,, ,,	1892,	,, 426,	,, 10s. 6d.
,,	XXVII.	,, ,, ,, ,, ,,	1893,	,, 530,	,, 10s. 6d.
,,	XXVIII.	,, ,, ,, ,, ,,	1894,	,, 368,	,, 10s. 6d.
,,	XXIX.	,, ,, ,, ,, ,,	1895,	,, 600,	,, 10s. 6d.
,,	XXX.	,, ,, ,, ,, ,,	1896,	,, 568,	,, 10s. 6d.
,,	XXXI.	,, ,, ,, ,, ,,	1897,	,, 626,	,, 10s. 6d.
,,	XXXII.	,, ,, ,, ,, ,,	1898,	,, 476,	,, 10s. 6d.
,,	XXXIII.	,, ,, ,, ,, ,,	1899,	,, 400,	,, 10s. 6d.

CONTENTS.

VOLUME XXXIII.

PAGE.

OFFICERS FOR 1899-1900 ... ... (vii.)

LIST OF MEMBERS, &c. ... ... (xi.)

ART. I.—PRESIDENT'S ADDRESS. By G. H. Knibbs, F.R.A.S. ... 1

ART. II.—Key to Tribes and Genera of the Florideæ (Red or Purple Marine Algæ). By Richard A. Bastow. (Communicated by J. H. Maiden, F.L.S.) (*Plates* i., ii.) 45

ART. III.—On the metamorphosis of the young form of *Filaria Bancrofti*, Cobb, [*Filaria sanguinis hominis*, Lewis; *Filaria nocturna*, Manson] in the body of *Culex ciliaris*, Linn., the "House mosquito of Australia" By T. L. Bancroft, M.B. 48

ART. IV.—Suggestions for depicting diagrammatically the character of Seasons as regards Rainfall, and especially that of Droughts. By H. Deane, M.A., M. Inst. C.E., &c.. (*Plate* iii.) 63

ART. V.—Observations on the determination of Drought-intensity. By G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney 69

ART. VI.—On the crystalline camphor of Eucalyptus Oil (Eudesmol), and the natural formation of Eucalyptol. By Henry G. Smith, F.C.S., Technological Museum, Sydney 86

ART. VII.—Divisions of some Aboriginal Tribes, Queensland. By R. H. Mathews, L.S.) 108

ART. VIII.—The Initiation Ceremonies of the Aborigines of Port Stephens, N. S. Wales. By W. J. Enright, B.A. (Com-municated by R. H. Mathews, L.S. 115

ART. IX.—Sailing Birds are dependent on Wave-power. By L. Hargrave 125

ART. X.—Some applications and developments of the Prismoidal Formula. By G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney 129

ART. XI.—Current Papers, No. 4. By H. C. Russell, B.A., C.M.G., F.R.S. (*Plates* v., vi.) 145

ART. XII.—Discovery of Glaciated Boulders at base of Permo-Carboniferous System, Lochinvar, New South Wales. By Professor T. W. E. David, B.A., F.G.S. (*Plate* iv.) 154

ART. XIII.—On New South Wales Copper Ores Containing Iodine. By Arthur Dieseldorff, M.E., Freiberg, Baden, Germany. (Communicated by A. J. Bensusan, Assoc. R.S.M., F.C.S.) ... 160

PAGE

ART. XIV.—On the *Darwinias* of Port Jackson and their Essential Oils. By R. T. Baker, F.L.S., Curator, and H. G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney... 163

ART. XV.—Orbit Elements Comet I., 1899 (Swift). By C. J. Merfield, F.R.A.S. 177

ART. XVI.—On the composition of N. S. Wales Labradorite and Topazes with a comparison of methods for the estimation of Fluorine. By G. Harker, B. Sc. (Communicated by Prof. Liversidge, M.A., LL.D., F.R.S.) 193

ART. XVII.—On a remarkable increase of temperature after dark at Seven Oaks, Macleay River. By Hugh Charles Kiddle, F.R. Met. Soc., Public School, Seven Oaks, Macleay River ... 204

ART. XVIII.—Records of rock temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain, Sydney, N.S. Wales. By J. L. C. Rae, E. F. Pittman, Assoc. R.S.M., and Professor T. W, E. David, B.A., F.G.S. 207

ART. XIX.—Note on Edible Earth from Fiji. By the Hon. B. G. Corney, M.D., Professor T. W. E. David, B.A., F.G.S., and F. B. Guthrie, F.C.S. 223

ART. XX.—Annual Address to the Engineering Section. By Norman Selfe, M. Inst. C.E. ... ... I.

ART. XXI.—The Sewerage Systems of North Sydney and Double Bay. By J. Davis, M. Inst. C.E. ... ... XI.

ART. XXII.—The manufacture of Monier Pipes. By F. M. Gummow XXXIV.

ART. XXIII.—"*Le Pont Vierendeel.*" By J. I. Haycroft, M.I.C.E.I. XXXVIII.

ABSTRACT OF PROCEEDINGS ... ... i.

PROCEEDINGS OF THE ENGINEERING SECTION... ... ... lxix.

PROCEEDINGS OF THE MEDICAL SECTION ... ... lxxi.

INDEX TO VOLUME XXXIII. ... ... (xxvii.)

Royal Society of New South Wales.

OFFICERS FOR 1899-1900.

Honorary President:

HIS EXCELLENCY THE RIGHT HON. WILLIAM EARL BEAUCHAMP, K.C.M.G.

President:

W. M. HAMLET, F.C.S., F.I.C.

Vice-Presidents:

PROF. ANDERSON STUART, M.D.
CHARLES MOORE, F.L.S.
PROF. T. W. E. DAVID, B.A., F.G.S.
HENRY DEANE, M.A., M. Inst. C.E.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. H. MAIDEN, F.L.S.
G. H. KNIBBS, F.R.A.S.

Members of Council:

C. O. BURGE, M. Inst. C.E.
J. W. GRIMSHAW, M. Inst. C.E.
F. B. GUTHRIE, F.C.S.
H. A. LENEHAN, F.R.A.S.
Prof. LIVERSIDGE, M.A., LL.D., F.R.S.
F. H. QUAIFE, M.A., M.D.
H. C. RUSSELL, B.A., C.M.G., F.R.S.
HENRY G. SMITH, F.C.S.
J. ASHBURTON THOMPSON, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*
PROF. WARREN, M. Inst. C.E., Wh.Sc.

Assistant Secretary:

W. H. WEBB.

FORM OF BEQUEST.

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

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

NOTICE.

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

Correct Address:

Name..

....

Titles, &c...

....

Address..

....

....

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

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

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

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

‡ Life Members.

Elected.		
1877		Abbott, The Hon. Sir Joseph Palmer, Knt., K.C.M.G., M.L.A., Speaker of the Legislative Assembly, Castlereagh-street.
1877	P 5	Abbott, W .E., 'Abbotsford,' Wingen.
1864		Adams, P. F., 'Casula,' Liverpool.
1895		Adams, J. H. M., Athenæum Club, p.r. Broughton Cottage, St. James' Road Waverley.
1890	P 2	Allan, Percy, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E., Engineer-in-Charge of Bridge Design, Public Works Depart., Sydney.
1885		Allworth, Joseph Witter, District Surveyor, East Maitland.
1898		Alexander, Frank Lee, Cement Works, Druitt-street.
1877		Anderson, H. C. L., M.A.. 161 Macquarie-street.
1896		Archer, Samuel, B.E. Roy. Univ. *Irel.*, Resident Engineer, Roads and Bridges Office, Mudgee.
1899		Atkinson, A. A., Chief Inspector of Colieries, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 5	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1894		‡Balsille, George, Sandymount, Dunedin, New Zealand.
1895	P 4	Bancroft, T. L., M.B. *Edin.*, Deception Bay, viâ Burpengary, Brisbane, Queensland.
1896		Barff. H. E., M.A., Registrar, Sydney University.
1895	P 6	Barraclough, S. H., B.E., M.M.E., Assoc. M. Inst. C.E., Acting Professor of Engineering, Sydney University; p.r. 'Lansdown,' 30 Bayswater Road, Darlinghurst.
1876		Bassett, W. F., M.R.C.S. *Eng.*, George-street, Bathurst.
1894		Baxter, William Howe, Chief Surveyor Existing Lines Office, Railway Department; p.r. 'Hawerby,' Vernon-street, Strathfield.
1898		Beale, Charles Griffin, 109 Pitt-street and Warrigal Club.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1875		Belisario, John, M.D., Lyons' Terrace, Hyde Park.
1876		Benbow, Clement A., 263 Elizabeth-street.
1869	P 2	Bensusan, S. L., 12 O'Connell-street, Box 411 G.P.O.
1895		Bensusan, A. J., A.R.S.M., F.C.S., Laboratory, 12 O'Connell-st.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Mount Barker, South Australia.
1893		Blomfield, Charles E., B.C.E. *Melb.*, Survey Camp, Moree.

Elected		
1898		Blunno, Michele, Government Viticultural Expert, Department of Agriculture, Sydney.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1895	P 1	Boultbee, James W., Superintendent of Public Watering Places and Artesian Boring, Department of Lands.
1891		Bowman, Archer S., C.E., 'Turuwul,' Redmyre Road, Burwood.
1893		Bowman, John, C.E., Tramway Construction Branch, Public Works Department.
1893		Bowman, Reginald, M.B. et Ch. M. *Edin.*, 261 Elizabeth-street and George-street, Parramatta.
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. Univ., Resident Medical Officer, Sydney Hospital, Macquarie-street.
1878		‡Brooks, Joseph, F.R G.S., F.R.A.S., 'Hope Bank,' Nelson-street, Woollahra.
1896		Brown, Alexander, Newcastle.
1876		Brown, Henry Joseph, Solicitor, Newcastle.
1891		Bruce, John Leck, Technical College, Sydney.
1898		Burfitt, W. Fitzmaurice, B.A., B. Sc., 1 Hereford-st., Glebe Point.
1891	P 3	Burge, Charles Ormsby, M. Inst. C.E., Principal Assistant Engineer, Railway Construction, 'Fitz Johns,' Alfred-street N., North Sydney.
1890		Burne, Dr. Alfred, Dentist, 1 Lyons' Terrace, Liverpool-st.
1880		Bush, Thomas James, Engineer's Office, Australian Gas-Light Company, 163 Kent-street.
1876		Cadell, Alfred, Dalmorton.
1897		Callender, James Ormiston, Consulting Electrical Engineer, c/o Callender's Cable and Construction Co., Ld., 90 Cannon-street, London.
1894		Cameron, Alex. Mackenzie, Walgett.
1899		Cameron, R. B., Secretary A.M.P. Society, 87 Pitt-street.
1879		Campbell, Rev. Joseph, M.A., F.G.S., F.C.S., Te Aroha, Auckland, New Zealand.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Road.
1897		Cardew, John Haydon, Assoc. M. Inst. C.E., L.S., 75 Pitt-street.
1894	P 2	Carleton, Henry R., M. Inst. C.E., 'Tarcoola,' Nelson-st. Woollahra.
1891		Carment, David, F.I.A. *Gt. Brit. & Irel.*, F.F.A. *Scot.*, Australian Mutual Provident Society, 87 Pitt-street.
1879	P 1	‡Chard, J. S., Licensed Surveyor, Armidale.
1878		Chisholm, Edwin, M.R.C.S. *Eng.*, L.S.A. *Lond.*, 82 Darlinghurst Road.
1885		Chisholm, William, M.D. *Lond.*, 139 Macquarie-street, North.
1888		Clubbe, C. P. B., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 195 Macquarie-st.
1896		Cook, W. E., M.C.E. *Melb.* Univ., M. Inst. C.E., District Engineer, Water and Sewerage Department, North Sydney.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, 'Holmsdale,' Chatswood.
1893		Cohen, Algernon A., M.B., M.D. *Aberd.*, M.R.C.S. *Eng.*, 71A Darlinghurst Road.
1378		Colquhoun, George, Crown Solicitor, 'Rossdhu,' Belmore Road, Hurstville.
1876		Colyer, J. U. C., Australian Gas-Light Co., 163 Kent-street.

Elected		
1855		Comrie, James, 'Northfield,' Kurrajong Heights, viâ Richmond.
1882		Cornwell, Samuel, Australian Brewery, Bourke-st., Waterloo.
1891		Coutie, W. H., M.B., Ch. B., Univ. *Melb.*, 'Warminster,' Canterbury Road, Petersham.
1892	P 1	Cowdery, George R., Assoc. M. Inst. C.E., Engineer for Tramways, Public Works Buildings, Phillip-street; p.r. 'Glencoe,' Torrington Road, Strathfield.
1880		Cox, The Hon. George Henry, M.L.C., Mudgee: and Warrigal Club, 145 Macquarie-street.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 16 College-street, Hyde Park.
1869		Creed, The Hon. J. Mildred, M.L.C., M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 125 Elizabeth-street.
1870		Croudace, Thomas, Lambton.
1899		Cullen, Hon. W. P., M.A., LL.D., M.L.C., Barrister-at-Law, 'Trygoyd,' Mosman.
1891	P 5	Curran, Rev. J. Milne, Lecturer in Geology, Technical College, Sydney.
1875		Dangar, Fred. H., c/o Messrs. Dangar, Gedye, & Co., Mercantile Bank Chambers, Margaret-street.
1890		Dare, Henry Harvey, M.E., Assoc. M. Inst. C.E., Roads and Bridges Branch, Public Works Department.
1876	P 1	Darley, Cecil West, M. Inst. C.E., Engineer-in-Chief, Public Works Department.
1877		Darley, The Hon. Sir Frederick, K.C.M.G., B.A., Chief Justice, Supreme Court.
1886	P 14	David, T. W. Edgeworth, B.A., F.G.S., Professor of Geology and Physical Geography, Sydney University, Glebe. *Vice-President.*
1892	P 1	Davis, Joseph, M. Inst. C.E., Supervising Engineer, Sewerage Branch, Public Works.
1878		Dean, Alexander, J.P., 42 Castlereagh-street, Box 409 G.P.O.
1885	P 2	Deane, Henry, M.A., M. Inst. C.E., Engineer-in-Chief for Railways, Railway Construction Branch, Public Works Department, p.r. 'Blanerne,' Wybalena Road, Hunter's Hill. *Vice-President.*
1877		Deck, John Field, M.D. Univ. *St. And.*, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 203 Macquarie-street; p.r. Ashfield.
1899	P 1	De Coque, J. V., Public Works Department, Sydney.
1894		Dick, James Adam, B.A. *Syd.*, M.D., C.M. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., Fellow of the Institute of Chemistry of Great Britain and Ireland, 97 Pitt-street.
1880		Dixson, Thomas, M.B. *Edin.*, Mast. Surg. *Edin.*, 287 Elizabeth-street, Hyde Park.
1879		Docker, Wilfred L., 'Nyrambla,' Darlinghurst Road.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Eltham,' Edgecliffe Road.
1899		Duckworth, A., A.M.P. Society, 87 Pitt-st.; p.r. 'Trentham,' Woollahra.
1873	P 1	Du Faur, E., F.R.G.S., Exchange Buildings, Pitt-street.
1899		Durack, J. J. E., B.A. *Syd.*, St. John's College University.

Elected		
1894		Edgell, Robert Gordon, Roads and Bridges Office, Wollombi.
1896		Edwards, George Rixon, Resident Engineer, Roads and Bridges Branch, Coonamble.
1879	P 4	Etheridge, Robert Junr., J.P., Curator, Australian Museum; p.r. 21 Roslyn-street, Darlinghurst.
1876		Evans, George, Fitz Evan Chambers, Castlereagh-street.
1892		Everett, W. Frank, Roads and Bridges Office, Muswellbrook.

1896		Fairfax, Charles Burton, *S. M. Herald* Office, Hunter-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.
1889		Farr, Joshua J., J.P., 'Cora Lynn,' Addison Rd., Marrickville.
1897		Fell, David, Public Accountant, Equitable Buildings, George-street.
1881		Fiaschi, Thos., M. D., M. Ch. Univ. *Pisa*, 149 Macquarie-street.
1891		Firth, Thomas Rhodes, M. Inst. C.E., 'Glenevin,' Arncliffe.
1891		Fitzgerald, Robert D., C.E., Roads and Bridges Branch, Department of Public Works, Sydney; p.r. Alexandra-st., Hunter's Hill.
1888		Fitzhardinge, Grantly Hyde, M.A. *Syd.*, District Court Judge, 'Red Hill,' Pennant Hills, Northern Line.
1894		Fitz Nead, A. Churchill, Lands Department, Lismore.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 141 Macquarie-street.
1881		Foster, The Hon. W. J., Q.C., 'Thurnby,' Enmore Road, Newtown.
1881		Furber, T. F., Surveyor General's Office, 'Tennyson House,' 145 Victoria-street.

1889		Gale, Walter Frederick, F.R.A.S., Mem. A.S.P. & B.A.A., Savings' Bank of New South Wales, Newcastle.
1899	P 1	Garran, Hon. A., M.A., LL.D., M.L.C., 'Roanoke,' Roslyn Avenue, Darlinghurst.
1899		Garran, R. R., M.A., Wigram Chambers, Phillip-street.
1876		George, W. R., 318 George-street.
1879		Gerard, Francis, 'Clandulla,' Goulburn.
1896		Gibson, Frederick William, District Court Judge, 'Grasmere,' Stanmore Road.
1891		Gill, Robert J., Public Works Department, Moruya.
1876	P 4	Gipps, F. B., C.E., 'Elmly,' Mordialloc, Victoria.
1883		Goode, W. H., M.A., M.D., Ch. M., Diplomate in State Medicine *Dub.*; Surgeon Royal Navy; Corres. Mem. Royal Dublin Society; Mem. Brit. Med. Assoc.; Lecturer on Medical Jurisprudence, University of Sydney, 159 Macquarie-st.
1859		Goodlet, John H., 'Canterbury House,' Ashfield.
1896		Gollin, Walter J., 'Winslow,' Darling Point.
1897		Gould, Hon. Albert John, M.L.C., J.P., Holt's Chambers, 121 Pitt-street; p.r. 69 Roslyn Gardens.

Elected		
1886		Graham, James, M.A., M.D., M.B., C.M. *Edin.*, M.L.A., 183 Liverpool-street.
1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c., Australian Club, Sydney.
1899	P 1	Gummow, Frank M., Vickery's Chambers, 82 Pitt-street.
1898		Gurney, Elliott Henry, 'Glenavon,' Albert-st., Petersham.
1877		Gurney, T. T., M.A. *Cantab.*, Professor of Mathematics, Sydney University; p.r. 'Clavering,' French's Forest Road, Manly.
1891	P 2	Guthrie, Frederick B., F.C.S., Department of Agriculture, Sydney; p.r. 'Westella,' Wonga-street, Burwood.
1880	P 1	Halligan, Gerald H., C.E., 'Riversleigh,' Hunter's Hill.
1899		Halloran, A., B.A., LL.B., 20 Castlereagh-street.
1892		Halloran, Henry Ferdinand, L.S., Scott's Chambers, 94 Pitt-st.
1887	P 5	Hamlet, William M., F.C.S., F.I.C., Member of the Society of Public Analysts; Government Analyst, Health Department, Macquarie-street North. *President.*
1882		Hankins, George Thomas, M.R.C.S. *Eng.*, 'St. Ronans,' Allison Road, Randwick.
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1877	P 18	‡Hargrave, Lawrence, J.P., 44 Roslyn Gardens, City.
1899		Harper, H. W., Assoc. M. Inst. C.E., 63 Pitt-street.
1884		Haswell, William Aitcheson, M.A., D. Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. St. Vigeans, Darling Point.
1899		Hawker, Herbert, Demonstrator in Physiology, University of Sydney; p.r. 14 Toxteth Road, Glebe Point.
1890	P 2	Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C.E., Assoc. M. Can. Soc. C.E., Assoc. M. Am. Soc. C.E., M.M. & C.E., M. Inst. C.E. I., L.S., 'Fontenoy,' Ocean-street, Woollahra.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1884		Henson, Joshua B., C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1899		Henderson, J., City Bank of Sydney, Pitt-street.
1899		Henderson, S., M.A., Assoc. M. Inst. C.E., 63 Pitt-street.
1891		Hickson, Robert R. P., M. Inst. C.E., Under Secretary, Public Works Department; p.r. 'The Pines,' Bondi.
1876	P 2	Hirst, George D., 377 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st., Ashfield.
1891		Hood, Alexander Jarvie, M.B., Mast. Surg. *Glas.*, 127 Macquarie-street, City.
1892		Hodgson, Charles George, 157 Macquarie-street.
1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 12 Spring-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin.*, 47 Phillip-street.
1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F. R. Met. Soc., Second Meteorological Assistant, Sydney Observatory.
1891		Hutchinson, William, M. Inst. C.E., Supervising Engineer, Railway Construction Branch, Public Works Department, Moree.

Elected		
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 157 Liverpool-street, Hyde Park.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P., M.R.C.S., L.S.A. *Lond.*, 213 Macquarie-street, North.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1884		Jones, Llewellyn Charles Russell, M.L.A., Solicitor, Sydney Chambers, 130 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*. 16 College-street, Hyde Park; p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Caer Idris,' Ashfield.
1875	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873		Keele, Thomas William, M. Inst. C.E., District Engineer, Harbours and Rivers Department, Ballina, Richmond River.
1877		Keep, John, Broughton Hall, Leichhardt.
1894		Kelly, Walter MacDonnell, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., M.A., Bell's Chambers, 129 Pitt-street.
1898		Kerry, Charles H., 310 George-street.
1892	P 3	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Roads and Bridges Branch, Public Works Department, Sydney.
1874		King, The Hon. Philip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 'Glenhurst,' Darling Point.
1892		Kirkcaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M. D. *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons' Terrace, Hyde Park.
1881	P 11	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney; p.r. 'Avoca House,' Denison Road, Petersham. *Hon. Secretary.*
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Rose Bay.
1875		Knox, The Hon. Sir Edward, Knt., M.L.C., 'Fiona,' New South Head Road, Woollahra.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1872	P 48	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F R.S.; Assoc. Roy. Sch. Mines, *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc., *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France;* Cor. Mem. Edin. Geol. Soc.; Roy. Soc., *Tas.;* Roy. Soc., *Queensland*; Senckenberg Institute, *Frankfurt;* Society d' Acclimat., *Mauritius*, Hon. Mem. Roy. Soc., *Vict.;* N. Z. Institute; K. Leop. Carol. Acad., *Halle a/s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point.

Elected		
1881		Lloyd, Lancelot T., 'Eurotah,' William-street, East.
1878		Low, Hamilton, 32 Cavendish-street, Petersham.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*, 223 Elizabeth-street, Hyde Park.
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1874		M'Cutcheon, John Warner, Assayer to the Sydney Branch of the Royal Mint.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street, North.
1897		MacDonald, C. A., C.E., 63 Pitt-street.
1878		MacDonald, Ebenezer, J.P., 'Kamilaroi,' Darling Point.
1868		MacDonnell, William J., F.R.A.S. c/o Mr. W. C. Goddard, Norwich Chambers, Hunter-street.
1877		MacDonnell, Samuel, 12 Pitt-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Hospital for Insane, Newcastle.
1891		McKay, R. T., L.S., Sewerage Construction Branch, Public Works Department.
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.*, 183 Liverpool-street, Hyde Park; p.r. 'Dunara,' Rose Bay.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 5	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C.E., Chief Engineer for Water Conservation, Athenæum Club, Castlereagh-street.
1876		MacLaurin, The Hon. Henry Norman, M.L.C., M.A., M.D. *Edin.*, L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1894		McMillan, William, 'St. Kilda,' Allison-st., Randwick.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 6	Maiden, J. Henry, J.P., F.L.S., Corr. Memb. Pharm. Soc. Gt. Brit.; of the National Agric. Soc. Chili; Hon. Memb. Royal Netherlands Soc. (Haarlem); of the Philadelphia Coll. of Pharmacy; of the Royal Soc. of S.A.; of the Mueller Botanic Soc. of W.A.; Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1879		Manning, Frederic Norton, M.D. Univ. *St. And.*, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Australian Club.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1897		Marden, John, B.A., M.A., LL.B. Univ. *Melb.*, LL.D. Univ. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1875	P 8	Mathews, Robert Hamilton, L.S., Cor. Mem. Anthrop. Inst. Gt. Brit. and Irel.; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem. Roy. Geog. Soc. Aust., Queensland; Cor. Mem. Soc. d'Anthrop. de Paris; 'Carcuron,' Hassall-street, Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin.*, 48 College-street.
1896	P 4	Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department; p.r. 'Branville,' Green Bank-street, Marrickville.

Elected		
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, The Hospital, Rydalmere, Near Parramatta.
1873		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 231 Elizabeth-st.
1882		Milson, James, 'Elamang,' North Shore.
1889	P 3	Mingaye, John C. H., F.C.S., M.A.I.M.E., Assayer and Analyst to the Department of Mines, Sydney.
1892		Mollison, James Smith, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Department of Public Works, Sydney.
1856	P 7	Moore, Charles, F.L.S., Australian Club ; p.r. 6 Queen-street, Woollahra. *Vice-President.*
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, 5 Bligh-street.
1882		Moss, Sydney, 'Kaloola,' Kiribilli Point, North Shore.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Billountan,' Challis Avenue, Pott's Point.
1888		Mullins, George Lane, M.A., M.D. Trin. Coll. *Dub.*, M.D. *Syd.*, F.R.M.S. *Lond.*, 'Murong,' Waverley.
1887		Munro, William John, M.B., C.M. *Edin.*, M.R.C.S. *Eng.*, c/o Miss Munro, 'Chester,' Stanmore.
1898		Murray, Lee, M.C.E. *Melb.*, 65 Pitt-street.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1890		Neill, Leopold Edward Flood, M.B., Ch. M. Univ. *Syd.*, No. 3, Bayswater Houses, Double Bay.
1891		‡Noble, Edwald George, 21 Norfolk-street, Paddington.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street ; p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., 'Waima,' Wentworth Road, Point Piper, Sydney.
1888		O'Neill, G. Lamb, M.B., C.M. *Edin.*, 291 Elizabeth-street.
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.
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1883		Palmer, Joseph, 133 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1899		Pearce, W., Union Club ; p.r. 'Waiwera,' Cecil-st., Ashfield.
1877		Pedley, Perceval R., 227 Macquarie-street.
1899		Perkins, E. W., 122 Pitt-street.
1877		Perkins, Henry A., 'Barangah,' Coventry Road, Homebush.
1899		Petersen, T. T., Mercantile Mutual Chambers, 118 Pitt-street.

Elected		
1876		Pickburn, Thomas, M.D., C.M. *Aberdeen*, M.R.C.S. *Eng.*, 22 College-street.
1879	P 5	Pittman, Edward F., Assoc. R.S.M., L.S., Government Geologist, Department of Mines.
1899		Plummer, John, Northwood, Lane Cove River.
1881		Poate, Frederick, District Surveyor, Tamworth.
1890		Pockley, Francis Antill, M.B., M. Ch. Univ. *Edin.*, M.R.C.S. *Eng.*, 227 Macquarie-street.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B. Sc., *Syd.*, Professor of Physics, Sydney University.
1891		Poole, William Junr., Assoc. M. Inst. C.E., 87 Pitt-street, Redfern.
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges, Public Works Department.
1893		Purser, Cecil, B.A., M. B. Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1876		Quaife, Frederick H., M.A., M.D., Master of Surgery *Glas.*, 'Hughenden,' 14 Queen-street, Woollahra.
1899	P 1	Rae, J. L. C., Manager Sydney Harbour Collieries Ltd.; p.r. 'Strathmore,' Ewenton-street, Balmain.
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And., F.R.S.E., F.L.S., Petersham.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D. Sc. *Lond.*, Professor of Chemistry, University, Adelaide.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 40 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, M.L.C., B.A. *Syd.*, M.A., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, Phillip-street.
1885		Rolleston, John C., C.E., Harbours and Rivers Branch, Public Works Department.
1897		Ronaldson, James Henry, Mining Engineer, 32 Macleay-st., Pott's Point.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, Hospital for the Insane, Kenmore, Near Goulburn.
1895		Ross, Colin John, B.Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895	P 1	Ross, Herbert E., Consulting Mining Engineer, Equitable Buildings, George-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club.
1894		Rowney, George Henry, Assoc. M. Inst. C.E., Water and Sewerage Board, Pitt-street; p.r. 'Maryville,' Ben Boyd Road, Neutral Bay.

Elected		
1864	P 64	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F.R. Met. Soc. Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory.
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 379*b* George-street; p.r. 'Mahuru,' Milton-street, Ashfield.
1883		Rygate, Philip W., M.A., B.E. *Syd.*, Phœnix Chambers, Pitt-st.
1892		Schmidlin, F., 44 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.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1877	P 3	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P., B.A. *Syd.*, F.R.A.S., Sydney Observatory.
1891		Shaw, Percy William, Assoc. M. Inst. C.E., Resident Engineer for Tramway Construction; p.r. 'Leswell,' Torrington Road, Strathfield.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1879		Shepard, A. D., Box 728 G.P.O. Sydney.
1882		Shewen, Alfred, M.D. Univ. *Lond.*, M.R.C.S. *Eng.*, 6 Lyons' Terrace, Hyde Park.
1894		Simpson, Benjamin Crispin, M. Inst. C.E., St. James' Chambers, King-street, City.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.
1893		Sinclair, Russell, M.I. Mech. E. &c., Consulting Engineer, 97 Pitt-st.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1891	P 1	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 18	Smith, Henry G., F.C.S., Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Syd.*, Marlborough Chambers, 2 O'Connell-street.
1899		Smith, R. G., M.Sc. *Dun.*, B.Sc. *Edin.*, Macleay Bacteriologist, 'Otterburn,' Double Bay.
1898		Smith, S. Hague, Colonial Mutual Fire Insurance Co., 78 Pitt-st
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1896		Spencer, Walter, M.D. *Brux.*, 13 Edgeware Road, Enmore.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., 'Athol,' Beaconsfield-street, Rockdale.
1882		Steel, John, L.R.C.P., L.R.C.S. *Edin.*, M.B., B.S. Univ. *Melb.*, 3 Lyons' Terrace, Hyde Park.
1889		Stephen, Arthur Winbourn, L.S., 86 Pitt-street.
1879		‡Stephen, The Hon. Septimus A., M.L.C., 12—14 O'Connell-st.
1891		Stilwell, A. W., Assoc. M. Inst. C.E., 'Oakstead,' Russell-st., Bathurst
1883	P 3	Stuart, T. P. Anderson, M.D. Univ. *Edin.*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay. *Vice-President.*

Elected		
1892		Sturt, Clifton, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 'Wistaria,' Bulli.
1893		‡Taylor, James, B. Sc., A. R. S. M., Adderton Road, Dundas.
1899		Teece, R., F.I.A., F.F.A., Actuary, A.M.P. Society, 87 Pitt-st.
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor for Railways; p.r. 'Camelot,' Forest Road, Bexley.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street; p.r. Woollongong Road, Arncliffe.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, Dugald, M.L.A., 'Wyreepi,' Milson's Point.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.
1898		Thow, Sydney, 24 Bond-street.
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., Locomotive Department, Eveleigh.
1886	P 5	Threlfall, Richard, M.A. *Cantab.*
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1876		Tibbits, Walter Hugh, M.R.C.S. *Eng.*, Dubbo.
1896		Tickle, Arthur H., 'Adderton,' Fullerton-street, Woollahra.
1894		Tidswell, Frank, M.B., M.Ch., D.P.H., Health Department, Sydney.
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1894		Tooth, Arthur W., Australian Club, Bent-street.
1873	P 1	Trebeck, Prosper N., J.P., 2 O'Connell-street.
1879		Trebeck, P. C., 2 O'Connell-street.
1877		‡Tucker, G. A., c/o Perpetual Trustee Co., 2 Spring-st.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'BayView House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., viâ Fazio 2, Spezia, Italy.
1896		Verdon, Arthur, Australian Club.
1890		Vicars, James, M.C.E., M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company, 2 Spring-street.
1898		Wade, Leslie A. B., C.E., Department of Public Works.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, J. T., 'Rosemont,' Ocean-street, Woollahra.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Supervising Engineer, Harbours and Rivers Department, Newcastle.
1896		Walsh, C. R., Prothonotary, Supreme Court.
1895		Ward, James Wenman, 1 Union Lane off George-street.
1891		Ward, Thomas William Chapman, B.A., B.C.E. *Syd.*, 'Birkdale,' 26 Mansfield-street, Glebe Point.
1898		Wark, William, 9 Macquarie Place; p.r. Kurrajong Heights.
1877		Warren, William Edward, B.A., M.D.. M. Ch. Queen's University *Irel.*, M.D. *Syd.*, 263 Elizabeth-street, Sydney.

Elected		
1883	P 10	Warren, W. H., Wh. Sc., M. Ins. C.E., Professor of Engineering, University of Sydney.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, 5 Richmond Terrace, Domain.
1876		Watson, C. Russell, E.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1897		Webb, Fredk. William, C.M.G., J.P., Clerk of the Legislative Assembly; p.r. 'Livadia,' Chandos-street, Ashfield.
1866		Webster, A. S., c/o Permanent Trustee Co., 16 O'Connell-st.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street; p.r. 52 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. ., 'Oaklands,' Edgecliffe Road.
1892		White, Harold Pogson, Assistant Assayer and Analyst, Dept. of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd*, 'Gowrie,' Singleton.
1888		White, The Hon. Robert Hoddle Driberg, M.L.C., Union Club; p.r. 'Tahlee,' Port Stephens.
1898		Wildridge, John, M. I. Mech. E, &c., 97 Pitt-street.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C P. *Lond.*, M.R.C.S. *Eng.*, 207 Macquarie-street.
1876		Williams, Percy Edward, The Treasury; p.r. Gladesville Road, Hunter's Hill.
1878		Wilshire, James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' off Ranger's Road, Shell Cove, Neutral Bay.
1879		Wilshire, F. R., P.M., Penrith.
1891		Wilson, Robert Archibald, M.D. *Glas.*, Mast. Surg. *Glas.*, 2 Booth-street, Balmain.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 10 Bligh-st.; p.r. 54 Darlinghurst Road.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe," Liverpool Road, Ashfield.
1899		Woolnough, W. G., B. Sc, Demonstrator in Geology, Sydney University.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1872		Wright, Horatio G. A., M.R.C.S. *Eng.*, L.S.A. *Lond.*, 4 York-st., Wynyard Square. *Hon Treasurer.*
1893		Wright, John, C.E., Toxteth-street, Glebe Point.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

HONORARY MEMBERS.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

Elected		
1878		Agnew, Sir James, K.C.M.G., M.D., Royal Society of Tasmania, Hobart.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1887		Foster, Sir Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., late Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1888	P 3 M	Tate, Ralph, F.G.S., F.L.S., Professor of Natural Science, University, Adelaide, South Australia.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Parkstone, Dorset.

CORRESPONDING MEMBERS.

Limited to Twenty-five.

Elected		
1886		Marcou, Professor Jules, F.G.S., Cambridge, Mass., United States of America.

OBITUARY.

1899.

Honorary Members.

Elected		
1895		Bunsen, Professor Robert Wilhelm.
1875		M'Coy, Sir Frederick.

Ordinary Members.

Elected		
1886		Collingwood, Dr. David.
1896		Elwell, P. B.
1887		MacAllister, Dr. J. F.
1878		Maitland, Duncan Mearns.
1859		Watt, Charles.
1878		Wilkinson, Rev. S.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

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

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen, K.C.B., F.R.S., Hampton Court.
1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.
1880 Professor Huxley, F.R.S., The Royal School of Mines, London, 4 Marlborough Place, Abbey Road, N.W.
1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.
1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.
1883 Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.
1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.
1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.
1886 Professor L. G. De Koninck, M.D., University of Liège, Belgium.
1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.
1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.
1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.
1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.
1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.
1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.
1895 Robert Etheridge, Junr., Government Palæontologist, Curator of the Australian Museum, Sydney.
1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.

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, for paper on the 'Timbers of New South Wales.

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

1895 C. J. Martin, B.Sc., M.B. *Lond.*, 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."

ANNIVERSARY ADDRESS.

By G. H. Knibbs, F.R.A S.,

Lecturer in Surveying, University of Sydney.

[*Delivered to the Royal Society of N. S. Wales, May 3, 1899.*]

The history of our Society during the past year calls for no special comment. It has been a year of steady work, and in respect of matters of internal economy, the placing of ourselves on a sounder basis, by removing from nominal membership those who after the fullest notice, failed to discharge their obligations to us. Daily the need of developing and properly caring for our fine library is impressing itself upon your Council, but the financial resources are wanting. The meaning of scientific libraries to a community is a matter to which I shall later refer. For the following abstract of our year's work I am indebted to our esteemed Assistant Secretary Mr. W. H. Webb:—

Roll of Members.—The number of members on the roll on the 30th April, 1898 was three hundred and ninety-seven. Fourteen new members have been elected during the past year. We have however, lost by death, five ordinary and one honorary member, and fifteen by resignation. Thirty-one have been struck off the roll for non-payment of their subscription and three have failed to take up their membership under Rule IX*a*. There is thus left a total of three hundred and fifty-seven on April 30th, 1899; this number, the lowest on record since 1878, however, does not include the honorary and corresponding members. It is to be hoped that our hands will be strengthened by the addition of members who have the interests of the cause for which the Society exists, very near their hearts. Such an influx would help us greatly to increase our influence in promoting the welfare of the colony.

Obituary.— *Hon. Member.*

Waterhouse, F. G., F.G.S., C.M.Z.S.; elected 1875.

Ordinary Members:

Bundock, W. C.; elected 1877.
De Salis, L. F.; elected 1875.
Kopsch, G. A.; elected 1877.
Long, A. Parry; elected 1887.
Roberts, Sir Alfred ; elected 1868.

In the death of Sir Alfred Roberts our Society and community lost a zealous worker. Born in 1823, and educated in England for the medical profession, he came to this colony about 1850. He was among the earliest founders of this Society, having been Hon. Secretary of its predecessor, the Philosophical Society of New South Wales, in 1862. He contributed several papers and occupied also the position of President, and almost to the end threw the weight of his influence into the work of the Medical and Sanitary Sections. The Prince Alfred Hospital, erected in commemoration of the preservation of the life of H.R.H. the Duke of Edinburgh, an institution whose development was largely due to his untiring and watchful care, will remain a permanent monument of his zeal, and invaluable service in the cause of humanity. His name will ever be borne, by those who knew his life and work, in respectful and affectionate memory.

Papers read in 1898.—During the past year the Society held eight meetings, at which the average attendance of members was thirty, and of visitors two ; the following sixteen papers were read:

I.—President's Address. By Henry Deane, M.A., M. Inst. C.E.
II.—Aeronautics. By L. Hargrave
III.—Australian Divisional Systems. By R. H. Mathews, L.S.
IV.—Artesian Water in New South Wales. By J. W. Boultbee
V.—On the "Stringybark" Trees of N. S. Wales, especially in regard to their Essential Oils. By R. T. Baker, F.L.S., Curator, and H. G. Smith, F.C.S., Technological Museum, Sydney.
VI.—Current Observations on the Canadian-Australian Route. By Capt. M. W. Campbell Hepworth, F. R. Met. Soc., F.R.A.S., R.M.S. *Aorangi*. (Communicated by H. C. Russell, B.A., C.M.G., F.R.S.)
VII.—Water-spouts on the Coast of New South Wales. By H. C. Russell, B.A., C.M.G., F.R.S. (*Plates* ii. - ix.)

VIII.—Some Physical Properties of Nickel Steel. By W. H. Warren, Wh. Sc., M. Inst. C.E., M. Am. Soc. C.E., Challis Professor of Engineering, and S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E., Lecturer in Engineering, University of Sydney.

IX.—Key to the Tribes and Genera of Melanospermeæ, (Olive-Green Seaweeds). By Richard A. Bastow, Fitzroy, Victoria. (Communicated by J. H. Maiden, F.L.S.) (*Plate* i.)

X.—Etude sur les Dialectes de la Nouvelle-Calédonie. Par Julien Bernier. (Communicated by C. Hedley, F.L.S.)

XI.—On the Pinenes of the Oils of the Genus Eucalyptus, Part I. By Henry G. Smith, F.C.S., Technological Museum, Sydney.

XII.—Soaring Machines. By L. Hargrave.

XIII.—Native Vocabulary of Miscellaneous New South Wales Objects. By Mr. Surveyor Larmer. (Communicated by Professor T. P. Anderson Stuart, M.D., by permission of the Honourable the Secretary for Lands.

XIV.—Current Papers, No. 3. By H. C. Russell, B.A., C.M.G., F.R.S. (*Plates* x., xi.)

XV.—The Group Divisions and Initiation Ceremonies of the Barkunjee Tribes. By R. H. Mathews, L.S. (*Plate* xii.)

XVI.—The Blue Pigment of Corals. By Professor Liversidge, M.A., LL.D., F.R.S.

Sectional Meetings.—The *Engineering Section* held eight meetings, at which the average attendance of members and visitors was twenty-one; the following papers were read and discussed:—

1. Annual Address to the Engineering Section. By T. H. Houghton, M. Inst. C.E., M. Inst. M.E.
2. The Narrow Gauge as applied to Branch Railways in N.S. Wales. By C. O. Burge, M. Inst. C.E.
3. Engineering Construction in connection with Rainfall. By J. I. Haycroft, M. Inst. C.E. I., Assoc. M. Am. Soc. C.E.
4. Some Notes on a Wharf recently built in deep water at Dawes' Point, Sydney, N. S. Wales. By Norman Selfe, M. Inst. C.E., &c.
5. Notes on Hydraulic Boring Apparatus. By G. H. Halligan, C.E.
6. Lighthouses in N. S. Wales. By H. R. Carleton, M. Inst. C.E.
7. A Testing Machine for equal alternating stresses. By Professor Warren, Wh. Sc., M. Inst. C.E.

The *Medical Section* held four meetings, at which numerous exhibits were shown, and the following papers read and discussed:—

1. Disinfection of Dwellings in notifiable Infectious Diseases, by Dr. W. G. Armstrong, Medical Officer of Health for the Metropolitan Combined Districts.
2. Notes on two cases of Amputation of the Rectum for extreme Prolapsus, by Dr. Fiaschi.

Financial Position.—The Hon. Treasurer's Financial Statement shows that the sum of £200 has been repaid to the Clarke Memorial Fund, and a balance of £35 8s. 4d. carried forward.

Library.—The amount expended on the Library during the past year was £98 10s. 11d., viz.: £66 6s. 9d. for books and periodicals and £32 4s. 2d. for binding. Amongst other works purchased were Silliman's American Journal of Science, Vols. I. – X., to complete the third series, and the Proceedings of the Royal Colonial Institute, Vol. III., to complete the set.

Exchanges.—Last year we exchanged our Journal with four hundred and three kindred societies, receiving in return two hundred and thirty-seven volumes, one thousand five hundred and sixty-five parts, seventy-five reports, two hundred and four pamphlets, and one portrait, a total of two thousand and eighty-two publications. The following Institutions have been added to the exchange list:—Royal Society of Sciences and Belles-Lettres, Gothenburg; Editor of "Science Abstracts," London; Philadelphia Commercial Museum, U.S.A.; Società Italiana di Fisica, Pisa; Illinois State Laboratory, U.S.A.

Original Researches.—In response to the offer of the Society's medal and grant of ten guineas for the best original paper on the following subject:—

Series XVIII.—*To be sent in not later than 1st May, 1899.*

No. 53—"On the life history of the Australasian Teredo, and of other species of Australasian wood-eating Marine Invertebrata, and on the means of protecting timber from their attack."

One paper has been received, but has not yet been adjudicated upon.

At this Annual Meeting of our Society, the last but one of a century distinguished from all others by the intensity and universality of its scientific activity, it will not be inappropriate to devote the hour at our disposal to some consideration of the influence of systematised knowledge upon the progress of humanity

—the part played by Science as a factor in Civilisation. In addressing ourselves to such a theme, it may be remarked that the constitution of our Society is sufficiently wide to include subjects outside the realm of merely physical science: the main drift and tendency of our work however, as in the Royal Society of England, has been in that specific direction, and for that reason it will be advantageous to confine ourselves to reviewing the part played by the physical sciences, rather than by Science in the more comprehensive sense of the word.

In focussing our attention upon special activities, there is always a danger of appearing to have ignored others of equal dignity and energy: by way of anticipating this, it is perhaps desirable to at once say, that, in tracing the incidence of scientific activity, no attempt is made at discriminating between what is to be credited to physical science, as such; and what may be credited to other sciences or other factors, no less potent, in human development. The reactions and interactions of all are so complex as to transcend any possibility of exact delimitation; and attempts at outlining their operation quantitatively, are as fanciful as they are futile. In human affairs it must therefore often suffice to watch, as well as one may, the part played by each factor, without uselessly essaying that precision of measurement which so delights the mathematical mind, and which the genius of the physicist demands as the consummation of knowledge.

Civilisation yields, indeed, rather to qualitative than to quantitative methods of analysis: it is not to be expressed in terms of wealth or material monuments, or in physical things which lend themselves to exact measurement, though these are in part its measure, and in and through them it is in part manifested. On the contrary, it is rather in the imponderable elements, in the intellectual and spiritual energy, in the genius, force, character, and solidarity of a nation or an age, that its degree of civilisation is really expressed. Remembering this, we are not likely, when we examine the functions of science, to forget that our view is restricted: we are not likely to forget that the discipline of our emotions and will, the cultivation of our understanding and imagination, the education of our thought and of its expression, and indeed all those things that are the concern not only of science, but of polite literature, philosophy, and religion, are also factors in civilisation, of transcendent importance. If in reviewing our indebtedness to the physical sciences, it may appear that the greater things have been forgotten, it is in appearance only.

That this is so, is obvious when we recognise that the glory of physical science lies not so much in the fact that it satisfies our material needs with relatively so small an expenditure of physical energy, or that it swiftly places at our disposal the products of industrial effort; but rather, that in doing these things, it becomes an instrument of culture, by intensifying, enlarging and enriching our life, and by giving us a finer appreciation of the possibilities of existence.

No science is so intimately interwoven in the plexus of human affairs, or may so justly be regarded as constituting the very warp and woof of the fabric of modern civilisation, as mathematics; and yet no equally weighty fact is perhaps more completely suppressed in our everyday consciousness. Touching even the simplest of its elements, the trivialities of ordinary arithmetic, which one might think almost beneath notice, it would be difficult to compute the magnitude of our debt to that scheme of notation, which assigns a constant ratio of increase in the unit value of each place of figures proceeding to the left, and to the congruity therewith of our system of numeration.[1] We are apt to overlook the value of

---

[1] The popular impression that the advantage of our notational and numerational systems depends upon its *decimal* character is of course erroneous. In respect to the facility of our ordinary arithmetical operations, the base or *radix* is a matter of comparative indifference, and a sexagesimal or duodecimal system has merits absent in the decimal system. The laws and processes of ordinary arithmetic are independent of the base of the system, and are dependent only upon its notational scheme, or 'law of position,' but that arithmetic may involve a minimum of mental labour, it is essential to have a congruous scheme of numeration. Our cumbrous English systems of weights and measures afford many examples of the difficulty introduced by absence of congruity.

things familiar, and this is no exception. The clumsy systems of the Hebrew, Greek, or Roman, would have placed burdens upon the computational necessities of the modern world, too heavy to be borne. It is only when we are compelled to appreciate this fact, that we can estimate the debt we owe to Hindustan, whence was derived our ordinary system of notation.

Civilisation may, from one point of view, be regarded as dependent upon our ability to levy tribute upon Nature, and to so utilise her material and direct her great sources of power, that they shall serve our purpose. In such issues Mind is regnant, and of all her instruments none compare with mathematics, the generality of whose function is unique. But whether this science had its genesis in the practical needs of mankind, or was begotten of speculative curiosity, would now be difficult to determine. The legendary origin of geometry supports the former view, and it must be admitted that the early Egyptian mind, where, according to Aristotle, geometry had its birth, gave little evidence of interest in purely theoretical results. The hieratic papyrus in the Rhind Collection of the British Museum, deciphered in 1877 by Eisenlohr, is perhaps the earliest mathematical document extant, taking us back, as it does, to the Egyptian mathematician Ahmes, whose "Directions for obtaining the Knowledge of all Dark Things" was written before 1700 B.C. Ahmes' treatise was based upon a still older work, to which the date 3400 B.C. has been assigned by Birch. The early Egyptian geometry and algebra, very elementary and not always accurate, was essentially practical in character. Cultivated by their priesthood, it was their guide in cadastral operations, and in constructing those great monuments of early civilisation, which even to-day are impressive in their grandeur. Herodotus tells us that Sesostris (Ramses II.) divided Egypt into equal quadrangles, from which after allotment he derived his revenues, by the imposition of a tax levied yearly. Many of the areas being affected by the overflow of the Nile, re-survey was involved for the purpose of adjusting the taxation, and thus many problems in geometry arose for solution. An examination of the temples and pyramids of Egypt, has shewn that their north and south lines were determined by astronomical observation: their east and west lines were then set out by the "Rope-Stretchers" [Harpedonaptai], using the 3. 4. 5 triangle. Thus the earliest and most striking monuments of human energy are indissolubly associated with mathematics.

There are strong reasons for believing that, whenever the mind of a people is wholly directed to purely practical issues, it is decadent. Be that as it may, the practical Egyptian seems to have remained content with his achievement; and for something like 2,000 years made no progress in mathematical knowledge: like the Chinese his mind had stagnated. Nevertheless his attainment became in time the inspiration of the Greek, who unlike his predecessor, was endowed with an ardent love of science for its own sake. The genius of the Greek impelled him onward to the discovery of abstract relations, regardless of all question as to the possibility of practical applications; and gave birth to a geometry, that in spite of its limitations as to generality, remains even to-day a model of logical exposition and rigour of thought. In a word the *Science* of Geometry and of Algebra, we owe to the Greek. The lofty scorn of the Greek mind for utilitarian considerations has left its impress on the world. With few exceptions that scorn has been the tincture of Genius ever since. It is a significant fact, and one that we do well to remember, that among the discoveries of truths, which have conferred inestimable benefits upon mankind, none can compare with those that have been vouchsafed to minds untarnished with a regard for material issues. Again and again have conquests in the most recondite regions of mathematical truth, proved not only eminently practical, but even essential to material advancement. To the mathematician, the knowledge of this will perhaps never operate as a motive, for no one can read the history of mathematics without realizing that the inspiration which has guided the votaries of the "queen of sciences" in their flights of genius, and has sustained them in their herculean labours, was from something nobler than material good. Forever it will be the fate of Archimedes to be esteemed by his fellow-citizens for his mechanical inventions, but forever his own grateful feeling will arise, because to him it has been given to penetrate the arcana of science and to reveal them to mankind. This however by the way, as shewing that the progress of humanity depends upon the love of abstract knowledge; depends first of all upon Science, rather than upon Art.

It is quite impossible under the limitations of our time to-night to review even in the briefest manner the history of mathematical progress: it is an *embarras de richesse:* any reference to significant advances must perforce ignore others of perhaps equal moment. Despite this, however, a reference to some elements of that history is absolutely essential to its intelligent understanding and we may therefore be pardoned for briefly scanning it.

Introduced from Egypt by Thales of Miletus [640 – 546 B.C.] about 600 B.C., raised by the genius of Pythagoras [? 582 – 504 B.C.] to the rank of a science less than one hundred years later, geometry made rapid progress in Greece, largely through Pythagoras' influence [about 550 B.C.], and still more through that of the immortal Plato, about 400 B.C., 'maker,' as he has been called, 'of mathematicians.' Plato [429 – 348 B.C.] himself was practically the founder of solid geometry. A contemporary, Archytas of Tarentum, [428 – 347 B.C.] was first in methodically treating the subject of mechanics, and in applying geometry thereto. To a brilliant pupil of Archytas and of Plato, Eudoxus of Cnidus [408 - 355 B.C.], belongs probably the honour of inventing the method of exhaustions, a method which contains the first germs of the infinitesimal calculus. To Eudoxus belongs also the credit of having so improved the methods of practical astronomy, as to win him the appellation of 'father of scientific astronomical observation.' A pupil of Eudoxus' viz., Menæchmus, was the inventor of the conic sections, destined afterwards to play so significant a part in dynamic and astronomical theory. About 350 B.C. Aristotle [384 – 322 B.C.] shewed that the logician may assist the mathematician in the matter of difficult definitions. His physics, it may be mentioned, contain suggestive hints of the principle of 'virtual velocities,' the foundation afterwards of the imperishable 'Mécanique analytique' of Lagrange.

About 300 B.C. the study of geometry was revived in Egypt by the establishment of the first Alexandrian school, with Euclid as it master. About fifty years later flourished the greatest mathematician of antiquity, Archimedes [287 – 212 B.C.], who shewed that the ratio of the circumference to the diameter of a circle lies between $3\frac{1}{7}$ and $3\frac{10}{71}$. The mean of these 3·1418, is sufficiently exact for most purposes. A contemporary, Eratosthenes, [276 – 196 B.C.], was the first to attempt to ascertain, on correct principles, the size of our earth. Forty years later again, the 'great geometer' Apollonius of Perga [b. 250 ? B.C.], second only to Archimedes, enriched the world with his talents : to him we owe the further development of the conic sections and developments in astronomical theory. About 150 B.C., Hipparchus of Nicæa in Bithynia, the greatest astronomer of antiquity, is said to have invented trigonometry ; it is worthy of mention that spherical, and not plane trigonometry, was first developed. For this branch of mathematics we are also no less indebted to Claudius Ptolemæus of the second Alexandrian School [about 130 A.D.], celebrated as the founder of the system of astronomy which bears his name. 'The theorems of Hipparchus and Ptolemæus,' said Delambre, 'will forever constitute the basis of trigonometry.'

The second Alexandrian School closes with Diophantus [246 – 330], about 300 A.D., so distinguished as an algebraist, that it has been said, that but for him algebra among the Greeks would, comparatively, have been an unknown science.

Splendid as was the Greek mind in respect of its love of pure science, it did not rise in mathematics, to generality of method. The brilliant talents of Euclid, Archimedes and Apollonius had indeed brought geometry to a high state of perfection ; the crystalline clearness of its concepts, and the logical rigour of its conclusions, were ideal : but its inherent limitation lay in the fact that it was essentially *special* in character. Further advance involved the invention of more general and therefore more powerful methods; but to this task the Greek was unequal.

The Romans contributed relatively nothing; their giant Boëtius [475 – 525 A.D.] compared with the Greek masters, was a pigmy; and mathematical inspiration vanished from the western world, to more feebly reappear in the eastern, in Hindustan. The Hindu however regarded arithmetic, algebra, and geometry merely as aids to astronomy; a science in which, as the irony of fate determined, he was to win no distinction. The historically oldest of Indian mathematicians or rather astronomers, Aryabhata [476 – 550 A.D.] assigned the value 3·1416 for the Ludolphian number. This, however, had been previously given by Ptolemæus as $3^{p}\ 8'.\ 30''$ or $3 + \frac{8}{60} + \frac{30}{3600}$ *i.e.*, $3{\cdot}141\dot{6}$. To Aryabhata, though the evidence is not quite decisive, probably belongs the credit of inventing the fundamental principles of our present system of arithmetical notation, the contribution of which to the general progress of intelligence, would be difficult to estimate. Coming to us through the Arab, it has improperly been called the Arabic system. Mathematics attained its highest position in India about 630 A.D. when flourished Brahmagupta [born 598 A.D.], the 12th and 18th chapters of whose work, 'Brahma-sphuta-siddhanta,' contains what of mathematics was then known to Hindustan. The Hindu was remarkable for skill in calculation, for being the first to recognise the existence of negative quantities, and for the development of general methods of solving indeterminate equations; his taste lay rather in the direction of algebra and trigonometry than in geometry, for Hindu geometry was poor. That both the form and spirit, however, of modern arithmetic and algebra are essentially Hindu, is sufficient evidence of the reality of our debt to his genius.

From India the torch of science passed to the ascendant Arab when at the close of the reign of Abú Ja'far ibn Mohammed, or Almansúr [772 A.D.] Hindu mathematics was studied at Baghdad, and a Hindu astronomer translated into Arabic the astronomical tables of his country. The oriental superstition that the progress of human affairs was associated with celestial portents, and the necessity for determining, for the convenience of the devout believer, the direction of Mecca from every part of the wide-extended Moslem dominion, greatly promoted the study of astronomy. Tables and instruments were perfected, observatories erected, observations systematised, and astronomy ardently cultivated. The first great Arabic author of mathematical books, Mohammed ben Musa Al Khárizmí [about 820 B.C.], has given us the words 'Algorithm' and 'Algebra,' the former being a corruption of his latinised name Algoritmi, the latter of the first word in the title of his algebra. "Aldshebr Walmukabala" or 'restoration and reduction.' With 'Omar bin Ibráhím Al Khayyámi, [? 1017 – 1123 A.D.] better known perhaps through his Rubá'iyát, immortalized in English by Fitzgerald, than through his method of solving equations by intersecting conics, the Arabian period culminated.

In the matter of scientific culture the Arab was liberal, but not inventive. Lacking the penetrative insight, and power to make great and original contributions to Science, he nevertheless was a faithful custodian and a broad disseminator of the intellectual possessions of antiquity. But the time seems to have come for the Semitic custody of Aryan culture of both East and West to be restored to Aryan hands. During the decadent period of the Arabian, Great Britain, Ireland, and France had become the locus of mathematical activity in Christian Europe. The centre changed however to Italy with the appearance, at the beginning of the 13th century, of Leonardo of Pisa, who among other things. strongly advocated the adoption of the so-called Arabic notation. In respect of mathematics generally he is said to have treated the rich material before him with skill and euclidean rigour.

In the European Universities the study of mathematics now began to be promoted, though it must be confessed in a half-hearted manner; for, by the fashion of the time, the energies of the brightest intellects were exhausted on the subtleties of scholasticism. With the fall of the Byzantine Empire in 1453, came, however, a new era. The precious manuscripts of Greek literature were studied directly, in place of resorting to corrupt Arabian translations; and by means of the then recently invented printing press, the intellectual wealth of the past was rapidly disseminated. The genius, assiduity, and enthusiasm of Johann Müller [Regiomontanus, 1436 – 1476] one of the greatest men ever given by Germany to the world, stirred up civilized Europe. His translations of ancient mathematical and astronomical literature, his construction of elaborate trigonometrical tables for practical use, his treatises on arithmetic and trigonometry—the form of this last being to-day substantially as it left his hands—and his splendid mastery of mathematics and astronomy, were a propitious inauguration of the new era.

The contributions to algebra during the remainder of the 16th century by Tartaglia [1500 – 1557],[1] by the clever but unscrupulous Cardano [1501 – 1576], and by Vieta [1540 – 1603], we cannot pause to survey; and must content ourselves with referring to the brilliant discovery by Vieta of twenty-three roots of an equation of the 45th degree, and to the ardent admiration which that evoked from the propounder of the problem, Adriaan van Roomen,[2] who, with Ludolph van Ceulen will be remembered in connection the value of π, or the "Ludolphian" number, so named after the latter, who carried the computation to thirty-five places of figures.

From the beginning of the 17th century the mathematical wealth, which burst upon the world, is beyond all computation. Mathematical discoveries became meteoric in their brilliancy, and the intellectual firmament coruscated with their frequency and splendour.

---

[1] Cajori gives 1506 as the date of Tartaglia's birth, evidently assuming that his mutilation occurred when he was six years of age, and on the occasion of the French, under Gaston de Foix, sacking Brescia in 1512. But Tartaglia was an esteemed teacher of mathematics at Verona as early as 1521.

[2] Henry IV. of France submitted to Vieta a problem propounded by 'Adrianus Romanus,' a Belgian mathematician:—$45y - 3735y^3 + 95634y^5 - \ldots + 945y^{41} - 45y^{43} + y^{45} = C$. Vieta saw at once that this was the equation by which $C = 2 \sin \phi$ was expressed in terms of $y = 2 \sin \frac{1}{45} \phi$.

Scotland's son, John Napier of Merchiston, [1550 - 1617] in 1614 discovered logarithms. Henry Briggs [1556 - 1631] and Napier together adapted them to the purposes of ordinary computation; the latter and Adrian Vlacq of Holland calculating the extensive tables with which we are familiar, and which have become a necessity to the modern world. About the same time the illustrious Johannes Kepler [1571 - 1630] made his great discovery of the ideal laws of planetary motion. The study of the conic sections by Menæchmus, Aristæus,[1] and Apollonius was a matter purely of intellectual interest: those discoveries however, furnished Kepler with the key, by which to unlock the real character of that motion, a splendid example of the fruition of abstract discovery. Into geometry Kepler introduced definitely, the conception of quantities infinitely great or infinitely small, another evidence that the infinitesimal calculus, yet only inchoate, was nevertheless taking form in the human mind. In 1635, Bonaventura Cavalieri's[2] 'geometry of indivisibles' marked a still further advance, and indeed this method was used as a species of integral calculus for fifty years afterwards. It was improved by Roberval [1602 – 1675], and by Pascal [1623 – 1662]. About the same time Pierre de Fermat [1601 – 1665], for whom the credit of inventing the differential calculus has been claimed by Lagrange, Laplace, and Fourier, developed the modern theory of numbers; in which, for one thousand years, no substantial discovery had been made.[3] Blaise Pascal, a still greater than Fermat, and a contemporary, developed with him the first elements of the theory of probability, afterwards enriched by the labours of Huygens, Jakob Bernoulli, and Laplace. Galileo Galilei [1564 – 1642] laid the foundations of dynamics; an office, as Lagrange points out,

---

[1] A contemporary of Euclid. [2] [1598 - 1647].

[3] An interesting fact in connection with this, is that Fermat believed that the expression $2^{2^n} + 1$ yielded always a prime number. Euler pointed out that $2^{2^5} + 1 = 4294967297 = 6700417 \times 641$. The American lightning calculator Zerah Colburn is said to have readily found the factors when a boy, though he was unable to say how he made so astonishing a mental computation.

demanding extraordinary genius, and beside which his astronomical discoveries, for which he is more popularly celebrated, fade into insignificance.

René Descartes[1] [1596 – 1650] distinguished alike as a metaphysician and mathematician, published in 1637 his new geometry; in which the application of algebra to geometry, though not novel, became a fruitful conception. As illustrating the power of the new method it may be said that the whole theory of the conic sections of Apollonius is implicitly contained in a single equation of the second degree!

To Holland belongs the credit of producing the first formal treatise on probability, with Christiaan Huygens [1629 – 1695] for author. In his 'Traité de la Lumière' written in 1678, he developed with great skill Robert Hooke's wave theory of light, establishing it upon a sure foundation. His great work 'De horologio oscillatorio' ranks second only to Newton's 'Principia.'

Passing Huygen's and Wallis'[2] quadratures of the circle, Lord Brouncker's[3] investigation of Wallis' expressions, leading him to the theory of continuous fractions, and Isaac Barrow,[4] whose method of tangents differs only from the differential calculus in notation, we come to Newton [1642 – 1727], the Archimedes of the modern world. Newton's great work, the 'Principia,' has been called by Brewster "the brightest page in the records of human reason." Laplace's testimony is scarcely less enthusiastic, when he says that the merits of the Principia will insure to it "a lasting preëminence over all other productions of the human mind."

Newton's development of the infinitesimal calculus, his conception and exposition of universal gravitation, and the genius with which he illumined natural philosophy, not only constitute his appearance a new era in that domain, but also mark him out as a unique figure in the intellectual history of mankind.

---

[1] Essais Philosophiques. Leyden.

[2] [1616 – 1703]. [3] [1620 – 1684]. [4] 1630 – 1677].

Leibniz [1646 – 1716], Newton's contemporary and co-discoverer in the calculus, established a notation which has, except for certain purposes in dynamics, considerable advantages over the fluxional notation of Newton. Among the first to appreciate the discoveries of Leibniz at their true worth, were Jakob and Johann Bernoulli, and Daniel Bernoulli, the son of the latter; all of whom like Newton, shewed the great power of the calculus in its physical applications.

The English mathematicians Roger Cotes [1682 – 1716], Brook Taylor [1685 – 1731], and Colin Maclaurin [1698 – 1746], immediately following Newton, though men of genius, suffer by comparison with their illustrious predecessor; and compared with their successors on the continent, they fare equally badly. The first third of the 18th century had not closed before the mathematical brilliancy of the Swiss, Leonhard Euler [1707 – 1783], had manifested itself. Euler, and his no less illustrious contemporaries, Lagrange [1736 – 1813], and Laplace [1749 – 1827], developed the analytical calculus with consummate genius, firmly establishing it as a science independent of geometry. Euler and Lagrange created also the calculus of variations; and to the former astronomy is indebted for the method of variation of arbitrary constants, by means of which he attacked the problem of planetary perturbations, and gave approximate solutions for certain cases of the problem of three bodies. Lagrange and Laplace are remarkable as being complementary in their talents; the former delighted in the abstract and general; his mastery of the calculus was unrivalled; his fertility of invention matchless; though Laplace surpassed him in ingenuity of the practical use of mathematics, and in intuition of physical truths. It has been happily said that "Lagrange saw in the problems of Nature so many occasions for analytical triumphs, while Laplace regarded analytical triumphs as the means for solving the problems of Nature." Lagrange's 'Mécanique Analytique' and Laplace's 'Mécanique Céleste' and 'Théorie Analytique des Probabilites' are monuments of the highest genius.

Contemporary with these giant mathematicians may be mentioned Alexis Claude Clairaut [1713 – 1765] whose researches in 'curves of double curvature,' theory of the figure of the earth and theory of the moon, will keep his memory green : Jean-le-Rond D'Alembert [1717 – 1783] notable for the discovery of the principle in mechanics which bears his name, and for his complete solution of the problem of the precession of the equinoxes : and Johann Heinrich Lambert [1728 – 1777] who introduced into trigonometry the hyperbolic functions. A little later Adrien Marie Legendre [1752 – 1833] devoted his genius to the study of elliptic functions —the starting point of which is to be found in the earlier work of the Count de Fagnano [1682 - 1766]—and to the theory of numbers. Legendre moreover calculated extensive tables of elliptic functions, which I believe will yet be greatly utilized : he also preceded Laplace in developing the theory of spherical harmonics, to which however the latter made splendid contributions.

Jean B. Fourier [1768 – 1830] in his 'La Théorie Analytique de la Chaleur' set at rest a long controversy as to the possibility of representing any arbitrary function by means of a trigonometric series.

The wealth of mathematical discovery and development is now so great that only the briefest reference can be made to even part of it. Synthetic geometry had, through the influence of Lagrange been contemned. The efforts of Mydorge [1585 - 1647], Desargues [1593 – 1662], Pascal, De Lahire [1640 – 1718], and even those of Newton and Maclaurin to revive synthetic methods seemed to be doomed to failure; when they reached their object through the genius of Gaspard Monge [1746 – 1818], who raised descriptive geometry to the rank of a distinct branch of mathematical science. It was further developed by the labours of Carnot [1753 - 1823] and Poncelet [1788 – 1867], still more by Möbius [1790 – 1868]—author of the 'barycentric calculus' and generaliser of spherical trigonometry, and abundantly enriched by the "greatest geometrician since the time of Euclid," Jakob Steiner of Utzendorf

[1796 – 1863].[1] Steiner's 'systematic development of the dependence of geometrical forms upon one another'; Chasles' [1793 – 1880] 'enumerative geometry,' afterwards extended by Hermann Schubert to *n*-dimensional space; von Staudt's [1798 – 1867], 'geometry of position,' interpreted by Reye, for it was too condensed for the average reader; Luigi Cremona's 'introduction to a geometrical theory of plane curves;' Karl Culmann's graphical statics; Lobatchewsky's and Wolfgang Bolyais' imaginary and absolute geometries; Johann Bolyais' science absolute of space; Riemann's thesis on *n*-ply extended magnitude; Beltrami's 'Essay on the interpretation of non-euclidean geometry,' and the investigations of Klein, Cayley and others, reveal with cumulative significance the splendour and reach of synthetic geometry.

The foundation of modern analytic geometry was laid by Plücker [1801 – 1868] and exposed in his 'New geometry of space founded on the consideration of the straight line as space-element.' Hesse [1811 – 1874] applied the 'determinant' advances made in algebra to the analytic study of curves of the third order. The results of these researches were carried forward by Cayley, Salmon, and Sylvester. Clebsch [1833 – 1872] shewed that 'abelian functions' and geometry could be mutually helpful. The theory of surfaces was developed by Serret [1819 – 1855], Kummer, Hamilton, Gauss, Lie and others.

Modern times have witnessed the birth of new and more generalised algebras. Among the great labourers in that sphere may be mentioned:—De Morgan [1806 – 1871]—whose 'double algebra' and 'calculus of functions,' will be remembered by all interested in higher mathematics:—W. R. Hamilton [1805 – 1865] whose renown depends no less perhaps upon his prediction of 'conical refraction' than upon his greater discovery of quaternions, popularised by P. G. Tait:—Hermann Grassmann [1809 – 1877] whose splendid work 'Lineale Ausdehnungslehre' contains in addition to a vector algebra, a geometrical algebra of wide applica-

---

[1] It may be mentioned that Steiner learned to write only when fourteen years of age.

tion, and was so wonderful in its richness as to be beyond the reach of his contemporaries:—J. Bellavitis, of Padua, [1803 - 1880], author of the calculus of æquipollences :—Benjamin Pierce [1809 – 1880] and his son C. S. Pierce, both of whom worked extensively at the theory of multiple algebras:—Arthur Cayley [1821 - 1895] in whose mind, the germs of the principle of invariants found in the writings of Lagrange, Gauss and Boole, ripened into a complete theory, thus creating a new branch of analysis :—J. J. Sylvester [1814 – 1897] co-worker in the theory of invariants and author of the theory of reciprocants :—Aronhold [1819 - 1884] also a discoverer in invariants:—and Hermite [born 1822], discoverer of evectants. Quite a host of other names, whose work was scarcely less brilliant should be mentioned, but time will not permit.

In the wider reaches of analysis, and in the theory of functions and theory of numbers we must not omit the name of Gauss [1777 - 1855] who according to the dictum of Laplace was the greatest mathematician in all Europe :—of Cauchy [1789 - 1857] whose researches covered almost the whole domain of mathematics, and whose critical work was invaluable :—of Abel [1802 – 1829] whose idea of inversion of the elliptic functions of Legendre led to such splendid developments, surpassed only by his investigations in what are now called abelian functions, studied since by E. Picard, Weierstrass [1815 - 1897], Madame Kowalevski [1853 – 1891], and Poincaré [born 1854]:—of Riemann [1826 – 1866] celebrated for his invention of the multiply-connected surfaces which bear his name, the theory of which has been extended by the researches of Lüroth, Clebsch, and Clifford [1845 – 1879]:—of Schwarz [born 1845] Weierstrass' pupil, notable for his work on hypergeometric series, and on developments on minimum surfaces :—of Kummer [1810 - 1893], who with Eisenstein [1823 – 1852], and Dedekind [born 1831] extended the work of Gauss and Dirichlet [1805 – 1859] on the theory of complex numbers. Besides these ought to be mentioned as contributors to the modern theory of functions, Hankel, Cantor, Dini, Heine, Du Bois-Reymond, Thomae, Darboux and Forsyth and others. But reluctantly we must pass on.

In this brief and very imperfect sketch of the world's advance in mathematical knowledge, it has been possible all through to mention but few of those who have taken part in that great movement. The achievements of many, whose names are unmentioned, are such as the most brilliant might well envy. What has been said will, however, have served its purpose if it has, even faintly helped us to realize with what success the realm of exact knowledge has been exploited, and under what obligations we have been placed by the devoted labours and splendid genius of the mathematician. The world which he explores, and in which his discoveries are made, is the world of mind: the depths he sounds are the depths of human consciousness: the forms of truth which he perceives are the structures of that imponderable world not seen by the eye, but by the soul, for the relations and laws discovered are conceptional not physical. The elements of the mathematician's world are those ideas, which it is the high function of intellect to project on to the world of sense in order to render it intelligible. This truth, as old as Plato, perhaps as the foundation of things, is that which lends its chief lustre to the "queen of sciences." It has been naïvely said that the truths of mathematics flow merely from its definitions: true, they are consequent upon its definitions, but that very fact asserts the reach and the structure of exact human thought, in respect of which mathematics attains to a unique position, both as regards generality and certainty. We may be allowed one illustration serving to shew how transcendently the power of abstract mathematical thinking surpassed all possibilities of physical verification, for *exact* knowledge is *never* attained by physical experiment or physical measurement. When once the law of a geometrical curve, surface, or solid, is defined, it is in general possible to ascertain by the processes of pure mathematics its length, area, or volume, to any degree of precision one might wish. In 1854 Richter[1] carried the calculation of the ratio subsisting between the diameter and circumference of a circle to 500 places of figures true to the

---

[1] Grunert's Archiv. xxv., p. 472.

last place, and in 1873 Shanks[1] carried it still further, viz., to 707 places of figures. Let us examine for a moment the significance of this :—In a year, light travels about 5·9 million million miles. Imagine the circumference of a circle whose radius was a million million years of light travel. To express that great circumference to a millionth of an inch would require only 37 places of figures out of the 707. That is to say, the mathematician has enabled us to express the circumference of a circle, to the degree of precision indicated, whose radius is 10^{670} times a million million years of light travel. This number is inconceivable, but one may get some further idea of its immensity thus :—Imagine a being capable of traversing the space covered by a million million years of light travel, in so inconceivably small a time as the millionth of a second, that is of covering about 31 μ^3 times that distance in a year : (μ denotes a million). The flight of that being for a million million years being taken as radius, would require only 69 figures instead of 37, to determine the circumference of the circle to a millionth of an inch, leaving over 600 figures unexhausted. The fact is that so great a number of figures requires the conception of a higher order of development, than mere change of scale, to apprehend it. Yet about the accuracy of the result there is not the shadow of a doubt.

To the mathematician the chief merit of his beloved science lies in its intrinsic interest and in its value as an instrument of severe intellectual discipline and culture. But we are not all endowed with the spirit of the mathematician, and hence must regard the Science also from other standpoints. We note therefore that it has a secondary and derived value, as our director and guide in the study of natural philosophy, or the study of the substance of the universe, and of its mode of being and action. And beyond this again, it is in some form or another, immediately ministerial to practice in almost every application of scientific knowledge.

---

[1] Proc. Roy. Soc. Lond., xxi.

At a few of the developments of its higher applications, we may be allowed to briefly glance; and first in regard to astronomy. Kepler's work therein has already been noticed. The illustrious Bessel [1784 – 1846] who sacrificed the prospect of affluence 'for poverty and the stars,' practically recast the science, introducing into it rigorous methods, and greatly improving the value of its constants, thereby making possible the accurate prediction of the positions of celestial objects. He alone appreciated the work of our own astronomer Bradley at its true worth, and utilized it. Geodesy—the connection of which with astronomy is very intimate—he founded as a science. For the development of the lunar theory we are indebted to Hansen [1795 – 1874], and to his indefatigable computations of extensive lunar tables, the basis of the positions of the moon on which the navigator is so dependent for his safety. Poisson [1781 – 1840] discussed the secular inequalities of the mean motions of the planets: Airy [1801 – 1892] the planetary and lunar theories and that of the tides, previously treated by Laplace. Leverrier [1811 – 1877] and J. C. Adams [1819 – 1892] shared the honour of discovering Neptune by studying the unexplained deviations of the place of Uranus. Delaunay [1816 – 1872] completed the explanation of the secular acceleration of the moon's mean motion, which Adams had shewn was defective. Newcomb [born 1835] investigated the imperfections of Hansen's tables and also greatly improved the determination of lunar places, and therefore of longitude by lunar methods. Adams and G. H. Darwin [born 1845] have developed a scheme of tidal analysis; Darwin himself studying also tidal friction. Quite a number of workers have attacked the problem of *n* bodies, which is really the problem of astronomy; but Bruns has shewn that no advance may be expected by algebraic integrals, and that if a solution be possible, we must look to the modern theory of functions for it.

Further improvement in the selection of a fixed point of reference for celestial positions, and in the determination of mean places, depend upon the ascertainment of the sun's path in space.

This question of the solar motion was raised by Halley [1656 – 1742], Bradley [1692 – 1762], J. Tobias Mayer [1723 – 1762], and Lambert [1728 – 1777], and the motion itself calculated first by Pierre Prévost[1] in 1781, from the proper motions in Mayer's table. The principle of a new and wholly independent method was conceived by Doppler in 1848, and from measurements of radial stellar velocity by Huggins and Seabroke, Homann in 1885 obtained a result roughly agreeing with the earlier deductions from proper motions. The range and scope of modern astronomy will not admit of anything like adequate reference to it: some idea of its extent may be had, however, by referring to the astronomies of Chauvenet, Main, Watson, or Faye, and the Mécaniques Celestes of Resal or Tisserand.

Apart from the æsthetic interest of this science or its practical value in determining time[2] for us, and in meeting the great requirements of navigation and geodesy, its work in developing the scale of our conceptions of time, space, and energy, and enhancing the reach of our imagination, can hardly be realized. It would be difficult to estimate how far civilisation depends upon the enlarging of our greater conceptions, but that it does so depend is without question. Whatever may be our individual opinion on this matter however, one thing is certain, viz., that the practical assistance of astronomy is invaluable; the commerce of the modern world, in so far as its safety is secured by good navigation, is under great and lasting obligation to the ardent labours of those whose lives have been spent in contemplating the stars, and in interpreting their motions.

Physics and engineering, which, with practical chemistry, lie immediately behind the material expression of modern civilisation,

---

[1] [1751 – 1839]. Nouveaux Mémoires of the Berlin Academy—R.A. 230° D 25° were the computed coordinates of the point toward which our system moves.

[2] Under the recently established standard time system, every adjusted mean time keeper shews the same minutes and seconds the whole world over.

are similarly indebted to mechanics, to the theory of elasticity, to thermodynamics and to like departments of applied mathematics, for their extraordinary development. Wherever in applied science, the mathematical method is relevant, its application seems to transform every conception and render it fruitful.

At the beginning of the century, viz., in 1804, Poinsot [1777 – 1859] published his 'Elements of statics,' the earliest introduction to synthetical mechanics, and to the idea of a couple. In elasticity particular problems had been solved before the beginning of this century by Jakob and Daniel Bernoulli, Lagrange and Euler. In the early part of the century Thomas Young [1773 – 1829] in England, J. Binet in France, and G. A. A. Plana [1781 – 1864] in Italy, advanced the subject mainly by criticism and correction of earlier work. The general development of the existing theory of elasticity however, was the work of Navier [1785 – 1836], Poisson [1781 – 1840], Cauchy, Mademoiselle Sophie Germain [1776 – 1831], and Félix Savart [1791 – 1841], among which Poisson and Cauchy were the greatest contributors. St. Venant [1797 – 1886] developed a theory of flexure which took cognisance of all known relevant phenomena; Poncelet, theories of resilience and cohesion, and Lamé [1795 – 1870], and Clebsch published mathematical theories of the elasticity of solid bodies, adding to the stock of acquired knowledge valuable contributions of their own. Among recent remarkable works touching dynamical problems, Ball's theory of screws, the last memoir of which has quite recently been published, may be mentioned: the theory has been applied by Lamb to the solution of the steady motion of solids in fluids. Stokes introduced, in 1843, the theory of images, of great value in attacking problems in fluid motion, an application which has since been developed by Hicks and Lewis. In 1856 Helmholtz [1821 – 1894] investigated the properties of rotational motion in an incompressible homogeneous and non-viscous fluid. J. J. Thomson in his well-known treatise on the "Motion of vortex rings," has discussed a peculiar conception of W. Thomson's (Lord Kelvin's) as to the nature of matter, viz.

that an atom is a vortex ring of ether, in ether. The theory of the motion of viscous fluids has so far however, been scarcely attacked.

The study of the circulation of the atmosphere was greatly advanced by William Ferrel [1817 – 1891], who, according to the dictum of Hann of Vienna, has contributed more to the knowledge of the physics of the atmosphere than any other meteorologist.

In electricity and magnetism, Cavendish [1731 – 1810], Coulomb [1736 – 1806], Ampère [1775 – 1836], Gauss and Wilhelm Weber [1804 – 1891] established systems of measurement, which made it possible to study these subjects quantitatively. The equation of Laplace modified by Poisson, was applied by Green [1793 – 1841] to the theory of electricity and magnetism, with significant results. W. Thomson's prediction of the oscillatory nature of the Leyden jar discharge, Lamb's and Niven's investigations of the screening effects of metal sheets against induction, Kirchhoff's [1824 – 1887] determinations of current strength under different circumstances, Maxwell's [1831 – 1879] electro-magnetic theory of light, afterwards experimentally verified by Hertz, and developed by Strutt (Lord Rayleigh), J. J. Thomson, Rowland, Glazebrook, Helmholtz, Boltzmann, Heaviside, Poynting and others, are some of the great advances in one department of physics.

In the theory of energy, Mayer [1814 – 1878], Colding, Joule [1818 – 1889], and Helmholtz, established the doctrine of conservation, Joule determining also the mechanical equivalent of heat. In 1824 Sadi-Carnot [1796 – 1832] evolved the theory of heat-engines. In February 1850, Clausius [1822 – 1888] published the second law of thermodynamics, and illustrated its physical significance, as also did W. J. M. Rankine [1820 – 1872] though he did not then explicitly state the law. The application of the thermodynamic method has completely transformed molecular physics and theoretical chemistry. In respect of this last Dulk has lately made an attempt, apparently,[1] to deduce atomic weights

---

[1] Atomgewicht oder Atomgravitation.—Breslau 1898. [I have not seen the work.]

from certain spatial and dynamic considerations based on chemical data (?). The differences of his values from the best deductions are about the same order as their uncertainty.

But it is quite impossible even to enumerate the developments of the great applications of mathematics to physical science, and we must be content to take what has been mentioned as illustrative of the whole.

We have already said that mathematics lies behind physics. When one regards descriptions of the development of these sciences, however, they perhaps appear, at first sight, merely theoretical and unpractical—matters rather of curiosity than of utility. This arises from the fact that the links by which conceptual or abstract truths are united, and by which they guide and control the operation of the human will upon the material world, are non-material. Day by day the truth is being forced upon us, with ever-increasing impressiveness, that all knowledge is inter-related ; and more and more do we perceive that the secret of our power in controlling the great energies of Nature, and in handling her material, lies in the acquisition of abstract truth. The mathematician supplies us with the subtlest and most far-reaching relations, with truths entirely general, of universal adaptation. His discoveries are revelations of the way in which, by the very constitution of our being, we must think, if we are to have intelligent existence at all. The physicist takes the splendid instruments furnished by the mathematician and applies them both in observing and in interpreting the phenomena of Nature; and is often richly rewarded, not only by the discovery of physical facts of great significance, but also by being able to shew the inherent wealth of mathematical conceptions, with a fulness unknown even to the pure mathematician.

The relation of the physicist to the material world, is akin to that of the mathematician to the conceptual world : his it is to study the world of matter in its generality, and in detail only with a view to the development of general conceptions, the interest of which, in the main, as with the truths of mathematics, is selfsufficient; and therefore, as such, the physicist is not charged with the great applications of his science. He is the hierophant, upon whom devolves the communication of the mysteries. It is well that it should be so, for his time is better occupied in cultivating the genius of observation, rather than that of application; and the world into which he penetrates is inexhaustible in its riches. Every accession of knowledge instead of making us feel that the content of the limitless unknown is poorer, has on the contrary made us feel it is infinitely richer than we imagined, and like the man in Richter's dream, we almost would hide ourselves from the persecution of the Infinite.

A cursory outlook upon the world and the arrangements by means of which we reach our material ends, may not instantly disclose our dependence upon the achievements of abstract science. Look but a little deeper, however, and at once it becomes apparent that at every turn those achievements are the condition of our progress. Glance, for example, for a moment at the commerce of the modern world, at the work which has devolved upon the mechanical engineer and the naval architect in its development, at the great handling machinery and tools by means of which commercial inter-communication is realized, at the necessity for the economic expenditure of energy in the attainment of these things; and then go back to the knowledge of material and construction which is all through implied, and to the mathematical knowledge which again lies behind the whole, and we shall not fail to be impressed by the reality of the service rendered by elements of knowledge apparently the most abstract and most remote. The same result is reached, if, when we regard the mechanisms by means of which we communicate information of all kinds, the modern printing press, the systems of telegraphing and telephoning, and the dependence of the latter upon researches in electricity and magnetism, and of all upon triumphs of mechanical genius, so common that we have ceased to wonder at them, we then think how the clear conception and wise application of physical facts, demanding in turn still more abstract knowledge, is involved. The more thoroughly we trace these inter-relations the better shall we understand that the distinction between theoretical and practical is modal, not essential.

Consider for a moment, even the part played in the modern world by computation. The actuary who deals with questions of value and of money, the navigator, engineer, surveyor, electrician, and often too the chemist, employ logarithms: who, *à priori*, would have imagined that the curious conception of two points moving on lines—the one on a finite line diminishing its velocity so as always to be proportional to the distance to the terminal toward which it is moving, the other on a line of indefinite length maintaining a uniform velocity, coupled with the conception of the ratio between the untraversed distance on the first line, to the traversed distance on the second—who, I say, would have imagined *that* conception[1] to have led to the production of the logarithmic tables which have become so indispensable to us, and without which much of our computation would be hopelessly tedious. Or if we may be allowed another illustration, who could have anticipated that the study of the properties of curves formed by the section of a cone by a plane, could have been so applied as to enable the navigator to guide his craft safely over the expanse of ocean. Apparently these belong to worlds of things wholly unrelated; yet the opposite is the truth. And so it is all through. We do well to remember that the spirit of the scorner of those great outreachings of the human mind after a fuller and deeper knowledge of the laws of thought and of the phenomena of the worlds, in short after abstract science, would lead us back to barbarism: we are never justified in suppressing our insatiate thirst for knowledge because its practical issue is wholly beyond our ken. But of this more anon.

One of the most striking facts in modern industrial progress is the daily increasing significance of the part played by chemistry, a science in its turn, dependent, for some of its most conspicuous

---

[1] Napier's, who did not recognise the exponential character of logarithms.

advances, on those in pure, and in other applied sciences. As a guide in metallurgical processes, in the production of foods, and in the manufacture of a vast series of inorganic and organic compounds required by civilised communities, it has proved itself, although of recent birth, a giant in its power of assistance, and there is abundant evidence that in the near future its achievement will transcendently eclipse that of the past. Not only so, but its deeper side has enabled us to penetrate further into the knowledge of the fabric out of which our world is built, for the contributions of chemistry to physics have been very great. No general view of molecular physics can be regarded as adequate, which does not take account of molecular chemistry, or the whole series of physical facts which have been revealed in the prosecution of chemical research. The difficulties which face the investigator are of course stupendous. Apart from those introduced in attempting anything like a complete molecular theory of chemical reactions, in which all energy changes and variation of physical properties, as related to chemical constitution, shall be explained; the difficulties inherent in a more elementary theory, which attempts nothing further than an explanation of the gaseous, liquid and solid states, and the elastic properties of substances, are overwhelming, as anyone will realize who critically reads, for example, any discussion of the foundations of the kinetic theory of gases. Up to a certain point the study is simple enough, but the moment the attempt to include the observed facts, of departure from the ideal gaseous law, is made, the intricate character of the problem really appears.[1]

---

[1] The total kinetic energy of a system of molecules is represented by the virial equation

$$\Sigma \tfrac{1}{2} m \bar{u}^2 = \tfrac{3}{2} p V + \tfrac{1}{2} \Sigma \Sigma R r$$

in which $\bar{u}$ denotes the mean of the squares of the velocities of the molecules, m the mass of a molecule, p the pressure per unit of surface on the envelope whose volume is V, R the attraction between two molecules separated the distance r, and Σ, as usual, the summation of the quantities which it precedes, being double in the final term to indicate that the summation is to include every pair of molecules that can be taken in the system. Now neglecting the attraction term and supposing the kinetic energy to be proportional to the absolute temperature θ of the system, the above equation becomes

Let us briefly glance at a few of the greater facts of chemical science, facts revealed to the world almost wholly in the century just closing. Its origin is shrouded in as much mystery as one of the most interesting personalities connected with its early development, viz., Abu Musa Dschabir (Geber) [died about 776 A.D.?]. It is questionable, however, whether the term 'chemistry' ought in strictness, to be applied to that body of knowledge concerning metallurgy, tanning, and dyeing, possessed by the ancients even long before Geber's time, since the facts were unassociated; that is to say, they were disconnected items of knowledge. The alchemists, who flourished between the eleventh and fifteenth centuries, and who made a considerable number of chemical observations, proposed what was to some extent a really general problem, viz., the transmutation of metals into gold, not even now a wholly ridiculous conception ; for the idea of a protyle is by no means excluded by the data of observation. But the attack on the problem was unsystematic. Paracelsus [1493 – 1541], on the other hand, boldly declared pharmacology to be the legitimate aim of chemistry. These facts are interesting as shewing the range and character of the early conceptions of the science. The then prevailing theory of the threefold constitution of matter was attacked in 1661 by the sceptical Boyle [1626 – 1692], an

---

$$pV = k\theta$$

which expresses Boyle and Mariotte's and Charles' laws, provided we reckon θ from the 'absolute zero.' In order to make this equation agree more exactly with the volume changes of gases of different density subjected to pressure, Van der Waals proposed in 1872 the modification

$$(p + \frac{a}{V^2})\,(V - b) = k'\theta$$

the a term denoting an attraction coëfficient and b the sum of the volumes of the molecules, or amount by which the space V in which they moved was actually diminished by their own dimensions. Unfortunately Van der Waals' equation does not wholly meet the difficulty. A fair idea of the problem to be solved may be had by reading say, Tait's 'foundations of the kinetic theory of gases,' and Burbury's criticism thereon, the latter points out that Tait's system of elastic-spheres cannot discharge all the functions of gaseous molecules, especially when the explanation of spectroscopic phenomena has to be made out.

attack which a little latter led to its complete overthrow by F. Hoffmann [1660 – 1742]. According to Ernst Meyer,[1] the history of chemistry proper commences with Boyle, forasmuch as he taught that the immediate object of the science was the acquisition of a knowledge of the composition of bodies. Though prior to his life and work, a considerable mass of isolated chemical facts was being acquired, it was in the crucible of Lavoisier's mind [1743 – 1794] that they were transmuted into something like the gold of true science. The greatest and most fruitful conception in the early development of chemistry was the atomic theory, which arising chiefly out of Richter's[2] doctrine of chemical proportions published about 1792, and Proust's[3] work confirmatory of the same, took definite form in Dalton's mind in 1804, when he communicated the conception to Thomson. The latter published it in his 'System of Chemistry' in 1807. This theory, viz., that every element is made up of homogeneous atoms of constant weight, and that compounds are formed by the union of these in the simplest numerical proportions, may be said to be the real foundation of the whole science of Chemistry. In 1808 Gay-Lussac [1778 – 1850] defined the law of gaseous combination by volume, and in 1811 Avogadro [1776 – 1856] enunciated the hypothesis that under the same conditions of temperature and pressure, equal volumes of gases contain the same number of molecules, an hypothesis espoused three years later also by Ampère, and which has played a signal part in the development of the science. These laws and hypotheses together with Charles' law, discovered about 1786, connecting volume and temperature, and Boyle and Mariotte's[4] law connecting pressure and volume, constitute the foundation of the physico-chemical theory of gases. The next great step was the founding in 1852 by Frankland [born 1825] of the doctrine of the saturation-capacity or valency of the elements, a doctrine which reached a fuller expression in Kekulé's theory of the 'linking of the atoms.' The theory of valency is

---

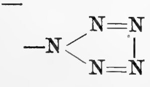
[1] History of Chemistry, 1898.

[2] [1762 - 1807]. [3] [1755 - 1826]. [4] Died 1684.

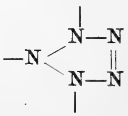
not without difficulties, owing to the fact that some elements have more than one valency: an explanation has been attempted by supposing the ordinary atom to consist of a number of smaller or micro-atoms, with links free to form bonds either with the members of the system, or with atoms outside thereof. Thus if nitrogen consist of five trivalent micro-atoms it ought to be monovalent, trivalent, or pentavalent.[1] This theory of linking has given birth to structural chemistry: which may be described as a symbolic system of so representing the constitution of a chemical substance, that the formula shall epitomise the whole story of its characteristic reactions and properties. It was soon evident in organic chemistry, that structural formulæ were a necessity, since the physical, chemical, and therapeutical properties of the vast series of organic compounds, depended even more absolutely upon structure than upon the proportion of the elements out of which they were compounded. The structural investigation of an organic compound is summed up in three determinations, viz., (1) the empirical formula or ratio of the constituent elements, (2) the molecular formula or actual number of atoms of each constituent, and (3) the structural formula or way in which the constituents are combined. The two first determinations involve nothing more than some degree of expertness in laboratory technique, and frequently the utilization of certain discoveries in chemical physics, as the effect of a substance in lowering the freezing point [De Coppet and Raoult, 1882], or elevating the boiling point of a solvent [Beckmann 1889], or the lowering of solubility [Nernst 1890]. The third determination however, involves not only a comprehensive knowledge of the chemical behaviour of organic compounds, but in addition a delicate appreciation of the whole range of avail-

---

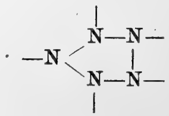
[1] Thus:—Arrange five micro-atoms in the form of a regular pentagon; then denoting the free links by exterior lines the results may be represented:—



Monovalent.

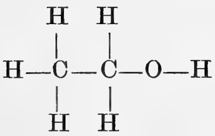


Trivalent.



Pentavalent.

able facts, which bear on the question of their constitution. Two simple examples will suffice to illustrate the matter to those who are not chemists. In ethyl-alcohol, molecularly C_2H_6O, the oxygen cannot be removed without at the same time taking away the active hydrogen, and hence the latter must be linked to the oxygen thus, $—O—H$, oxygen being divalent. Since carbon is quadrivalent and hydrogen monovalent and consequently incapable of serving as a link, the two carbon atoms must be directly united, and their valencies must grasp the hydrogen atoms, and the free valency of the oxygen. The only structure which fulfils all the conditions, is

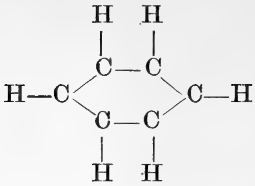


$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & - & C & - & C & - & O & - & H \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

which for convenience is represented by the constitutional formula $C_2H_5 \cdot OH$, or ethyl hydroxide. Acetylene consists of two atoms of hydrogen and two of carbon, the latter being united with three valencies since the hydrogen exhausts only one: thus $H—C\equiv C—H$. When passed through a red-hot tube it polymerises, or condenses, into one-third the volume, forming benzene, C_6H_6. From the fact that the hydrogen atoms may be shewn to be really equivalent and can very readily be replaced by other monovalent atoms or molecules, while the carbon nucleus is of great stability; that the molecule will suffer the addition of six halogen atoms and no more; that only one mono-substitution product, and not more than three di-substitution products can be formed from it, and from a number of other considerations of an analogous nature, it is evident that benzene is structurally represented by a hexagon or ring of six carbon atoms, with the six hydrogen atoms on the outside, thus[1]:—

---

[1] It will be noticed that one valency of the quadrivalent carbon has not been utilized. This enables benzene to take up six monovalent atoms as in benzene hexahydride, or hexamethylene. The free valencies have been supposed by Armstrong [1887] to be exercised in increasing the stability of the nucleus.



The reasoning by which in di-substitution products the ortho- or vicinal, the meta- and para- positions are identified, is equally ingenious. It is obvious from these simple illustrations that the determination of structure often calls for the exercise both of a comprehensive knowledge of chemistry and also of genius; and the enormous number of organic substances, the structure of which has been ascertained beyond all doubt, is a testimony not only to the assiduity but also to the splendid intuition of the world's chemists.

Organic substances fall into two great divisions, viz., the open-chain or aliphatic series, and ring-compounds or the aromatic series; the latter may also have monovalent radicles from the former externally attached. One of the most significant achievements of modern chemistry has been the formation of ring-compounds from open-chain ones; as when, on heating mannoheptitol with hydriodic acid, it is reduced to tetrahydrotoluene. Another achievement of equal potentiality is the converse process of breaking up ring-compounds into open-chain ones; as in the chlorination of phloroglucinol, which converts it into dichloracetic acid and tetrachloracetone; or in its hydrolysis through heating with strong caustic alkali, which breaks it into acetone, acetic acid, and carbon dioxide. The power of hypochlorous acid in breaking ring-structures renders it a reagent of great value in the hands of the technical chemist.

The story of the powers of modern chemistry might be indefinitely continued, but may be summed up by saying that the secret of the chemist's ability to synthesise such an infinitude of substances, lies in the discovery of far-reaching chemical truths; a discovery arising out of the study of structure and out of the attempt to reach general views respecting chemical reactions. *A priori*, the chemical achievements of this century seemed an impossibility, but success has transcended the most sanguine expectations, and there can be no doubt that in the future the science will play even a still greater part in the world's development.

Were it not an intrusion on the solemnity of these proceedings, I might have been permitted to shew that chemistry reacts on the æsthetic faculties of the world. Who, for example, looking at a brilliant social function, graced by the presence of the sex that lends it all its subtle beauty and charm, recognises how much is due to the delicacy and glory of colour which the genius of the chemist has provided! Perhaps, after all, such recognition were a profanity on such an occasion, and the highest tribute to that genius is the fact that we are overwhelmed with æsthetic pleasure.

The service of organic chemistry to therapeutics would be difficult to over-estimate. Not only have many natural substances required by physicians been prepared artificially, but the comprehensive study of the relation of chemical structure to physiological and therapeutic activity, has enabled the chemist to predict with some degree of confidence the action of new substances. For example, the hypnotic sulphonal is chemically dimethyl-diethyl-sulphone-methane. The substitution of ethyl for one of the methyls gives trional, and of ethyls for both methyls, tetronal, substances of identical character but with reinforced physiological activity. That inferences of this nature have to be drawn with extreme care, however, is indicated in the quaternary amido-compounds betaïne, choline, and neurine, the two first being innocuous while the last is extremely poisonous:—

$$\begin{aligned}\text{Choline} &= CH_2OH \cdot CH_2 \cdot NMe_3 \cdot OH \\ \text{Neurine} &= CH_2 : CH \cdot NMe_3 \cdot OH\end{aligned}$$

It is impossible here to give any sufficient idea of the reaction of structural chemistry on physics. One instance will shew something of its significance. To the labours of Brühl, Landolt, Conrady, Kannonikoff, and others, we owe the knowledge that the molecular refraction of a compound—or product of its specific refraction and molecular weight—is the sum of the atomic refractions, provided the mode of union of the atoms be taken into account; and to those labours we owe also the actual determination of a large number of atomic refractions for different lines in the spectrum.

Another great feature of chemical advance is the recent analysis of substances produced in living organisms. As remarked by Lassar-Cohn, there is no reason why chemists should not turn their attention to living forms rather than forever study the products derived from the relics of a long-extinct organic world.

Time prevents any reference to the great influence of mathematics and physics on modern chemistry: of the part played by heat, pressure, and electrical energy in controlling chemical reactions; of the potency and promise of the future of the science when the resources of the latter form of energy shall have been exploited. One has no doubt that the brilliant advance of the century now closing is but the earnest of a still brighter future, and that not only will the services of the chemist, which directly or indirectly affect every industrial process of to-day, be year by year, more and more fully utilized, but also that even in purely theoretical advances his genius will shine, if possible, with even greater lustre than in the past.

The great applications of science have practically transformed the material blessings of civilisation. I am unable, for lack of time, to indicate how other sciences contribute, but throughout the whole range, the service is incalculable. The industrial requisition of the achievements of the student has produced the most striking transformations. Nowhere has the change been so remarkable as in those countries where the intellectual life has been strongly cultivated and science ardently followed. And among these Germany stands in the first rank, reaping a well-deserved and rich reward. Full of intellectual energy, systematic in method, and rich in genius, she has produced a body of literature, philosophy and science, which the world may well envy; and she has done this with high aspirations. No charge can be urged against her of having sought out Minerva with unworthy motive. The splendid sacrifices, with which her history is replete, for the attainment of preëminence in all that ennobles a people; the unqualified respect which nationally and individually she pays to intellectual achievement, the opportunity she offers for the cultivation of great talents, the generous way in which she nurtures every impulse to advancement, these are the secret of her renown, these are the occasion of her consciousness of dignity and power, and these are what have made her a signal example of the reward of noble purpose.

It has been said by moralists that the world is so constituted that they who seek higher ends, will incidentally reach the lower also. Be that as it may, Germany's devotion to science, art, and literature has certainly been compatible with preëminence in rate of industrial development, for during the latter part of this century her advance has been such as must satisfy even the most sanguine of her patriots. It is no mere matter of opinion, that this has been the result of her attitude to scientific progress. Nowhere have so many discoveries been made in all departments of science: nowhere have the most recondite elements of knowledge been so ardently discussed and analysed. To this is due the great generality of her attainments, and the fine development of her scientific prescience and intuition; and to this is due also her keen appreciation of the advantage of utilizing that body of knowledge won by the genius and assiduity of the mathematician and the investigator of Nature.

The evidence of German appreciation of the value of science is characteristically shewn in the scientific equipment, both in respect of personnel and material, of those great industrial works whose operations are guided by its great results. Their laboratory equipment is even more splendid than that of the universities. The prosecution of research in them is conducted on no narrow basis, nor with regard to immediate issue in results of commercial value. No where in the world is the recognition so keen that in the end the most unpromising accessions of knowledge will prove either directly or indirectly of utility; that if they are *per se* commercially valueless, yet they will not fail to render aid in that general progress, on which the whole depends, and which has strengthened their hands among the nations. A gratifying feature in the history of such laboratories is the great amount of original research which they undertake, and communicate to the world.

To a wise people the striking progress of another nation is occasion for serious reflection : and if it be possible for us to profit by that example, surely what we have to learn is this, that our national welfare depends—setting aside the transcendently great elements of high character and vigorous purpose—upon our nationally fostering a spirit of scientific research, and an appreciation of achievement in that direction. If in this we fail, we shall pay dearly for our purblind ignorance, as indeed we have done already. No one can contemplate the relative growth of German commerce, the progress of her iron works, of her manufacture of electrical machinery, or the progress of her great dye and chemical works—the two last unrivalled for the excellence of their preparations—without realizing how abundantly she has been rewarded for nurturing in her people a real and practical affection for science, and a high respect for mental exploits.

What is the spirit which we intend to foster in these young colonies, just quickening with the first impulses of national feeling and sentiment? Are we going to make sacrifices of time and money to cultivate that intellectual ardour, so finely manifested in our Teutonic friends and so rich in its results? Are we going to throw all the energy of purpose of which we are capable, into the impulse to acquit ourselves right royally, and to vie with the old established centres of learning in the world in the struggle after knowledge? Are we going to develope the resources of this land with all the powerful assistance which intelligence and education can furnish? Are we going to employ as instruments in so doing, the great inheritance of scientific lore, which the patient research, penetrative insight, and potent genius of the past has accumulated for us? If the answer to these questions be yes—and who with any patriotic feeling, or sense of his duty to the country in which he is nurtured, or in which he lives and moves and has his being can answer otherwise—then we shall have to fitly take our part in the general progress; we shall have to do what lies in our power to make, to the ever-increasing body of knowledge, such contributions as shall worthily express our appreciation of the inheritance, that by the labour of others is ours. If a people attempt to thrive on the intellectual, industrial or economic activity of others, they will fall into their proper place as parasites. The only path of progress is self-help, and the only way to hold our own with the great centres of activity, is to foster all that tends to engender noble aspirations after those things which have made other nations great, and their histories a stimulus to high effort. The race may not be to the swift, but it is to the people of strong purpose; and the giant strides made through the progress of science, warn us not to be supine, lest we be left hopelessly in the rear. The time for action is now.

What are the conditions under which it will be possible to advance? We have already indicated that on the spiritual side it is determined by our character, by a high appreciation of the dignity of intellectual effort and intellectual achievement, and an earnest purpose to take our part in the higher progress of the world. On the material side, we must make the opportunity for the student to work, and give him all the advantages which accrue from instant acquaintance with everything that is being done in other parts of the world. The laboratories of our land must be so arranged as to facilitate research, and efficiently placed at the disposal of students willing to devote themselves. Mere teaching of the acquisitions of the past is *not* sufficient; to be of value they must be the seed of further progress. And here I may be allowed to ask whether we are adequately utilizing our opportunity in the laboratories of government departments. Properly equipped, what facilities they would offer for true research work —the life-blood of scientific progress—provided their able chiefs merely *directed* routine work, and were free to employ their unexhausted energies on such original scientific researches as they deemed worthy of attack. This method of working is consistent with the traditions of the greater seats of intellectual activity, and is productive of the best possible results. It assigns a higher class of work to both subordinate and chief, and makes the post one which might be eagerly sought by the most highly qualified.

The same principle applies in a University : if it is to have any reputation, if it is to become a living factor in the world's progress, and honourably take its place among the Universities of the world, it must produce : any scheme which exhausts the energies of a staff in mere teaching, or in routine demonstration, is a failure, and will react badly on the future. Although there are signal instances to the contrary, our University is not as yet sufficiently at the disposal of the research student : nor, under its present material limitations, can it be ; for the existing endowment is wholly inadequate. Look at what is elsewhere produced, and compare it with our own results, if you would know where we are. We shall have done well only if we go on and make the instruments of culture, already in part provided, really effective.

But to return to the bibliographical element. In the University and the scientific societies here, we have the nuclei of splendid libraries. Most of the great scientific periodicals of the world are in them. We may be pardoned for referring to our own library. Those members of our Society who consult it know, what a splendid monument it is of the labour on behalf of this institution of our esteemed colleague Professor Liversidge, to whose effort more than to that of any other member of our Society, the creation of this library is due. You will all recollect the testimony paid to its excellence by Professor Threlfall, when I had the honour to convey to him, our sense of regret at losing his services as a member of our Society, University and community. What he said, was—to quote his own words—"Personally I am immensely indebted to the Society for the encouragement it has always given me, and also for the great use I have had of its fine library, without which it would have been impossible at one time for me to have done any work at all."

There is another fact, however, touching our library here which demands our urgent attention. At the present time our resources are not adequate for the proper binding and accommodation of what even now we receive as donations from other parts of the world, and what is still more serious, many of our scientific series, both here and at the University, are not only incomplete, but the opportunity of completing them is rapidly passing away never to return. The great and munificently endowed institutions of America are exhausting the market; series which we are anxious to complete and some which we have not yet acquired, are often bespoken years beforehand. The scientific libraries of Sydney—the capital of the mother colony of Australia—should surely be the most complete in the southern hemisphere; and it is to be hoped that neither ignorance nor niggardliness will prevent us equipping them with those great works and journals absolutely necessary to our efficient coöperation in the intellectual and industrial advance of the world. Access to the complete records of all scientific work done elsewhere must be available, if we are to progress as we should. Daily it becomes more and more imperative that the scientific worker shall be cognisant of every advance, and it is the keen recognition of this necessity that has led to the undertaking of the international scientific catalogue. That record of scientific work will make it impossible to be ignorant of what is being done throughout the world. To reach its object, however, we must also have copies of the investigations themselves. The field is too vast, the cost in brain effort, time, and money too great, to admit of the duplication of real work, and moreover the rate of progress depends upon that economy of time and effort which accrues from appreciating and utilizing the results reached by our predecessors in research. Our capital, the evergrowing achievement of the past, the intellectual fortune acquired by centuries of exploitation by Genius, is that with which we start, and to this we must add. A community failing to use as a point of vantage the intellectual wealth of the world at large, must inevitably fall back in the race, because it is the methodical availment of that advantage which has been fruitful of result, a fact, as we have indicated, testified to so forcibly, by the brilliant history of Germany's recent progress.

Enough has been said to show that it is of national importance that we should without delay, still further develope our libraries. In respect of our Society's own, what has already been accomplished should be worthily continued. The generous impulse which has instigated the issue to us of the leading scientific journals of the world in return for our own, is a feature we regard with pleasure. Since 1878 and up to the present time, we have expended out of our very limited income, no less than £4,704, in the purchase and binding of books and periodicals. The exchanges annually received, have now a still greater money-value than our purchases; so that in publishing we not only afford investigators an opportunity of adding their results to the sum-total of the world's information, but we also acquire by this means, additions to our library of great intrinsic value. The importance of this cannot be overestimated: it is a beginning full of promise for the scientific future of the colony, and fully justifies our publishing expenditure of £3,602 during the last twelve years.

In the matter of the scientific equipment of our city, we are in some respects well off, but in others the reverse. The science schools of the University, are in every instance fine monuments of the earnestness of purpose of the professors in charge, to whose untiring efforts their equipment is largely due. But for their proper utilization they are not sufficiently endowed; in fact, it is not putting the case too strongly to say that their energies are sadly crippled by that very fact. The view has been expressed that we can well rest content on past achievement: that our learned institutions have been more than liberally treated, and that we expect overmuch if we anticipate further assistance. That both private individuals and the Government have splendidly helped us, we gladly and gratefully recognise: but it must not be forgotten that we do not, in either respect, compare favorably with America. On the basis either of population or area, the United States has wholly surpassed us in the generosity of its treatment of educational or scientific establishments : this is so both in respect of state and private benefaction. It is indeed a gratifying feature of recent American history, to notice the munificence of its citizens to their institutions. Great fortunes are largely the outcome of those conditions which have been produced by the general spread of intelligence. The devotees of science, have necessarily adandoned the paths that lead to possible affluence; and yet from their limited means, they contribute, as a rule, liberally to the cause which lies near their hearts. But the institutions on which the progress of humanity depends, require assistance in the material means for their maintenance, far beyond what lies in the power of men of science to provide. It is peculiarly gratifying therefore, when those whose financial genius has won for them affluence, use the great power which that brings, to promote the welfare of the people. I do not believe that in this country we are less liberal or less intelligent than in others: but, that the nature of our needs is not sufficiently known, is certain. Once it is clearly understood that we are languishing for want of the means to do that which ought to be done for our future national prosperity, the assistance will not be long in forthcoming. It is our duty to the community as a whole, to explain our wants : when we have efficiently done so, when we have made it manifest that the development, especially of our scientific libraries is an immediate and pressing need, that our educational establishments cannot with their present endowment compete with those of the older intellectual centres of the world, then we may have some expectation that the generous impulse of the people, will lift us out of our trouble. It has been freely enough shewn in the past, and no doubt will in the future. I hold it to be the solemn duty of those who realize what higher culture means to the world, to publicly explain the circumstances of their day in that respect. Only when that has been done have we discharged our duty to the cause, which our Society has espoused.

The picture I have tried to give in merest outline of the progress of pure and applied mathematics and of chemistry, may be taken as illustrative of what might be given in almost any great branch of learning. The devoted labours and brilliant talents to which the world owes so much, have, I am painfully conscious, been inadequately represented. I can but hope that the earnestness of your efforts to hold aloft the torch of science will a thousandfold atone for my shortcoming. That the history of our Society shall throughout, be that of strong intellectual stimulus to those who live under Austral skies, that it shall be among those bright influences which will make our people emulate the splendid examples of the past, and nobly take their part in the progress of civilization, is an aspiration, that will ever unite us in bonds of sympathy, and will ever inflame our hearts with enthusiasm, in the cause of Science.

KEY TO TRIBES AND GENERA OF THE FLORIDEÆ.

(RED OR PURPLE MARINE ALGÆ.)

By RICHARD A. BASTOW.

(Communicated by J. H. MAIDEN, F.L.S.)

[With Plates I., II.]

[Read before the Royal Society of N. S. Wales, June 7, 1899.]

IT is essential in the study of the Florideæ in the first place to acquire some knowledge of the organs of fructification characteristic of each tribe; it is then much easier to become familiarised with the habits of the various genera constituting each tribe. Knowing by experience that in botanical studies a few lines however roughly drawn may, in many cases, convey more information than a large amount of letterpress, I have made a chart of the tribes of Florideæ on *Plate* 1, showing the conceptacular fruit common to each tribe, the fruit being shown in section or in outline, and where necessary the spores also are shown.

Immediately under each drawing of the tribes a tribal description will be found, and each tribal description embraces, in brackets, the genera of which each respective tribe is composed. It will also be observed that there is a short description to each genus, with a reference to the authority I have relied on. Also, each genus is numbered plainly, and the number corresponds to the numbers of genera in Dr. Sonder's Catalogue of Australian Algæ contained in the eleventh volume of Baron von Mueller's Fragmenta Phytographiæ Australiæ. The generic number also corresponds with the number of the generic illustrations on *Plate* 2.

I have spared no trouble to obtain the most reliable authority for each item of information on the plates. Free use has been made of the beautiful illustrations contained in the various works of Dr. W. H. Harvey, also of those in Flor. Tas., Flor. Nov. Zeal., Flor. Antarct., Rabenhorst's work, etc.; and wherever I could utilize the work of a good authority I have done so.

The written information is in great part from Dr. Agardh's works, but in a few cases I have been unable to obtain any information, and have then fallen back upon reliably named specimens in the National Herbarium of Melbourne; these, for the most part were named by Dr. Harvey, Prof. Agardh, or Dr. Sonder; but where I have had the slightest doubt as to the correct illustration of any genus I have used a mark of interrogation.

Although the Florideæ are known as red algæ, it must not be supposed that they are always red; the red plants, as a rule, will only be found in deepish water; if they are much exposed to the light they assume an olive or brownish tint; but with very little experience the student will soon find out by the fruit and the general habit of the plant whether it belongs to the Florideæ or not.

The Florideæ have two kinds of fruit, these are tetraspores and conceptacular fruit. The tetraspores have been supposed by some to be the normal fruit, and the conceptacles abnormal. I see no particularly good grounds for such a supposition. Both kinds are alike reproductive, but they are never found on the same plant. Both kinds appear to me to be normal, for they always and invariably retain the constant forms for each genus.

The conceptacular fruit or sporiferous nucleus is either naked (as in *Callithamnion* and *Wrangelia*); or immersed in the substance of the frond (as in *Gratiloupia*, *Halymenia*, &c.); or evolved in wart-like tubercles (as in *Polyides*); or contained within hollow conceptacles of various forms (as in *Polysiphonia* etc.), and has generally, if not always a connection with the central stratum.

The tetraspores are formed by the evolution of cells of the cortical layer; they are either dispersed through the cortical cells of the whole frond, or confined to the ramuli, or grouped together in sori, or lodged in wart-like excrescences called nemathecia, or on proper leaflets (sporophylla), or in pod-like receptacles called stichidia. In some tetraspores the mass is divided by two lines crossing each other; they are then called cruciate; in others three lines radiating from the centre divide the mass; they are called tripartite, and again some of them are divided by parallel transverse lines, and are named zonate tetraspores.

I well recollect some years ago that I collected a beautifully branched crimson seaweed and preserved it in the usual way after having examined and drawn it from the microscope. After many fruitless efforts to get at the genus of the plant, I obtained Kutzing's book and turned over page after page until I arrived at its proper description; it was *Dasya villosa.* If I had only had *Plate* 1, what a vast amount of labour I should have been spared; the conceptacular fruit being very large, I should have most easily seen that the plant belonged to the tribe Rhodomeleæ, genus *Dasya;* and on reference to *Plate* 2, I should have found the plant illustrated under sub-genus *Rhodonema.*

ON THE METAMORPHOSIS OF THE YOUNG FORM OF *FILARIA BANCROFTI*, COBB, [*Filaria sanguinis hominis*, Lewis; *Filaria nocturna*, Manson] IN THE BODY OF *CULEX CILIARIS*, LINN., THE "HOUSE MOSQUITO" OF AUSTRALIA.

By THOS. L. BANCROFT, M.B. *Edin.*

[*Read before the Royal Society of N. S. Wales, June 7, 1899.*]

Dr. Patrick Manson in a paper read before the Linnean Society of London, March 6th, 1884,[1] remarked :—" Six years ago I described the metamorphosis undergone by the embryo *Filaria sanguinis hominis*, in the body of the mosquito.[2] I hoped that (considering the practical importance of a correct knowledge of the life-history of this parasite) the statements I then made would, long ere this time, have been thoroughly confuted or confirmed. . . . With the exception of Lewis in India, Myers in Formosa, and Sonsino in Egypt, I do not know that anyone has worked seriously at the subject. And although both Lewis and Sonsino have confirmed my statements as to the entrance of the Filaria into the mosquito, and followed up part of the metamorphosis, neither of them has advanced his observations so far as to be able to confirm my statements as to the later stages of this, or positively to prove that the mosquito is or is not, the intermediary host. Some eminent helminthologists in England accept my statements and endorse the inferences I have drawn—Cobbold for example. But in other quarters, so far from securing acceptance of my theory, the work of Lewis, on account of the hesitation and scientific caution with which he expresses himself, has had the effect of inducing a certain amount of scepticism. Leuckart is sceptical;

---

[1] Trans. Linn. Soc. Lond., Vol. II., part x., Zoology, p. 367.

[2] Proc. Linn. Soc., March 7th, 1878. China Customs Medical Reports, Sept. 1877.

and of course the scepticism of so eminent an authority is of great weight in influencing opinion, especially in Germany."

In answer to an inquiry from me as to whether there was any recent work on the subject of "filarial metamorphosis," Dr. Manson wrote, November 15th, 1898:—"So far as I know, nothing has been done in "filarial metamorphosis" since my Linnean Society's paper. Lewis did not go very far with the work. There is an excellent opportunity for work on this subject, and were I in your place, I should certainly go on with it."

In writing to Dr. Manson, I had mentioned the circumstance of my being able to verify his "filarial metamorphosis," but that I had never seen the "actively moving filaria," which he stated left the mosquito's body and lived a free life in water until transferred to the human host.

To this he replied in these words:—"I have seen the "actively moving filaria" in the seven days' old mosquito a good many times; I used to be able to pick out the mosquitoes containing it. Their thoraces looked plump and juicy to the eye. Of course you must have hundreds of mosquitoes from which to select such."

Now in my former investigation there was no difficulty in finding the early stages of the metamorphosis in every mosquito *(Culex ciliaris)* without exception, which had imbibed filariated blood; those mosquitoes which lived seven days—and none ever lived longer—never contained any actively moving filariæ; they contained forms more or less resembling Figure 4.

It were useless to make further search for this "actively moving filaria"; either Manson must be in error I thought, or the *Culex ciliaris* was not an efficient host.

The recent work in India on the metamorphosis of the Malarial parasite in mosquitoes induced me to study the habits of these insects in this district. I found that I could keep certain kinds of mosquito, particularly *Culex ciliaris* and a large black species hitherto undescribed, alive in confinement for about two months; one individual actually lived seventy days. Banana was found to be a good food for them. It was ascertained that unimpregnated mosquitoes lived the longest; those that had been impregnated lived two or three weeks, whilst the males rarely lived a fortnight. In my former investigation into filarial metamorphosis, it never occurred to me to feed my filariated mosquitoes whilst in confinement, accepting the common belief of their only feeding once and dying within a week. Manson, Lewis and Myers, who had worked at the subject, never fed the mosquitoes, and it never dawned upon me that my mosquitoes were dying from starvation.

Having discovered that mosquitoes could be kept alive long periods in confinement if fed on banana, I was anxious to ascertain what would become of the filariæ, which were to be seen in mosquitoes that lived seven days; would they go on developing if the mosquitoes lived longer?

Unfortunately E. S., the filariated subject, a girl of sixteen, from whom I had obtained filariæ had left the district, having secured a situation as domestic servant; she was the only person affected with filariasis I knew of.

Dr. Manson's encouragement and a grant of £7 from the Queensland Branch of the British Medical Association to defray the cost of E. S. returning and living with her parents for three months and submitting to be bitten by mosquitoes, induced me to enter upon a fresh investigation on February 1st, 1899. It was found that the actively moving filariæ were to be seen, but not before the sixteenth or seventeenth day, sometimes in cold weather not until twenty days, and that no further development occurred in them even after a sojourn of sixty days in the mosquito's thorax.

The final stage of the metamorphosis, *i.e.*, the preliminary alternation of generations, is attained in sixteen or seventeen days; (Fig. 6) the young filariæ are then $\frac{1}{13}''$ in length by $\frac{1}{850}''$ in breadth, some only $\frac{1}{15}'' \times \frac{1}{1000}''$; there is no apparent difference except in size; there is a well marked intestine with œsophageal bulb, also some differentiation of the body protoplasm into reproductive organs (ovary and testicle) but I have not been able to make out any sexual difference.

The young filariæ are generally only to be found in the thorax, yet a few occur in some instances in the abdominal cavity. There are usually three or four filariæ present, sometimes as many as twenty-five. In twenty filariated mosquitoes that were killed and examined between sixteen and sixty days, every one of them contained actively moving filariæ.

Mosquitoes bearing filariæ do not appear to be injured seriously; one that was killed fifty days after its meal of blood contained eleven filariæ in the thorax and two in the abdominal cavity.

In mosquitoes fed on non-filariated blood no filariæ could be detected.

When the mosquito's thorax is torn across several times with dissecting needles in a watch-glass containing water on the stage of a dissecting microscope, the filariæ are liberated and sink to the bottom; they can be seen fairly easily with the naked eye and by aid of a needle picked out; they cannot swim nor move away from the spot where they happen to sink, yet they twist and wriggle about in a violent manner; by means of what appear to be caudal suckers some of them stick to the glass, also to the dissecting needle when touched by the same.

Water is injurious to them for after three or four hours therein they die. Water therefore cannot be the medium, as was generally supposed, by which they ultimately reach the human subject.

Directly after having seen the first "actively moving filariæ" wriggling about in water for a couple of hours, I concluded that water was the medium, and wrote a letter to the Editor of the *Australasian Medical Gazette*[1] to that effect, being anxious to correct a former statement[2] of mine to the effect that the young filariæ died in water; [as subsequent observation has shewn that statement did not require correction]. Shortly after having written the letter I found the young filariæ were dead but concluded that they must have been injured by the cyanide of potassium by which the mosquito was killed. Many experiments

---

[1] *Australasian Medical Gazette,* March 20, 1899. [2] *Ibid.,* June 20, 1898.

were afterwards made with filariæ from mosquitoes that had been dissected whilst alive to insure no injury to the filariæ they contained; it made no difference however, for the young filariæ always died after three or four hours' immersion in water. In mosquitoes that had died a natural death, when examined twenty-four hours afterwards, the filariæ were dead; this occurred whether the mosquito died on water or not. The filariæ never escape naturally from the mosquito's body.

In order therefore, for the young filariæ to reach the human subject, it would appear that the mosquito must be swallowed. It is not uncommon to meet people, who have accidentally swallowed one of these insects, and it seems possible enough that such might occur, especially in those who sleep with the mouth open. In the act of killing mosquitoes with the hand their bodies are ruptured and any young filariæ, that might be present, would be extruded on to the fingers and afterwards transferred to the mouth. Mosquitoes when aged frequently get bogged in jam and honey, and by such food it is possible, although somewhat improbable, they could gain entrance into the human stomach. To be infected, some may imagine that there must be an easier way than by swallowing mosquitoes; they must remember, however, that Nature has not ordained that the life-cycle of entozoal parasites shall be easily attained; obviously for the reason that were it easily accomplished, gross infection would occur causing the death of the host and with him the parasites.

Leuckart in his work[1] makes the following reference to Manson's discovery, p. 64, footnote:—" From the observations of Manson[2] there can no longer be any doubt that the few embryos which can pass without danger to themselves through the intestine of the mosquito undergo further development in the body-cavity, in consequence of which they now differ in size and in the structure of the mouth parts from the embryo at an earlier stage. Manson is of opinion that embryos, having thus reached a certain stage in

---

[1] Parasites of Man by Rudolph Leuckart—Young J. Pentland, 1886.
[2] Trans. Linn. Soc., Lond., pp. 367-8, 1884.

the body-cavity, get into water only on the death of the host, and that they are taken into the human body with the water. This statement still requires demonstration, but even were this proof forthcoming there would yet remain a possibility that the embryos evacuated with the urine (which probably no more represent a useless production than the eggs of intestinal worms which pass out with the fæces) may be transported to certain small hosts, and by these means human beings may perhaps be infected more commonly than in the way pointed out by Manson."

From these remarks it would appear that Leuckart imagined that it was a normal occurrence for embryo filariæ to pass out of the body with the urine; such is not so, however, and is by no means common in those affected with filariasis; it occurs in cases only when there is rupture of a lymphatic or blood vessel in the kidney or bladder; the filariæ when mixed with urine are rapidly altered by endosmosis or exosmosis and live but a short time. The same applies to dogs affected by the *Filaria immitis* in which however it is even of rarer occurrence.

How did it come about that Manson saw the final stage of the metamorphosis in mosquitoes seven days old?

This I believe to be the explanation:—The filariated mosquitoes upon which he made his observations were not bred out and thus in confinement from the moment of their emergence from the pupa state; they were free mosquitoes obtained from a room where filariated persons slept. A few of the mosquitoes that were captured doubtless had imbibed blood weeks before and already contained advanced stages of the metamorphosis. They were imprisoned and never fed, consequently they died about the sixth or seventh day, when they were microscopically examined. Manson evidently believed that their last meal of blood was their first.

Manson has remarked[1] "that various stages of the metamorphosis were occasionally to be seen in the same mosquito." Such

---

[1] *Op. cit.*, p. 379.

a thing never occurred to me, and is inexplicable except on the supposition that his mosquitoes had imbibed filariated blood on several different occasions.

In the following details my observations differ from those of others, who have worked at this subject.

1. Pressure of the cover-glass more particularly and endosmosis are the cause of rupture and escape of material at the anus in the young filariæ; such is not a natural phenomenon; it will not happen if the thorax be teased out in Müller's fluid and examined without a cover-glass or with a small piece of cover-glass.

2. After the meal of blood is digested, the mosquito's stomach and intestine contain no filariæ.

3. The filariæ after imbedding themselves in the thoracic muscles lie quiescent until about the fourteenth or fifteenth day, when very slight movements can sometimes be detected.

4. I have been unable to satisfy myself that the embryo filariæ cast their sheaths before leaving the mosquito's stomach; when seen in the thorax they appear to have lost the long collapsed sheath following tail; the sheath may however have only shrunk or it may be filled out by the worm, which has already grown longer and thicker; the tail is peculiar in the early stages, which may be due possibly to retention of the sheath.

5. The filariæ, which emigrate to the thorax, do so directly they are withdrawn from the human host; those that are to be seen in the mosquito's stomach several hours later are they, that for some reason, whether being too young, or from injury or from having been already acted upon by the digestive juices, are not destined to enter upon a metamorphosis. Loss of sheath, striation of body, changes in the body protoplasm in them are due to endosmosis and digestion.

6. No apparent sheath can be seen in the embryo filariæ in freshly drawn blood, but a flagellum-like body generally following the tail (Fig. 1); sometimes the flagellum-like body is momently protruded from the head, and *pari passu* disappears from the tail;

this only occurs when the worm is swimming tail first; such appearance cannot be seen in every embryo, and I am inclined to think that it is not normal (Fig. 2). The flagellum-like body is the collapsed sheath, which can only be diagnosed as a sheath when endosmosis has taken place. Those who have figured the embryo, have represented a worm inside a distended sack; such appearance is unnatural. The purpose of the sheath is possibly to anchor the worm to the side of a blood vessel when the latter is resting.

Manson in his recent work[1] p. 460, has remarked :—"It is also manifest that the purpose of the "sheath" with which it is provided while circulating in the human host, is to muzzle the embryo filaria and prevent its breaking through the blood-vessels, and so missing its chance of gaining access to the mosquito."

If any should care to decide the question for himself, let him prepare a slide of filariated blood and paint a little oil round the edge of the cover-glass to prevent evaporation and examine under the microscope twenty-four hours afterwards, when a certain amount of coagulation and crystallisation has taken place; this forms some resistance to the filariæ and they may be seen crossing from one edge of the cover-glass to the other in a tortuous but definite course with the collapsed sheath following tail.

I cannot agree with Manson that the sheath muzzles or impedes the filaria in any way; normally I believe the sheath is never separate from the body. The embryo in freshly drawn blood wriggles about but never seems to leave the same spot; this peculiarity was considered due to some impediment caused by the sheath, but the embryo of *Filaria immitis*, which is not possessed of a sheath, wriggles precisely in the same manner.

7. Some writers would lead you to imagine that there is but a single pair of adult filariæ in each filariated subject; judging from analogy of what occurs in other animals harbouring filariæ, I believe that there are generally a good many present, a dozen or

---

[1] Tropical Diseases—Cassell and Coy. Ltd., 1898.

so, or possibly in some cases fifty. The number of embryos that are to be found in a drop of blood is some criterion of the number of adults in the subject; if the embryos are scarce, it is likely that there are few adult females, but if plentiful it is probable there are many females.

It is not known how long the embryo filaria lives in the blood, probably it is several months, and probably the adult worms live several years.

Provided a filariated subject could prevent reinfecting himself, it is very likely that in course of five years, he would be entirely free from the parasites. To accomplish this, it might be wise to emigrate to a country where there are no mosquitoes, and failing that, to sleep under perfect mosquito-net bed curtains.

Fortunately it is easy to rid the house of the *Culex ciliaris;* it appears that this insect was introduced into Australia ;[1] it will not go wild but always frequents habitations, breeding in receptacles holding water in or about the house; such receptacles should be covered with gauze, net, perforated zinc or other material to exclude mosquitoes; cattle and poultry water troughs should be emptied out at least every ten days, as by so doing, the mosquito larvæ could never mature; it takes fourteen to twenty days from the mosquito egg to the perfect insect.

In this investigation the following methods were found the best. In breeding "house mosquitoes" it is necessary to obtain their eggs or larvæ. Galvanised iron washing tubs are convenient vessels wherein to rear the larvæ; these are filled with fresh water and placed in a shady spot; into them is put a handful of rotting leaves and a small piece of flesh, preferably flesh that has passed the putrefactive state in water, having been converted partly into adipocere. When animal matter forms part of the diet, the larvæ grow faster and to a larger size. The larvæ soon die should the water become foul. In a fortnight or so the larvæ will have changed into pupæ; by means of a miniature scoop-net (the size of

---

[1] Proc. Linn. Soc. N. S. Wales, Vol. III., (Series 2nd) p. 1718.

a tablespoon) made of wire and mosquito net the pupæ are transferred to a glass vessel of water such as a fish bowl (about six inches in diameter at the mouth). The mouth of bowl is covered with muslin the material known as "white leno" was found very serviceable; mosquito net is not suitable as mosquitoes can, when they try, creep through the meshes, especially when the net is stretched tightly. The pupæ do not require food, and in a day or two the perfect insects will have emerged from them. The male mosquitoes are easily distinguished by their large feathery antennæ; they do not suck blood. Transference of mosquitoes to a glass cell is performed by means of a "collecting tube"; this is a hollow glass cylinder conveniently four inches long and one and a half inches in diameter, one end is covered with mosquito net, whilst a cork is loosely fitted to the other (Fig. 8); pieces of Argand gas-lamp chimney make good collecting tubes.

Glass cells, about ten inches high and six inches in diameter, are convenient wherein to store living mosquitoes; they are fitted

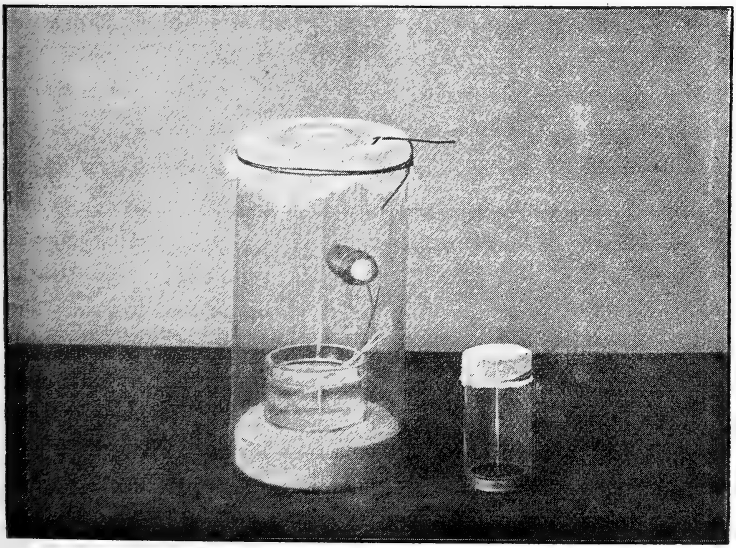


Fig. 7. Fig. 8.

up as follows :—At the bottom is placed a little dry sand, also a vessel holding three or four ounces of water ; the sand serves to weight the cell and steady the water vessel; into the vessel of water is put two or three bits of straw or cork, this is to assist the mosquitoes rising from the water; as the mosquitoes age they get infirm and frequently get drowned unless they reach some floating object. Over the mouth of the cell is stretched a piece of wet leno and tied tightly with twine; when the leno is dry a circular hole an inch in diameter is cut out of the centre, and this hole is covered with a watch-glass, concave side upwards (Fig. 7).

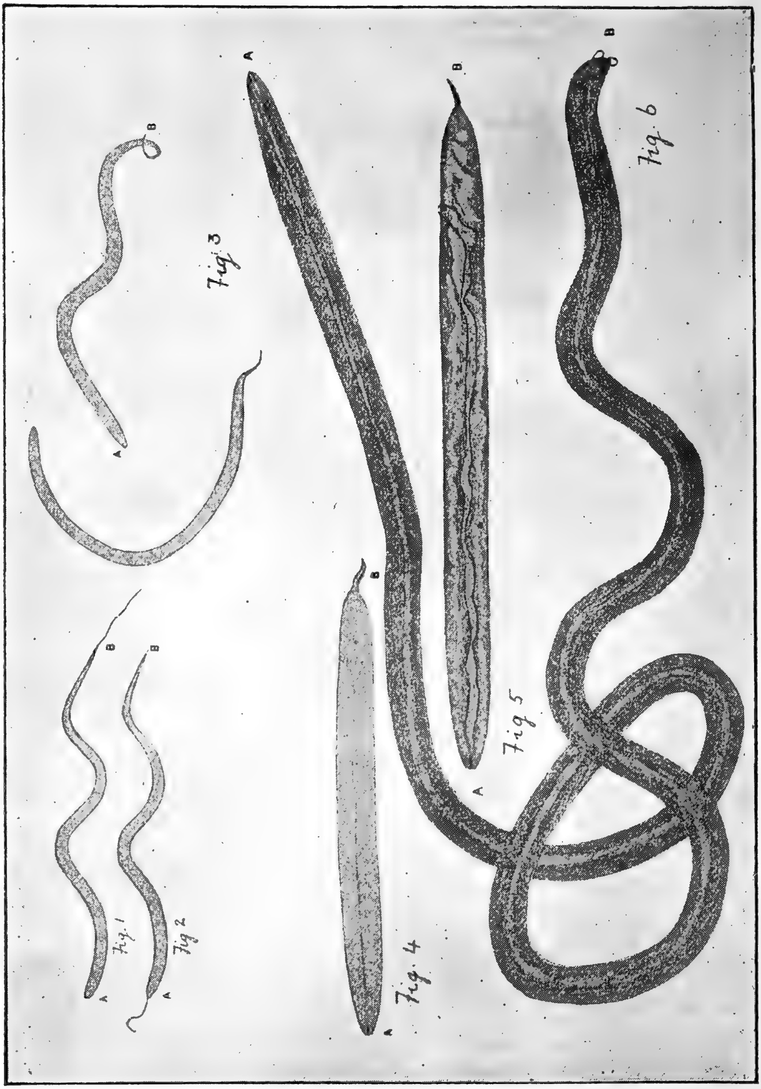
The transference of mosquitoes to a glass cell is done in the following way:—The mosquitoes are allowed to escape under the mosquito-net curtains; the cork being removed, the mouth of a "collecting tube" is placed over a mosquito, which then flies up the tube; the cork being now replaced the tube is brought close to the glass cell, the cork being directly over the watch-glass; the cork is removed and the tube put right on to the watch-glass, and at the same time the watch-glass is slid aside, the open mouths of the tube and cell are now together; a puff of air blown down the tube causes the mosquito to fly down into the cell; the watch-glass is again placed in position. By such means a dozen mosquitoes might be put into a cell in a minute without any danger of injuring them.

Female mosquitoes bred out by me were put into an empty cell of the capacity of forty ounces of water and sent to the home of the filariated subject, who liberated them under the bed curtains upon retiring; next morning any with distended abdomen she captured by means of a collecting tube transferred back to the cell and returned the same to me; they were again liberated under curtains and transferred to larger vessels. In the cell storing mosquitoes a section of ripe banana is suspended; it was found best to cut the banana at right angles to its length in pieces one and a half inches in length with the skin left on. Moulds very soon grow on the cut ends when the mosquitoes prefer to pierce the rind and thus get at the sound tissue. It is advisable to remove the piece of banana and replace by fresh every three or four days. Should the air in the cell become foul from the decomposition of banana, or from the odour of mould fungi or the water at times contaminated by banana juice, it is advisable to liberate the mosquitoes under a mosquito net curtain and transfer them to a clean cell. It is also well to place a plug of cotton wool in the hole in leno and over this the watch-glass, concave side down. The cells are placed in a room in the house where the light is subdued, or shaded by brown paper from too strong a light. Half a dozen mosquitoes is a sufficient number to put into one glass cell of the capacity of one hundred ounces of water.

When mosquitoes are required for examination, they are liberated under the curtains, captured and killed in the entomologist's cyanide bottle, or by means of chloroform etc. Two pairs of ciliary forceps are useful with which to pull off the wings, legs and head ; afterwards the body is divided by dissecting needles into thorax and abdomen, and each portion examined separately, teased out in water, or better in Müller's fluid with or without a cover-glass under a magnification of fifty diameters.

The following is a short account of the life-cycle of *Filaria Bancrofti*:—Commencing with the mature parasites in the human subject; these are three or four inches in length by $\frac{1}{90}''$ in breadth, they live in the lymphatic vessels; they produce the embryo filariæ, which are $\frac{1}{90}'' \times \frac{1}{3500}''$; these latter live in the blood vessels, swimming about when the host is sleeping and resting themselves when he is awake.

Mosquitoes when biting a filariated subject during the night withdraw together with blood some of the embryo filariæ. Soon after the embryos reach the mosquito's stomach they pierce the stomach wall and find their way to some muscular mass, particularly the thoracic muscles, in which they imbed themselves (Fig. 3); there nourished by the mosquito's plasma they grow at a prodigious rate, becoming longer and thicker and assume by the fifth day the appearance represented in Fig. 4, in which a distinct line,



Metamorphosis of *Filaria nocturna* in Mosquito's thorax. × 200 diameters.

Fig. 1 Normal appearance of filaria in the blood.

Figs. 3, 4, 5, 6, Stages of the metamorphosis, 1—5—10—16 days respectively. A = Head; B = Tail.

the rudimentary intestine, can be seen from the mouth to the anus; the body protoplasm, at first homogeneous, has been changed into large cells with numerous vacuoles; in ten days the intestine presents a double line, the large cells have given place to very small cells, Fig. 5; from this time on to the seventeenth day most remarkable changes occur too intricate and difficult to describe; in seventeen days thereabout the young filaria has attained its maximum development as far as its life in the mosquito is concerned; it now awaits the chance of gaining entrance to the human host; in the event of which, we presume that it will start upon a second metamorphosis, the final alternation of generations, in which it grows to the length of three or four inches and becomes sexually mature.

It remains to be proved that these young filariæ will become sexually mature in the human host; I have elsewhere[1] suggested how this might be accomplished, viz., by inducing a life-sentenced prisoner to swallow some mosquitoes bearing filariæ on condition that he be given a free pardon.

Besides proving that the *Culex ciliaris*, Linn. is an efficient host for *Filaria nocturna*, I have shewn that two other species of mosquito are not hospitable, viz., *Culex notoscriptus*, Skuse, and *C. annulirostris*, Skuse. Both these mosquitoes will live in confinement at least twenty days. *Culex notoscriptus* sucks out plenty embryos, but as far as I have seen none of these ever migrate to the thorax; they appear to have been killed by the salivary juice. Only rarely do some embryos migrate in the case of *Culex annulirostris;* after two days however, any that did reach the thorax have died and been absorbed. Other mosquitoes have been experimented upon, but as I have been unable to keep these alive sufficiently long for the final stage of the metamorphosis, it is impossible to say definitely that they are not hospitable, yet every thing tends to that conclusion.

In the case of *Culex hispidosus*, Skuse and *C. vigilax*, Skuse, these two species live about seven days in confinement, and a

---

[1] *Australasian Medical Gazette,* March 20, 1899.

number examined about that time contained no filariæ. In the case of *Culex nigrithorax*, Macquart., *C. procax*, Skuse, and *Anopheles musivus*, Skuse, I have been unable to keep them alive more than three days; a good many experiments were made with *Anopheles musivus;* this mosquito sucks out a very large number of embryos, and the most of these migrate to the thorax.

For the scientific names of the mosquitoes I am indebted to Henry Tryon, Esq., Entomologist to the Queensland Government. Thanks are due also to E.S., the filariated subject, without whose assistance this investigation could not have been carried out, and Manson's important discovery might for some time to come have remained unbelieved.

EXPLANATION OF FIGURES.

Figs. 1 to 6—Stages of Filarial Metamorphosis. × about 200 diameters.

Drawings to scale were made of the filaria × 1,000 diameters, afterwards reduced by photography.

Figs. 7 and 8—Apparatus for collecting and storing mosquitoes.

Added June 1st.

A number of mosquitoes imbibed filariated blood on April 26th and the final stage of the metamorphosis did not occur in them until May 31st, *i.e.*, thirty-five days. The weather was cold.

It has occurred to me that the young filariæ may gain entrance to the human host whilst mosquitoes bearing them are in the act of biting. The entrance of warm blood into the mosquito may excite the young filariæ in consequence of which they pierce the œsophagus and pass down the proboscis into the human skin. In this way injury from the human digestive agents would be avoided; it is not unreasonable to suppose that like water the digestive fluids would soon kill the young filariæ, but it is probable that those that may have been set free by rupture of the mosquito's body would immediately pierce the mucous membrane and enter a lymphatic or other vessel.

SUGGESTIONS FOR DEPICTING DIAGRAMMATICALLY THE CHARACTER OF SEASONS AS REGARDS RAINFALL, AND ESPECIALLY THAT OF DROUGHTS.

By H. Deane, M.A., M. Inst. C.E., &c.

[*Read before the Royal Society of N. S. Wales, July 5, 1899.*]

The usual methods of plotting the rainfall which merely show in some form or other the quantities of rain which have fallen during a period, do not altogether achieve the desired result. Generally speaking people are apt to judge of whether a particular season is to be placed in the category of droughts or of good seasons, according as the total rainfall has been below or above the average respectively. It need scarcely be pointed out that any conclusion thus arrived at must be entirely erroneous. It not infrequently happens that a few months of droughty conditions are followed by one or more months of excessive rainfall, by means of which the total rainfall has been brought up to or above the average. Judging by averages the whole period would pass as a good one, whereas the dryness of the earlier part of the period may have resulted in disaster, which is not at all compensated for by the subsequent excessive rain, the greater part of which runs to waste.

The value of a year's rainfall is therefore not to be reckoned by the total, but by the manner in which it falls and its distribution throughout the year. Thus looked at, a year's rainfall under the average coming at proper times may produce very much better results than one that comes at unsuitable times, or that falls on few occasions in excessive quantities with long dry gaps in between.

My method will be seen to be particularly useful in reviewing rainfall as affecting agriculture, but it also has the advantage of showing what portion of the rainfall runs off the ground or soaks away and is available for storage and for keeping up the flow of rivers and streams.

It is of importance that at times there should be an excess of rainfall over that required to effect saturation of the soil as water is required for drinking and other purposes. A season may be a good one from an agricultural point of view if the soil is kept in a fair condition of moisture throughout the period, although no surplus may run off. On the other hand a season of occasional heavy rainfalls with droughty conditions in between may as regards water supply be superior to the other.

It is worth while inquiring what are the conditions producing a drought. We know the effect of a drought in losses of crops and stock, but it is as well to notice how these are brought about. A drought is marked chiefly by its effect on vegetation. It is a period during which the drying process of the soil is of such duration as to cause vegetation to wither and eventually fail altogether. In wheat districts a drought may be short and yet destructive if it comes at a time when the crops should be growing. In the pastoral areas longer duration is necessary to produce harmful results. A drought is not measured wholly by the amount of the deficiency of rainfall, but by the accumulated result of the evaporation of the moisture in the soil without the compensation of rain to restore what is being thus lost, this condition of things being much intensified by strong winds and high temperatures. It is the progressive drying which I have endeavoured to represent diagrammatically.

A few more observations are desirable before I proceed to explain the diagram.

The drying process which goes on in the soil consists partly of evaporation at the surface of the ground of the moisture rising by capillary attraction, and partly of the exhaustion of its moisture due to the evaporation from leaves and external surfaces of plants of the water which has been drawn up out of the soil by their roots: partly also, no doubt, by the gradual effect of gravitation on the suspended moisture in the soil, but I think this is very small.

The exhalation from the vegetation must be a most important factor in the drying of the soil. Otherwise the rate of drying would rapidly decrease if the storage below could be drawn upon by the aid of capillary attraction alone. The effect of the vegetation however, is probably to make the rate of soil-drying a much more even one.

After continued dry weather, grass and herbs begin to wither and may fail altogether, while the moisture below may be still sufficient to keep deep-rooted plants, shrubs and trees in a flourishing condition. After the ground has been thoroughly desiccated a succession of light rains may have the result of putting grass and herbage in good condition, but at the same time be too sparing in quantity for any of it to find its way down to any great depth. With my method the temporary revival of grass and herbage as the effect of light rain during the progress of a drought may be shown.

Mr. H. C. Russell gives the mean rates of evaporation from water for each month calculated from a long series of years as follows:—

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
·22	·16	·14	·09	·07	·05	·06	·08	·13	·20	·22	·24

The total mean evaporation from water surface amounts to 48·9 inches per annum.

After consulting with Mr. Russell I decided to adopt half the rates in the above table as the rates at which evaporation from the surface of the soil would probably begin to take place. These are as follow:—

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
·11	·08	·07	·045	·035	·025	·03	·04	·065	·10	·11	·12

My method, which I will now explain, rests on the fact that as soon as rain leaves off the drying process commences and continues till rain falls anew and makes up in whole or in part for loss previously sustained. On the diagrams, (*Plate* 3) periods of time are measured horizontally, and each division of $\frac{1}{10}$ inch represents a day.

The upper line on each diagram represents saturation. Vertical measurements are in inches and tenths of inches, and the distance of any point on the "drought line," as it is convenient to call it, from the line of saturation, is intended to represent the number of inches or tenths of inches of rainfall required to restore the saturated condition on that particular day. The rises represent rainfalls. The drought line cannot of course rise above the line of saturation. If at any time when rain begins, it only requires a certain quantity to complete saturation, any balance of a rainfall larger than this quantity must be treated as surplus and not recorded in the diagram. It may however, be entered in figures below. This quantity as a rule, flows off or drains away through the soil, and is useless as regards the particular area on which it has fallen, though it may be collected and made available for water supply, and it helps to keep up the flow of rivers and streams, but that is a different question altogether.

Starting now at a point where complete saturation has been effected and rain has ceased to fall, the drying process is shown by the descending line, the vertical descent for each day is the amount of drying which has taken place. This is dependent on the weather conditions, temperature, dryness of the air and the existence or otherwise of wind.

At starting, the amount for the first day must bear some definite proportion to the evaporation from water under the particular conditions. As stated already this evaporation must vary according to the weather conditions. It is greatest in summer and when the air is dry and wind is blowing, and least under the reverse conditions. In making the diagrams however, I have found it convenient to use the calculated averages for each month. This is of course not quite correct, but the general results will not be far wrong.

As the ground dries, the rate of evaporation slackens because the moisture has to be drawn up from increasing depths; the daily drops of the drought line becomes less, and the effect is to produce on the diagram a curve with increasing radius the direction of which more nearly approaches the horizontal as time goes on.

The curves have been arrived at by a tentative process in the first instance, but I am convinced that the results on the whole are fairly representative of the actual facts. With careful study and experiment, probably a considerable degree of exactness could be arrived at.

The diagrams of the years 1883 to 1899 inclusive, are based on rainfalls recorded by myself from time to time at my residence on the Parramatta River. The records for 1883 and 1893 are unfortunately incomplete.

Diagrams of this kind might be plotted so as to represent, with very great accuracy, the combined effect of the weather conditions. The daily evaporation due to dry winds and high temperatures, and reverse conditions could be taken into account, and once the right equation is found, x being the inches of rain required for complete saturation, the angle of descent could be calculated. On the other hand I have little doubt that an empirical method for obtaining the proper curves to use for each set of weather conditions would come pretty near the truth. What is wanted is to represent the character of each drought so as to be able to compare it with those of others of the same locality.

Of course any diagram would in all its details only apply to the district over which the same conditions extended. On other soils and with other climatic conditions one would get somewhat distinct results.

It is not to be expected that one set of diagrams would suit a whole country or even a whole district any more than one set of thermometers and one rain gauge would serve, but for those who like to try the method, I would say that the diagrams are rapidly done, when once the curves are decided upon.

The black line is what I have called the "drought line" or the curve of drying. The space between that line and the top line or line of saturation, shows the dryness or droughtiness of the period.

And the extent of the drought is directly proportional to the area, the intensity of any drought being the particular area divided by the length. It is proportional to the mean depth of area coloured brown. The peculiarity of the different years is well shown in the diagrams (*Plate* 3).

(Added July 31).

I would recommend that as in any district many differences in soil and situation occur, some standard might be adopted for purposes of recording observations. If the evaporation from this standard soil under different conditions could be determined once for all, the observer would only have to note the temperature and hygrometric conditions as they occur each day and plot the corresponding rates of evaporation on the diagrams. The gauging of the differences in drought effects through any variation of soil and surroundings could then be left to the individual judgment. A decision as to what should be taken as standard soil and conditions is in the first place necessary, after which an exhaustive system of experiments should be made as to daily drying under varying conditions of temperature, dryness of air, wind, etc.

OBSERVATIONS ON THE DETERMINATION OF DROUGHT-INTENSITY.

By G. H. KNIBBS, F.R.A.S., Lecturer in Surveying,
University of Sydney.

[*Read before the Royal Society of N. S. Wales, August 2, 1899.*]

1. Drought-intensity a definite function of measurable meteorological phenomena.
2. Essential features of Mr. Deane's solution.
3. Nature of the problem.
4. Characteristically similar areas.
5. Both quantity and rate of rainfall essential factors.
6. Permeability.
7. Laws of flow in permeable strata.
8. Relation of rate of rainfall to saturation.
9. Effect of slope of surface.
10. Percolation into or through permeable strata when the interstices are full.
11. Percolation when interstices are not filled.
12. Exhaustion of moisture in soil by percolation.
13. Exhaustion of moisture by evaporation.
14. Solar radiation.
15. Diffusion of aqueous vapour into the atmosphere.
16. Effect of air temperature.
17. Humidity and its influence.
18. Effect of wind.
19. General expression for degree of saturation.
20. Necessity for the study of elementary cases.
21. Graphs representing natural phenomena.
22. Natural phenomena to be observed.
23. General remarks.

1. *Drought-intensity a definite function of measurable meteorological phenomena.*—The suggestive paper by Henry Deane, M.A., M. Inst. C.E., entitled "Suggestions for depicting diagrammatically the character of seasons as regards rainfall, and especially that of drought," and read at the last meeting of this Society, is essentially an attempt to derive, from the record of meteorological facts, a *graph* representing a dependent phenomenon, viz., *drought-intensity.*

Whatever the possibilities of its determination, such a phenomenon is without doubt a definite function of several meteorological as well as physical conditions :—*(a)* the *quantity* and *rate* of rainfall; (*b*) the character and circumstances of the soil and surface on which the fall takes place; and (*c*) the evaporative conditions; these last including temperature, radiation, humidity, wind, the presence of vegetation, and to a very slight extent barometric pressure; that is to say all circumstances which affect the drying of the soil. Compared with other factors, the element of pressure is probably so small as to be quite negligible: it will not further be referred to.

2. *Essential features of Mr. Deane's solution.*—In Mr. Deane's suggested solution of the problem indicated, the general principle of which must I think be accepted as valid, the presence of soil susceptible of instant saturation is tacitly assumed, and also certain rates of exhaustion of the contained water,[1] such rates depending upon *average* monthly conditions of temperature, humidity, wind, etc., and the length of time such conditions have continued. The first derivatives of Mr. Deane's evaporation-curves are negative, and continually diminish with the increase of the abscissæ representing *duration;* that is to say the rate of evaporation is assumed to continually diminish, as doubtless it does, throughout unbroken periods. There is an admitted discontinuity in Mr. Deane's graph, every time that the saturation line—the axis of abscissæ denoting time—is reached; and since as long as rain continues, no exhaustion of the *degree* of saturation is assumed, and since also all fall is considered positive whatever its rate, the curve is really reconstituted only at the end of the rainfall. That is to say the curve is identical with the saturation line for such periods. This method applied to the determination of the contents of a reservoir, in which no losses could occur while the supply or influx continued, would correctly represent the facts, provided the consideration was limited to the reservoir itself: once full, all further supply would run off and be lost.

---

[1] These have an empirically assumed relation to the evaporation of water in exposed vessels.

3. *Nature of the problem.*—On the adequacy of this conception of the facts, the solution suggested by Mr. Deane really depends. I propose therefore to indicate what I conceive to be a more approximate statement of the actual facts to be considered in a solution, and how it is affected thereby; and further to offer some observations on the means of obtaining one, which will present no discontinuities other than are inherent in the data themselves, that is, in the meteorological phenomena from which the graphs are deduced. It is proper to mention that Mr. Deane did not propose a *general* solution, but one restricted merely to the saturation element. It may not be inappropriate also, here to remark, that so far as I am aware, meteorological science has not yet determined, even approximately, the form of the functions connecting the data with such derived phenomena, and even in ideally definite cases; and further, that in order to reach a practical solution, such cases must not only be *experimentally* studied, but also so chosen as to cover the range of actual conditions. That is to say, the meteorological phenomena usually recorded at an observing station must be experimentally connected with their consequences, in specific cases, in order that those phenomena may be intelligently considered in relation to their general influence on a territory. Without results of such experiments to hand, the application of the method of averages will advance our knowledge at least one step beyond the purely empirical stage, and will prepare the way for a better and more efficient study of a problem so profoundly affecting our well-being, and of such moment to this province. I may be permitted to add that, in discussing Mr. Deane's attack on the problem, I wish to express my appreciation, not only of the method which he has advanced, but also of his very suggestive conversations on the subject; a subject which from several points of view, I have studied for a considerable time.

4. *Characteristically similar cases.*—Since practically, determinations of drought-intensity are required for areas governed by generally similar conditions, a territory must be subdivided into such areas as present characteristically similar features, and

average conditions for these must be discussed. Here, it must be confessed, lies one of the greatest practical difficulties in the way of even approximate deductions. It is evident also that evaporative and other conditions must similarly be locally considered, and also treated by the method of averages. The nature of the difficulties of so doing will incidentally be more fully specified hereinafter.

5. *Both quantity and rate of rainfall essential factors.*—Reverting to §1, there is no serious difficulty in regard to the measurement of the first element, viz. (*a*); and measurements of the *rate* of rainfall, together with the time, give by integration the *quantity* of fall—see §21, hereinafter. In practice the rate is *derived* from measurements of quantities received in short periods; the discontinuities and irregularities of the natural phenomenon rendering other methods unnecessary. It will be seen hereinafter, that the *rate of fall* greatly affects the question of the *degree of saturation* produced by a given amount; so that if one makes this latter the measure of the *intensity* of a drought—as Mr. Deane has done—and probably no better measure could be suggested—it is necessary to take account of, not the *total* fall, but that part of it, depending on the rate of fall, on the permeability, and on the general conditions and characteristics of the soil, which serves to produce saturation: in other words, of that part which does *not* run off. The determination of the amount that runs off is important to engineers in the design of waterways.

6. *Permeability.*—The permeability of the materials of the earth's surface probably never absolutely reaches zero: the rate of flow in some however is so insensible in relation to the slowest rate of deposition of water as to justify their treatment as impermeable. In the sensibly permeable materials however, there is every gradation, viz., from material which will instantly absorb the heaviest tropical shower, to that from which the lightest rain will flow off.

7. *Laws of flow in permeable strata.*—Experiments on the flow of liquids through permeable strata of uniform fineness, shew that

the velocity of the liquid varies *directly* as its density, the rate of fall in pressure in the direction of flow, and the square of the linear dimensions of the interstices of a stratum, and *inversely* as the viscosity of the liquid. That is, if U denote the mean interstitial velocity, K a constant, ρ the density and η the viscosity of the liquids, R any homologous linear measure of the size of the interstices, and P the difference of pressure between two points L apart, between which the velocity is uniform—so that dP/dL is the *rate* of fall of pressure—then the expression

$$U = K\frac{\rho}{\eta}\frac{dP}{dL}R^2 \ldots\ldots\ldots\ldots(1).$$

defines all the laws of flow. Apart from experiment this formula may be deduced rationally: *i.e.*, by abstract mechanics. The value of the constant K can also be obtained mathematically—*i.e.*, without recourse to experiment—when the *form* of the interstices is given, and the particular dimension denoted by R is indicated. For water ρ may be taken as sensibly unity: and, other things being equal, the change of rate of flow with temperature will be as follows:—

Temperature Celsius	0°.	10°.	20°.	30°.	40° C.
Rate of flow (f)	1·00	1·37	1·77	2·22	2·72.

This covers the entire range of conditions naturally occurring. Hence, if we put I for the rate of fall in pressure—*i.e.*, for the 'hydraulic gradient'—the above equation may be written

$$U = f'K'IR^2 \ldots\ \ldots\ldots\ldots(2)$$

in which R measures the coarseness of the soil, and $f' = \rho/\eta$; for water very nearly f as above.

8. *Relation of rate of rainfall to saturation.*—In order to clearly apprehend the manner in which the saturation of a soil is dependent upon the mutual relation of rate of rainfall and permeability, consider the case of a uniform unsaturated soil of indefinite depth, with a uniform surface slope, and subject to rainfall of varying degrees of intensity. For every rate of fall—dz/dt say, since fall is conveniently measured by the height (z) to which any level closed surface is covered in some definite time (t)—less than what

the soil is capable of taking up, the total quantity goes directly into the soil and is efficient in helping to saturate it. But for rates of fall greater than that, more or less of the rain will run off, and only *part* will be efficient in respect of saturation. Hence clearly there is, for any given set of circumstances, some ***critical value*** of dz/dt, changing however with the circumstances, above which it becomes necessary to consider how much is lost by flowing away. (See the point t_1 in Fig. 1, § 21 hereinafter). The quantity efficient in producing saturation is obviously not only a function of the permeability and temperature, it is also, even in dry soil, a function of the slope (s say) of the surface; for the rate, at which flow will take place over the surface, increases with the slope. In other words in the case of falls of rain which are not entirely absorbed by the soil, for a given quantity falling in a given time, less enters the ground in a steep slope than in a slight one; and for the same soil and the same degree of saturation, somewhat less enters in winter than in summer.

9. *Effect of slope of surface.*—The effect of slope demands further consideration. For any definite rate of rainfall on an impermeable surface—let us suppose of uniform slope—the rate of run-off will finally equal that of fall, and the depth to which the surface will be covered will depend on its rugosity—n say—and the slope; that is to say the depth will increase until the velocity depending on that depth and on the roughness, is sufficiently developed to carry off the entire amount of rain falling. A *similar*, but not identical thing happens, when the surface is permeable, provided that more rain falls than can be simultaneously absorbed. The rapidity of the flow into the permeable stratum, also increases with increase of the depth to which the surface is covered, and is moreover affected by the depth in the stratum to which the flow has reached, so that the rate of surface-flow, or 'run-off' is not only dependent on the intensity of rainfall and on the character and slope of the surface, it too is similarly dependent on the depth to which flow into the soil has attained. It is thus evident that both 'surface-flow' and 'permeable-flow' are definite functions[1] of the

---

[1] Not necessarily discoverable functions.

duration of the rainfall – t say. If we divide the total fall into two portions, z_1 and z_2, denoting respectively 'surface-flow' and 'permeable-flow,' then dz_1/dt will be zero for all values of dz/dt below the critical value. And always, if we neglect losses by evaporation—$d\epsilon/dt$ say—while rain is actually falling, we should have the total rate of fall equal to the sum of the rates of 'run-off' and saturation: that is

$$\frac{dz}{dt} = \frac{dz_1}{dt} + \frac{dz_2}{dt} \text{ ....} (3)$$

To recapitulate:—Both elements of flow are functions of the duration and rate of fall, the permeability, the temperature of the soil (θ say) and the slope and roughness of the surface; and may be symbolically represented by

$$\left.\begin{aligned} \frac{dz_1}{dt} &= \phi\left(t.\ \frac{dz}{dt}.R.\theta.s.n\right) \\ \frac{dz_2}{dt} &= \psi\left(t\ \frac{dz}{dt}.R.\theta.s.n\right) \end{aligned}\right\} \text{ ....} (4)$$

the functions ϕ and ψ being however by no means easy to determine. One necessary element in the solution, viz., the law of flow of a thin stratum of liquid over a rough inclined surface, has not as yet been satisfactorily solved, though roughly approximate solutions are available. The matter however is actually *not* as simple as indicated by these equations, which represent the solution for an extremely elementary case. This will more fully appear latter.

10. *Percolation into or through permeable strata when the interstices are full.*—When a permeable stratum is covered by a liquid, the flow thereinto is, for cases naturally occurring, always *irrotational.*[1] Hence, for a stratum whose interstices are uniform in size, the resistance to flow—due to the total shear or distortion of the fluid in translational motion only—will vary as the square of their linear dimensions (as R^2 say); and for a stratum whose inter-

---

[1] In a thin stratum of say pebbles, rotational flow would be developed, in which case the potential is exhausted not only by translational, but also by the rotational motion.

stices vary in size, as the mean of the squares of their linear dimensions (as R^2_m say). Thus it is easy to determine by a single experiment, the constant for any kind of stratum considered; as we proceed to shew.

Let q be the efflux per unit of time from a cylinder of soil of sectional area A, in which the rate of fall of pressure along the axis of the cylinder is I. Then if $a = cA$, be the *efficient* interstitial area on the surface through which the efflux takes place, so that c is always and necessarily a proper faction, we have from (1)

$$q = Ua = cA\ K\frac{\rho}{\eta} IR^2 \text{...........}(5)$$

In an experiment it is not possible to discriminate between c, K, and R^2, so that we may practically include all these under the symbol k, and shall then have

$$q = k\ A\frac{\rho}{\eta} I \text{...........}(6)$$

Since the value of ρ/η for any definite liquid depends solely on temperature, it may be denoted by f' and obtained from tables with that argument. The constant k which varies only with different soils may then be formed from the equation

$$k = \frac{q}{f'IA} = \frac{U'}{f'I} \text{...........}(7)$$

U' denoting not *actual*, but *average* mean velocity of flow for the whole area A. Since for water ρ does not differ sensibly from unity—in regard to the general precision possible in the question under consideration—f' is sensibly equal to f in §7.[1] Thus a series of simple experiments will determine the values of the constants k for any classes of soil.

It may here be noticed that since the velocity of the permeable flow is also dz_2/dt we have from (6)

$$\frac{dz_2}{dt} = \frac{q}{A} = U' = k\frac{\rho}{\eta} I \text{...........}(8)$$

---

[1] For a table of accurate values of f see "On the steady flow of water etc."—Journ. Roy. Soc., XXXI., pp. 318 - 319, 1897; a paper by the author.

U' of course must be considered a variable, and therefore also I, in practical cases: k depends only on the class of soil.

11. *Percolation when interstices are not filled.*—The supposition that the interstices are filled with water can be made only when ground is completely saturated, a relatively rare condition. When the interstices are *not* filled the velocity is much less than would be given by expressions like (7), viz. $U' = kf'I$. In flow of this character, what is known as the 'hydraulic radius' of the flow, is diminished, and therefore the resistance to flow is increased. For as the quantity diminishes indefinitely, so the resistance similarly increases, and thus the dryer the soil, the slower the rate of motion of the percolating liquid. The rate at which water will flow downward into relatively dry soil, especially when the quantity is small, is much less than its rate when the soil is saturated.

Again, when there is any discontinuity in the liquid network, the phenomena of surface tension come into play, and finally the soil may contain water which is entirely prevented from moving downward under the action of gravity, by the relatively greater effect of molecular forces—that is those forces which come into play in surface-tension.

The effect of temperature, decidedly sensible as regards viscosity, is relatively smaller in this respect. Since if T denote the surface tension at θ degrees Celsius, and T_0 that at the zero of the same scale, then

$$T = T_0 \,(1 - \cdot 002\theta) \ldots\ldots\ldots\ldots (9)$$

that is to say the effect here is considerably less than $\frac{1}{10}$ of the viscosity effect. The influence however is the same in kind; increase of temperature promotes flow, by diminishing both viscosity and surface tension. It is extremely doubtful whether 'partial interstitial flow' can, like 'full interstitial flow,' be made satisfactorily subject to rational mathematical deduction in cases such as are here considered; it will probably have to be experimentally determined, and expressed by purely empirical formulæ.

12. *Exhaustion of moisture in soil by percolation.*—Neglecting the by no means inconsiderable effect of vegetation, soil containing

water is exhausted either by evaporation alone, or by evaporation and percolation together. We consider the loss by percolation first. This will occur whenever the quantity of moisture is greater than what would be retained in position by surface-tension. Consider a horizontal stratum of soil cut away on one side, so that its water may drain off. Then for any defined conditions it is possible to compute the circumstances of flow, once the constant k for the soil is ascertained, provided the supply to the stratum is maintained, and if in the supply the question is not complicated by what I have called 'partial interstitial flow.' In actual cases where a porous soil is partially exhausted by draining—for it can be only *partially* exhausted in such a manner—the soil above that surface which marks the boundary between the portion where the interstices are filled with water and where they are not so filled, probably contributes afterwards only negligible quantities to the flow under the action of gravity: that is to say the greater part of the water left in the soil is sensibly held in suspension by surface-tension, and can be exhausted only by evaporation.

13. *Exhaustion of moisture by evaporation.*—Again neglecting vegetation, the external factors affecting the rate of evaporation from soil are:—solar radiation, temperature, the humidity of the air, and its motion. The quantitative efficiency of these are modified by conditions in the soil itself, *e.g.*, it fineness, its general nature as affecting the surface tension element, the presence of hygroscopic materials, of vegetation of course, and the amount of water it already contains. The first four elements may be fairly well measured; but their influence in promoting drying of the soil is not so readily evaluated.

14. *Solar radiation.*—Solar radiation raises the temperature of the surface of the soil, and a wave of heat is propogated downward at a rate depending partly on its conductivity, and partly on the possibility of energy being expended in other ways, as in the evaporation of contained moisture; the promotion of growth in vegetation, and so on. The intensity of this heat-wave rapidly diminishes, and finally becomes insensible within a few feet—4 or

5—from the surface. Part of the heat of the surface layer of soil is also abstracted by the heating of the superficial layer of air above it, and by the distributive effect of the resulting convection currents. It is easy to see, from the foregoing, what a significant part is played by solar radiation in exhausting the moisture of soil: it is that form of energy which contributes most directly and to the conversion of the moisture with aqueous vapour. Water vapour has a density as compared with dry air of only about 0·623 under the same conditions of temperature and pressure, so that even with saturated air at ordinary temperatures, this difference of density would promote considerable convectional motion, if not counteracted by commensurate resistances arising from the great interstitial surface-area of the soil. These resistances, however, are so great as to make the effect of mere difference of density probably negligible.

15. *Diffusion of aqueous vapour into the atmosphere.*—Relatively to the diffusion into the atmosphere of the aqueous vapour produced from the moisture in the soil, the difference-of-density element just considered is certainly negligible. As Graham's experiments clearly shew, porous substances, even when sufficiently dense to maintain as diaphragms very considerable differences of pressure between two gases, scarcely affect the rate of interdiffusion. The interstitial-surface resistance here therefore sensibly disappears, and obviously the drying of soil must be regarded as mainly dependent on the phenomenon of molecular diffusion. And since its rate, other things being equal, varies probably nearly as the square of the absolute temperature, the solar-radiation effect is important as regards the soil, not only in respect of the conversion of its water into aqueous vapour, but also, by increasing the temperature, in promoting diffusion as the aqueous vapour is produced.

16. *Effect of air temperature.*—The influence of the temperature of the air is at least twofold: on the one hand it affects the rate at which the heat in the soil is dissipated: and on the other it affects the rate of diffusion by altering the saturation value of the

air itself; since the quantity of aqueous vapour in saturated air is a function of the temperature. Regnault's beautiful researches furnish the necessary data for the determination of this total amount.

17. *Humidity and its influence.*—The rate of drying of a soil—depending as it has been said on diffusion—requires as the factors for its determination not only the soil temperature, but also both the air temperature, and either the *relative* or *absolute* humidity of the air; because of their reaction on the velocity of diffusion.

18. *Effect of Wind.*—The effect of atmospheric motion on the rate of drying is very striking, and is due to the acceleration of diffusion by the rapid removal of the layer of air highly charged with aqueous vapour, next to the soil; so that for the deductive determination of this rate, it is very necessary to take into account the velocity of wind on the surface. Mr. Deane, in his diagram, has made use of curves of evaporation, whose parameters were empirically deduced from the rates of evaporation of water. The tentative character of such a proceeding is, of course, fully admitted. It is not at all improbable that direct and convenient relations, as has been assumed, may be ascertained between these rates, and those of the drying of definite classes of soil under definite conditions; so that in place of a complicated function to determine drying, depending on radiation and on atmospheric temperature, humidity and motion, it may be possible to substitute an empirical, but sufficiently exact and relatively very simple one, depending merely upon the rate of evaporation of water, subjected of course to similar circumstances. This would greatly simplify the problem, and the investigation would be of value.

19. *General expression for the degree of saturation.*—The exhaustion of the moisture of a soil is dependent, we thus see, on drainage losses (p), and is a function of solar radiation (σ), air temperature (τ), humidity (μ), the coëfficient of diffusion between air and aqueous vapour (δ), and the velocity of wind (ω say). That is to say, the saturation of soil, neglecting the effect of vegetation, is represented in its entirety not merely by an expression like (4) but requires

also the inclusion of the terms just indicated. If we represent the rate of the loss of moisture from all causes by dz_3/dt, then the rate of saturation $d\zeta/dt$ say, is

$$\frac{d\zeta}{dt} = \frac{dz_2}{dt} - \frac{dz_3}{dt} \ldots\ldots\ldots\ldots(10)$$

and since this is affected by the circumstances of supply as well as of loss, the one reacting complexly on the other, we must put

$$\frac{d\zeta}{dt} = \psi'\left(t.\frac{dz}{dt}R.\theta.s.n.p.[\sigma.\tau.\mu.\delta.\omega]\right)\ldots\ldots\ldots\ldots(11)$$

in which, however, it may be possible, as I have said, from a purely practical point of view, to substitute for $[\sigma.\tau\,\mu.\delta.\omega]$ the rate of evaporation from water, $d\epsilon/dt$ say.

20. *Necessity for the study of elementary cases.*—The degree of saturation of the earth's surface to a sufficient depth to include all sensible effects on vegetation, is probably one of the best measures by which to determine the reciprocal of the intensity of drought. It is however not easy practically to assign this limit of depth,[1] and this is one of the real difficulties that will occur in applying the results of theoretical investigations and investigations made with well-defined conditions. It must be quite clear from the above discussion, and from the necessity of an expression like (11) to symbolically represent the facts, that the analysis even of elementary cases will be involved in no ordinary difficulty. By studying the reaction of the involved phenomena upon limited areas, whose surfaces, soils, and general circumstances are susceptible of somewhat exact definition, something like an intelligent general application of the facts learnt thereby *may* become possible, provided the range of conditions in the analysed cases be sufficiently wide. But short of such a study sound conclusions seem hardly possible. And, even with the elementary solutions to hand, it will be no easy task to apply them to the complexity of natural conditions. For example the very necessity of limiting our consideration to some particular depth, and the general

---

[1] See Bull. 121, Univ. Calif. Agric. Expt. Station—The Conservation of Soil Moisture, etc , by Hilgard and Loughridge, 1898.

uncertainty as to the laws governing this depth, very much increases the complexity of the problem.[1]

21. *Graphs representing natural phenomena.*—The absolute necessity for considering the *rate* of rainfall in attempting to ascertain what proportion is taken up by the soil, and how much runs away, has already been adverted to. It may incidentally be remarked, that the "run-off" from given areas, due to certain types and quantities of rainfall, is an unsolved problem of great practical importance, as civil engineers well know. In order to deduce these two elements, the 'intensity curve' of the rainfall, as it may be called, is as we have already said, required. Graphically this may be shewn by ordinates (OY) giving the values dz/dt, *i.e.*, *rate* of fall, with the abscissæ (OX) representing time, t. See Fig. 1. Thus in the illustrative figure the curve (1) represents a fall, at first gradually and then more rapidly increasing its intensity, reaching a maximum, then somewhat rapidly diminishing, afterwards very slowly, and finally ending rather abruptly. In curves of this type, where

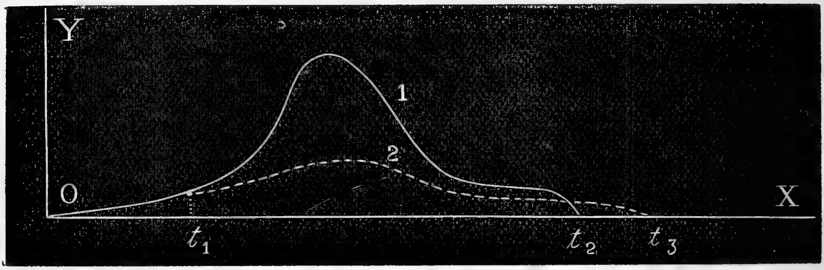


Fig. 1.

$$y = \frac{dz}{dt}, \text{ so that } dz = y\,dt \ldots\ldots\ldots\ldots (12)$$

we obtain the total fall in the unit of z—inches practically—by integration. Thus from (12) we have on integrating

$$z = \int_0^t y\,dt = A \ldots\ldots\ldots\ldots (13)$$

that is, the area A between the abscissa and the curve is the total fall. Similarly if the ordinates of curve (2), shewn by the broken

---

[1] In the paper previously referred to it is shewn that plants root more deeply in arid climates.

line, are the values dz_2/dt, that is of the rate of absorption by the soil, the curve would indicate that at first the whole fall—from the commencement of the rain till the time t_1—was absorbed: but that from that time on, only part was absorbed: and finally that absorption was going on, even after the rain ceased at the time t_2, owing to the fact that the water lying on the surface still contributed to the saturation of the soil right up to the time t_3. The quantity absorbed is determined by the area between curve (2) and the axis of abscissæ, and if there be no loss by evaporation or otherwise, the difference of these areas would give the quantity running away. These two curves serve merely to illustrate, in a most elementary way, the nature of the invesigation. Curve (1) is directly obtained by suitable observation of the rainfall: curve (2) is deduced from all relevant facts. The ordinates of the first are *independent* of one another: those of the second are not only *not independent* but they are also continuously dependent on all ordinates of the phenomena of which the instantaneous condition is the resultant.

22. *Natural phenomena to be observed.*—The following list of phenomena to be observed, includes those usually registered at meteorological stations and are all that are necessary for the computation of the saturation of a soil, as the measure of 'drought-intensity.' The abscissa in all cases is time: the ordinates should be as specified:

Rainfall	Ordinates	Rate of fall	dz/dt.
Air temperature	,,	Temperature	τ
Velocity of wind	,,	Velocity	ω
Humidity of air	,,	Humidity	μ
Solar radiation	,,	Temperature	σ
Evaporation of water	,,	Rate of Evap. $d\epsilon/dt$.	
Deposition of dew etc.	,,	Quantity (if necessary as materially affecting result).	

23. *General remarks.*—The careful study of the phenomena as affecting soils even under perfectly definite conditions would, as I have already said, be elaborate, but would doubtless throw con-

siderable light upon the possibility of reaching merely approximate, but sufficiently exact solutions for practical requirements in characteristically similar areas or at least of interpreting meteorological records therein. Speaking generally, all hope of attaining mathematical exactitude is quite utopian. The complexity of natural conditions is utterly beyond our mental grasp : the variety of character, condition, and configuration of soils—on the state of which vegetation is dependent—eludes all possibility of mathematical expression. And besides this the effect of weather itself in changing the character of soil in respect of the very thing we propose to solve, viz., its degree of saturation, is wholly unsusceptible of statistical definition.[1] The hope of attaining even a tolerably exact solution must therefore be regarded as illusory. The exact solutions of ideal cases would however afford so valuable a guide in an attempt to form numerical estimates of the resultants of meteorological phenomena, and even in interpreting them, as to fully justify their being undertaken. At the very least they will afford either definite hope that we shall better understand those physical conditions on which life and progress on this planet are ultimately dependent, or else will compel us to realize the futility of attempting to analyse conditions so complex as those which here present themselves. Either would be gain: if one might venture an opinion : the more hopeful view is the more probable.

Finally it ought to be said that what may be called the biological factors in the problem have not been yet adequately referred to. As has been said vegetation itself is a source of exhaustion of moisture on the one hand, and on the other it probably always assists the saturation of the soil when rainfall occurs. In a satisfactory solution its presence cannot be neglected, since it enters with a large factor into the determination of the relation between the amount absorbed and that lost. Human activity, in producing conditions which promote absorption, is also a factor of moment and cannot be ignored. Cultivated lands present distinct features

---

[1] For example :—The effect of frost in heating up the surface of a soil, and the cracking of the surface during hot and dry weather.

in this respect, and are not directly comparable with those which are uncultivated.[1] To deal with every variety of physical circumstances, and with meteorological phenomena which in no two places are exactly reproduced, is a task which may well exhaust the powers of the ablest meteorologist: it is only Ulysses who can bend Ulysses' bow. Still it must be confessed that a partial solution—which is the only one that ever will be possible—is better than none at all; and it is to be hoped that a solution on the lines suggested by Mr. Deane, and including such other data as may be found necessary will be attempted.

---

[1] See p. 11, Bull. 121 above referred to.

ON THE CRYSTALLINE CAMPHOR OF EUCALYPTUS OIL (EUDESMOL), AND THE NATURAL FORMATION OF EUCALYPTOL.

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

[*Read before the Royal Society of N. S. Wales, August 2, 1899.*]

IN August 1897, a paper was read before this Society by Mr. R. T. Baker and myself,[1] in which was announced a crystalline camphor or stearoptene isolated by us from the oil of *Eucalyptus piperita.* The specimens then shown only consisted of a few isolated crystals as the camphor does not appear to exist in quantity in the oil of this species. At that time no investigation could be undertaken to determine its constitution, it being obtainable in such minute quantities, but it was thought that it must be a constant constituent in these oils, and that it might be obtainable from other species of Eucalypts in larger quantity.

This surmise was correct, as the camphor has been found to be present in the oils of several species of Eucalyptus, and as will be presently shown, should be isolated, at certain times of the year, from the oils of all those species of Eucalypts whose ultimate constituent is eucalyptol. The results so far obtained in reference to this camphor may assist somewhat towards a more complete knowledge of the chemistry of Eucalyptus oils, and help to explain the differences, found at certain times of the year, in the constituents of the oils of this genus. The differences found existing in the several members, apparently made a correct expression of opinion in reference to them exceedingly difficult, but as our knowledge increases these difficulties partly disappear, and the explanations that can now be given considerably simplify the study of these trees. In the determination of the chemical constituents of the several species of Eucalypts, we have a check

---

[1] On the Essential oil and the presence of a solid camphor or stearoptene in the "Sydney Peppermint" *Eucalyptus piperita.*

upon their botanical diagnosis, as the chemical constituents of each species appear to be identical under certain conditions, and governed by laws that will eventually be better understood. A large number of facts have accumulated, without exception supporting this statement, and will later be published. It is hoped that by working on material of undoubted authenticity the results may be of permanent value from a commercial as well as a scientific standpoint, and I wish to express my thanks to my colleague, Mr. R. T. Baker, F.L.S., for the botanical diagnosis of the species.

The presence of the camphor, and the natural formation of Eucalyptol.

The oil of *Eucalyptus goniocalyx* was found to be exceedingly rich in eucalyptol, and the presence of eudesmol was very marked. Dextropinene was also present, the oil somewhat resembling, in colour and constituents, that of *E. globulus* and belongs to the same group of trees giving like oils. Phellandrene could not be detected, nor was any to be expected, because in the oils of this class, already determined by me, no phellandrene could be found.

The oil of *Eucalyptus Smithii*[1] was found to be richer in eucalyptol than any oil yet obtained during this research. Eudesmol was present in the oil obtained from the leaves of two consignments, a month separating the dates of the collections, (August and September 1898, from Monga N.S.W., yield of oil 1·345 per cent., mean of four distillations). Dextropinene was present in this oil, and the specific rotation of the rectified oil was $[a]_D + 7{\cdot}01°$. The constituents which give the oil of *E. globulus* its comparatively high specific gravity were largely absent in this oil, the consequence being that rectified oil of this species, representing 92 per cent. of the crude oil, and containing over 70 per cent. of eucalyptol, only just satisfies the specific gravity requirements of the new British Pharmacopœia, and has a less specific gravity than many other oils containing considerably less eucalyptol; again illustrating the weakness of the specific gravity

---

[1] See paper by Mr. R. T. Baker, "On three new species of Eucalyptus." —Proc. Linn. Soc. N. S. Wales, June 28, 1899.

standard as fixed. The oils from these two consignments of *E. Smithii* were identical in all constituents, equally rich in eucalyptol and the specific gravity, optical rotation, &c., were practically the same in both. Phellandrene was of course absent.

The oil of a species of eucalyptus, locally known as "Sallow" or "Swamp Gum" and named by my colleague (Mr. Baker) *Eucalyptus camphora (loc. cit.)*, was rich in eudesmol at the time of year when the leaves were obtained, (2nd September 1898). On redistillation of the crude oil a fraction was obtained, representing 18 per cent., boiling between 280° and 290° C., which in less than one hour had solidified into a solid crystalline mass in the bottle, and which after nine months remains unaltered. The first fraction of this oil contained at that time 33 per cent. of eucalyptol and a large percentage of the pinenes, but had less than 1° of rotation to the right in a 100 mm. tube. Phellandrene was absent.

Besides the species enumerated above, eudesmol has been found by us in the oils of several other Eucalypts that were rich in eucalyptol at the time of distillation, as *E. stricta*, *E. elæophora*, etc., but, *so far eudesmol has not been found in the oil of any species in which eucalyptol is absent, or only present in traces*, as *E. dives*, *E. radiata*, *E. dextropinea*, *E. microcorys*, *E. lævopinea*, *E. Dawsonii*, and many others, and it has not been found to be present in any oil without a fair percentage of eucalyptol being present also.

Having considered the oils of those species of eucalyptus found to be rich in eucalyptol, containing eudesmol, and in which phellandrene is absent; we turn to those oils in which phellandrene is present at certain times of the year, and which also contain eucalyptol and nearly always eudesmol.

The oil of the "Red Stringybark" *Eucalyptus macrorhyncha*, when first distilled appears always to contain eudesmol, but in greater abundance at certain times of the year. Eucalyptol is always present; phellandrene can usually be detected; and when the oil is most abundant in the leaf lævopinene is present also.

In the spring time phellandrene appears in greatest amount in the oil of this species, while in the autumn it is almost or quite absent. As the phellandrene diminishes in this oil, the eucalyptol increases in quantity, other alterations also taking place. In a paper[1] by Mr. Baker and myself, published July 1898, analyses are given of the oil of this species, in which a good quantity of eudesmol had been found. A reference to that paper will shew that only about 48 per cent. distilled below 183° C., and that the oils contained a fairly large fraction boiling above 268° C. consisting largely of eudesmol. It was from the high boiling constituents of this oil that the eudesmol was obtained for the purpose of this research. On opening some months afterwards, the glass stoppered bottle in which the crude oil had been stored, it was found that there had been absorption of the oxygen from the air filling the vacant space above the oil, there being apparent suction on the stopper of the bottle; little notice was taken of this at the time, but the same thing having occurred again investigation of the contents was made to determine if possible the result of the alteration. It was then found that the greater portion of the high boiling fraction containing the eudesmol had disappeared, and that the oil had become much richer in eucalyptol. The following is the analysis of this oil after having been kept in the crude condition for nine months. No pinenes were found, nor could phellandrene be detected. On redistillation only a few drops came over below 170° C., but between that temperature and 175·5° C. 27 per cent. had distilled, and by 182·8° C. 74 per cent. had been obtained against 48 per cent. distilling below 182·8° C. when originally investigated. The fractions were divided as follows:—

Below 175·5° C. = 27 per cent. = First fraction
Then to 182·8° C. = 47 ,, = Second ,,
,, 268·6° C. = 10 ,, = Third ,,
,, 276·8° C. = 11 ,, ... Fourth ,,

The fourth fraction only contained eudesmol in very small quantity at this second distillation, and only crystallised on long standing.

---

[1] On the Stringybark Trees of N.S. Wales—Proc. Roy. Soc. N.S. Wales, July 6, 1898.

Specific gravity, First fraction = ·9124 @ 15° C.
" " Second " = ·9164 "
" " Third " = ·9188 "
" " Fourth " = ·9446 "
" " Crude oil = ·9307 "

$[\alpha]_D + 2{\cdot}33°$ for first fraction and $[\alpha]_D + 2{\cdot}14°$ for second fraction.

Eucalyptol First fraction = 68·5 per cent.
" Second " = 71·1 "

Originally the mean of several determinations of first and second fractions gave 51 per cent. of eucalyptol.

It will be seen that the first fraction is almost as rich in eucalyptol as the second, and this is also found to be the case in those oils that are exceedingly rich in eucalyptol at time of distillation, *E. Smithii* particularly.

From these results it is apparent that by the alteration of the high boiling constituents, marked changes have taken place. The rotation has become more dextrorotatory, the specific gravity of the lower boiling fractions has increased, the increase in eucalyptol content is most marked, and the eudesmol has practically vanished.

The investigation of the oil of *E. eugenioides* further emphasises the specific alteration undergone by this class of oils on keeping in the crude state under certain conditions. This oil is that marked No. 2 of *E. eugenioides* in the paper previously referred to (the Stringybark trees of N. S. Wales). Unfortunately a full investigation was not made of that particular oil at the time, but enough data are given to determine the direction of change. The same absorption of oxygen was apparent as in the oil of *E. macrorhyncha* and the alteration of the constituents was in the same direction as found in that oil. No eudesmol was originally detected in this oil, but there appears little doubt but that it should be found, if carefully sought for, as it exists in other oils of the class to which this species belongs, viz.:—*E. macrorhyncha*, *E. piperita*, and *E. amygdalina* (not the species from which much of the supposed "amygdalina oil" that has been sent to Europe under that name was obtained, as the tree from which this so-called "amygdalina oil" has been distilled, is now proved by botanical characters and chemical evidence to be specifically distinct from *E. amygdalina* of Labillardière, and is *Eucalyptus dives* of Schauer, which species was founded on immature trees).

On redistilling this sample of the oil of *E. eugenioides* after nearly two years, 5th July, 1899, 96 per cent. distilled below 182° C., the fraction being very rich in eucalyptol. The crude oil which originally only contained 28·4 per cent. of eucalyptol, now contained 62·5 per cent. eucalyptol, a marked increase. The rotation had changed but little in this oil, being slightly more dextrorotatory ($[a]_D + 5{\cdot}5^\circ$) than when originally determined. The specific gravity of the crude oil was ·9171 @ 15° C., and of the large fraction ·9127 a slight increase on that of the crude oil.[1]

In the alteration of the other sample of the oil of *E. eugenioides*, marked No. 1 in paper referred to, we are able to show the necessity of a small quantity of oxygen to bring about the desired change in the formation of eucalyptol. After the completion of the original investigation on these oils, the crude oil remaining was stored in the dark with other oils, and remained untouched for nearly two years. A marked improvement in the eucalyptol content having taken place with the oil, No. 2 sample of *E. eugenioides;* investigation of oil No. 1 was then made, with the result that the same alteration had not then taken place with this oil as in that of No. 2, it was but little richer in eucalyptol than when first distilled, containing then under 40 per cent. eucalyptol. It appeared only possible to account for this discrepancy by the fact that the bottle containing No. 1 oil was quite full when put away, whereas the bottle containing No. 2 oil was less than half full and besides had been opened two or three times during the time. This pointed to the fact that oxygen was necessary to bring about the

---

[1] The temperature at which the original specific gravity was given in the paper is 22° C. This can be readily corrected, as by a determination of a Eucalyptus oil at all temperatures between 10° C. and 22° C. it was found that the increase below 15° C. and the decrease above that temperature was almost identically ·00075 for every degree of temperature, water at 15° C.

change. To test the accuracy of this surmise the oil No. 1 was transferred to a large bottle which it only half filled, and by occasionally shaking and removing the stopper, change soon commenced; so much so, that in two weeks the improvement in eucalyptol could be readily detected, and on the expiration of one month the oil was analysed with the following result:—

On redistillation only a few drops came over below 167° C., by 170° 4 per cent. had been obtained; between that temperature and 176·5° there distilled 70 per cent., and at 181° 88 per cent. had come over. The oil distilling between 171° and 181° was taken as one fraction. This was slightly yellowish in tint, but brilliant in appearance and had a pleasant odour and taste. The specific gravity of the rectified oil was ·9102 at 15° C., specific rotation $[\alpha]_D + 3{\cdot}85°$ and it contained 58 per cent. of eucalyptol. The crude oil had a specific gravity ·9202 at 15° C. (an increase in specific gravity on original determination), specific rotation $[\alpha]_D + 4{\cdot}5°$ (a slight dextrorotatory increase) and contained at this time (31·7·99) 55 per cent. of eucalyptol, an increase in eucalyptol of nearly 24 per cent. from time of distillation from the leaves, and an increase in eucalyptol of about 15 per cent. in one month by alteration under the conditions described. It is evident that the change is not yet completed in this oil, but more time could not be given, and another analysis will be eventually made. It will be observed that the other sample of the crude oil of *E. eugenioides* contained 62·5 per cent. of eucalyptol, equal to about 65 per cent. in the rectified portion, as the maximum of alteration. The maximum content of eucalyptol in the rectified portion of any Eucalyptus oil appears to be about 70 per cent. (the fraction representing about 80 to 85 per cent. of the whole), and although this amount of eucalyptol is very rarely found to be present, yet it appears that on natural alteration of oils like *E. macrorhyncha*, *E. eugenioides*, etc., this standard may be reached by judicious management. It may be that eventually we shall obtain complete control of these results, and that the oil from prolific yielders will be made to reach this standard.

From the results of the oil of *E. eugenioides* it is seen that the formation of eucalyptol in the crude oils of this class does not apparently take place without oxygen being present. How much oxygen is necessary to bring about the maximum change is a problem to be solved.

In the paper on *E. piperita (loc. cit.)* eudesmol, eucalyptol 26 per cent., and phellandrene were shown to be present in the oil at the time of distillation. It is possible in the oil of this species to show the result of alteration in the formation of eucalyptol while in the leaf. On 26th July 1898 (the end of our Australian winter) a consignment of the leaves of *E. piperita* was received from Currawang Creek, near Braidwood, N. S. Wales, the oil of which on analysis contained no phellandrene, and the presence of an extraordinarily large amount of eucalyptol was found, but no eudesmol could be detected at that time. The oil on redistillation gave a fraction boiling between 172° and 180° C., representing 75 per cent. of the crude oil, which fraction had a specific gravity ·915 at 15° C., specific rotation $[a]_D + 3{\cdot}66°$ and contained 70 per cent. eucalyptol. The rectified oil is almost colourless, exceedingly brilliant in appearance and as rich in eucalyptol as any; it resembles the oil of *E. macrorhyncha* and other first quality oils of this class. In appearance, taste, odour and eucalyptol content, the oils of this class of Eucalyptus, when obtained under correct conditions are of superior quality, and it appears that by taking advantage of known natural alterations in the constituents of these oils, or by keeping the crude oils under certain conditions until the maximum alteration has taken place, that we may govern the formation of the constituents required, even if we do not succeed eventually in bringing about the required alteration at once by artificial means.

From the consideration of the facts enumerated above, it appears certain that the Eucalyptus camphor (eudesmol) is an intermediate product in the natural formation of eucalyptol, and as such is not to be expected to be present always in constant proportions. It will be shown presently that the formula of eudesmol is $C_{10}H_{16}O$

and that it is isomeric with ordinary camphor, but has no rotation.

Eucalyptus globulus belongs to a group of Eucalypts, of which we have several in this colony, the oils of which have great resemblance to each other and when distilled are always rich in eucalyptol, they contain dextropinene in varying quantities and are free from phellandrene. In this group the alteration of the constituents through eudesmol to eucalyptol is rapid and but little reserve material of high boiling constituents is stored in the leaf, although both in the case of *E. goniocalyx* and *E. Smithii* eudesmol was found. It is probable for this reason that phellandrene is found to be always absent in the oils of the globulus group, which on distillation appear to generally contain nearly their maximum amount of eucalyptol, and therefore undergo little alteration on keeping. In those oils like *E. macrorhyncha*, *E. piperita*, *E. eugenioides*, etc., which contain a fair percentage of eucalyptol, and mostly some phellandrene, the change is not usually completed at time of distillation, and we can thus trace the process of alteration of the constituents and the formation of the ultimate product, eucalyptol.[1] In the redistillation of those oils under atmospheric pressure, besides the water always given off at about 100° C., it is found that water is again always split off from the constituents boiling at a high temperature particularly that fraction containing eudesmol. The constitution of eudesmol indicates that the oxygen atom is attached to the molecule previous to the formation of eucalyptol. Which particular terpene is necessary to this formation of eucalyptol is uncertain, but phellandrene cannot be detected when the apparent maximum of alteration has taken place. It is found that the pinene present in the oils of the group of Eucalypts to which *E. macrorhyncha* belongs is always lævopinene, whereas in the oils of the globulus group the pinene always appears to be dextropinene, and the indication thus is that it is the lævo-terpenes

---

[1] In this paper I have not dealt with that group of Eucalypts whose oils consist very largely of phellandrene, nor those whose oils consist very largely of pinene.

that are necessary to this alteration, and this probably accounts for the fact that the oils of the globulus group are always dextrorotatory, as it is found that when the maximum of eucalyptol has been reached in the oils of *E. piperita*, *E. macrorhyncha*, etc., that the oils are always dextrorotatory, and in about the same proportion as is found in the oils of the globulus group. As a result of experiments on the terpenes, by Armstrong and Tilden ;[1] they arrive at the conclusion that American turpentine contains a substance which either has a less dextrorotatory power or is lævorotatory, and which is more readily polymerised than its chief constituent. This also appear to be the case with the pinenes of Eucalyptus oils.

If eudesmol is the intermediate stage in the formation of eucalyptol, we ought to find that those oils which have been found to contain eudesmol in quantity should, at certain times of the year, become rich in eucalyptol, and that has been found to be so. The oil of *Eucalyptus camphora* distilled from material sent from Delegate, Feb. 1899, was found to be rich in eucalyptol, the oil much resembling that of *E. globulus*, eudesmol was only present in small amount at that time of the year. This is probably the case with *E. Smithii* also, and it is to be expected that the oil from this tree will be found rich in eudesmol at certain times of the year, as when distilled only a small quantity was present, but the maximum eucalyptol had been practically reached at that time, and 97 per cent. was obtained on redistillation boiling below 180° C. so that the constituents boiling at a high temperature were practically absent. The crude oil had almost the same specific gravity as the large fraction, and the first portion distilling was almost as rich in eucalyptol as the last portion.

EXPERIMENTAL.

Preparation of the pure Eudesmol.

The oil of *Eucalyptus macrorhyncha* was taken for the preparation of this camphor, but any oil rich in eudesmol, as *E. camphora*, would do as well. The constituents boiling below 188 – 190° C.

---

[1] Chem. Journ., xxxv., 733.

were removed by distillation from the crude oil, and the remainder (about 40 per cent.) poured from the still into shallow glass vessels and left a few days to crystallise. It then formed a soft crystalline mass of the consistency of butter. This was then spread upon porous plates to absorb the fluid portions. This was found to be important as a very small quantity of adhering terpenes makes subsequent purification difficult. When the adhering oil had been absorbed a whitish product was obtained. This was dissolved in alcohol, water added until slight turbidity remained, and left in open vessels to crystallise. This was found the better way as by adding excess of water an oily product was obtained very difficult to crystallise. On standing a day or two the camphor crystallised, this was removed as a cake, the mother liquor being used for a further crop of crystals. The adhering liquid was removed by porous plates and the process repeated until a perfectly snow-white product was obtained, having the correct melting point 79 – 80° C.

The crystalline substance is quite white, silky in lustre, and beautiful in appearance. It is very soft and inclining to a paraffin nature, the crystals are fairly well developed, acicular, and when sufficiently transparent to allow light to pass, polarize partly in colours, and extinguish parallel. Only a comparatively small amount of crystals could be obtained of this nature, the remainder on purification consisting of small interlaced crystals giving the product a matted appearance. In its purified state it is exceedingly light. When the fraction containing the eudesmol was first obtained from the oils of *E. macrorhyncha* and *E. camphora* it was thought that we might obtain the camphor in good quantity, as the faction crystallised into a solid mass on standing, but this was more apparent than real, as when purified only a comparatively small amount of eudesmol had been obtained, and it would be necessary to distill a very large quantity of oil to enable one pound of pure eudesmol to be obtained.

Eudesmol is insoluble in water and alkaline solutions. It is soluble in chloroform, petroleum ether, ether, alcohol, glacial acetic acid (crystallises out again on adding water), acetone, benzene, olive oil and oils generally. The volatile solvents all leave the eudesmol in a crystalline condition on evaporation, either at once or crystallisation soon takes place on standing.

Melting Point.

Perfectly purified eudesmol melts at 79 – 80° C. The crystallised substance from dilute alcohol, from acetic acid, and the sublimed material, all melted at that temperature, and by no method of purification was 80° C. exceeded. The tendency to give lower melting points was most troublesome, necessitating many scores of determinations on different material. Minute portions of the high boiling terpenes are prone to be retained, and these lower the melting point considerably. The best method of taking the melting point was found to be as follows :—the camphor was melted at the lowest possible temperature, and a portion drawn into a capillary tube and allowed to perfectly crystallise again in the tube; 3 mm. of the column was then retained; the tube was attached to the thermometer and suspended in water which was slowly heated. The substance was considered to have reached its melting point at the instant when it began to rise in the tube.

Sublimation.

Purified eudesmol, melting at 79 - 80° C. was taken. This sublimed readily, care being taken to keep the upper glass cool; fine crystals of a good length were obtained. Is was found that when the sublimation was carried out at the lowest possible temperature, that the sublimate melted at the same temperature as at first, but that if heated too much, the melting point of the sublimate had been lowered; this was found to be the case under all conditions, the tendency being to form substances having a lower melting point. Sublimation takes place at a little above 100° C.; a distinct sublimate was obtained by heating in a tube closed at one end when suspended in boiling water for some time.

The melting point of the sublimate being lowered by overheating, an attempt was made to determine at what temperature this decomposition commenced. A small U tube was taken with one limb a little longer than the other, and the end of the longer limb closed. A small portion of eudesmol was then melted in the closed end and the remainder filled with mercury; this was attached to a thermometer and the whole immersed in glycerol. On heating it was found that slight decomposition commenced at about 180° C. and continued to slowly increase until 250° C. had been reached, when the determination was stopped. No alteration, therefore, takes place at 150° C., and eudesmol sublimes readily below that temperature.

Rotation.

Eudesmol has no rotation; 2·5 grams dissolved in 50 grams of alcohol had no action on a ray of polarised light in a 200 mm. tube.

Analysis of Eudesmol.

The material was melted in the platinum boat at the lowest possible temperature. Results of five of the determinations made are given—

0·1725	gave	0·5006 CO_2	and	0·1764 H_2O.	C. = 79·13;	H = 11·36
0·2324	,,	0·6704 ,,	,,	0·2294 ,,	,, 78·66;	,, 10·97
0·1962	,,	0·5646 ,,	,,	0·1951 ,,	,, 78·44;	,, 11·06
0·1611	,,	0·4657 ,,	,,	0·1622 ,,	,, 78·83;	,, 11·17
0·1608	,,	0·4624 ,,	,,	0·1614 ,,	,, 78·42;	,, 11·15

$C_{10}H_{16}O$ requires 78·94 C., and 10·53 H. per cent.

Mean of the above analyses C = 78·7 and H = 11·14 per cent.

The material used for determinations Nos. 4 and 5 was that previously used for the molecular determination; it was regenerated from the acetic acid solution by the addition of water.

Molecular determination.

The molecular determination was made by the cryoscopic method, glacial acetic acid being used.

Eudesmol taken = 0·3855 gram.
Acid = 29 grams.
Acid alone, first time freezing = 5·56°
,, ,, second ,, ,, = 5·54°
,, ,, third ,, ,, = 5·53°

After solution of the eudesmol

First time freezing = 5·22°
Second „ „ = 5·185°
Third „ „ = 5·185°
∴ Molecular value = 150
$C_{10}H_{16}O$ = 152

Di-nitro compound.

On the addition of strong nitric acid to eudesmol, little change takes place at once in the cold. After a little time it darkens somewhat, the eudesmol becoming liquid and changing to a purple colour. On gently heating until reaction commenced, the colour changed at once to yellow with rapid solution of the substance and evolution of dark brown fumes. After about fifteen minutes the action apparently ceased and if kept cool no more brown fumes escaped. On addition of water a yellow crystalline mass was at once formed. The filtrate remained yellow. The nitro-compound is slightly soluble in cold water, more readily in hot water. It is soluble in alkaline solutions and reprecipitated on acidifying. It was purified from alcohol. When dry it is of a primrose colour. It is soluble in alcohol, ether and acetone, but does not form a well defined crystalline substance with these solvents. It melts at 90° C., but changes to a deep orange colour at 75° C.

A determination of the nitrogen gave results as follows :—

Material taken = ·1147 gram.
Moist nitrogen obtained = 11·5 cc.
Barometer = 767 mm.
Temperature of gas = 16° C.
∴ Nitrogen = 11·8 per cent.
$C_{10}H_{14}(NO_2)_2O$ requires nitrogen 11·57 per cent.

Dibromide.

The purified eudesmol was dissolved in a small quantity of glacial acetic acid and bromine added. This was readily and quietly absorbed, no substitution taking place. The bromide is an addition product. The rise of temperature was prevented as much as possible. The bromide soon separated as a semi-solid substance especially on shaking and adding a few drops of water. The bromide was then boiled repeatedly with water, with very dilute potash solution, and with dilute alcohol. It was then purified from chloroform, and as it did not form a well defined crystalline compound it was again boiled with water and with dilute alcohol. When cold it was a plastic mass, sufficiently hard to rattle like shot in a bottle. It is of a yellowish-brown colour. It is exceedingly soluble in chloroform and in ether, but difficultly soluble in alcohol, and not at all if the alcohol be at all dilute. It melts at 55° to 56° C.; the melting point was taken with minute spheres on the surface of mercury; with the aid of a lens the exact melting point was readily seen.

A determination of the bromine in 0·2008 gram of the bromide gave 0·2470 AgBr. = 0·1051 Br = 52·34 Br per cent.

$C_{10}H_{16}Br_2O$ requires 51·3 Br per cent.

Eudesmol does not apparently form a nitrosochloride, as amyl nitrite in acetic and hydrochloric acids failed to react, no crystals being obtained even on long cooling to – 10° C.

When eudesmol was treated with phenylhydrazine no alteration of the original material took place.

It was not possible to introduce other hydrogen atoms into the eudesmol molecule by ordinary methods. When a solution in alcohol was treated with sodium no alteration took place, the regenerated material being identical with that taken. Several other methods were tried but without effect. It appears, therefore, that the oxygen atom is not ketonic, as eudesmol cannot be reduced to an alcohol. This coincides with the known peculiarities of eucalyptol as that substance does not apparently contain an hydroxyl group, so that the remaining H_2 required to form eucalyptol from eudesmol must be attached to the molecule of the latter in another way. Alcoholic potash effects no alteration in eudesmol even on boiling for a long time.

Oxidation.

On heating eudesmol with dilute nitric acid, energetic action took place with evolution of brown fumes, and rapid solution of the camphor. On continued boiling no crystalline product was obtained. The acid solution was boiled continuously for two days, and even then no crystalline product was obtained. On addition of water no precipitate was formed. The nitric acid was removed by evaporation, and to the small quantity remaining, still in solution, water was added; a minute quantity of a camphoraceous substitute was obtained, but no crystals were precipitated. This camphoraceous substance does not appear to be the unaltered material, as it melted below 40° C. The filtrate was evaporated to dryness on the water bath, water again added, filtered, and this process repeated a few times. The filtrate on again evaporating to dryness crystallised in microscopic crystals on standing. These crystals were soluble in cold water to an acid solution, which on addition of barium chloride and ammonia gave no precipitate in the cold, but on boiling a precipitate was soon obtained. This was filtered off, washed, treated with hydrochloric acid and the solution agitated with ether. On evaporation of the ethereal solution the residue showed microscopic crystals, this was again crystallised from water. The product was a mass of microscopic needles resembling camphoronic acid. No oxalic acid was obtained. To be sure the crystals were camphoronic acid, that acid was formed from ordinary camphor in the usual way, and treated under exactly the same conditions; the product resembled in every respect that obtained from eudesmol, with the exception that the melting point of the product from eudesmol (165 – 168°C.) was a few degress higher than that from camphor, and that on repeated crystallisation rather better defined crystals were obtained with the acid from eudesmol. From the results by Aschan[1] and by Perkin and Thorpe it is shown that the *i*-camphoronic acid melts at a higher temperature than either *d*- or *l*- forms, and that the *i*- acid has better defined crystals. It thus seems that the acid derived from eudesmol will be found, when sufficient shall have been obtained, to be *i*-camphoronic acid. Eudesmol is readily oxidised by chromic acid. The oxidation products of eudesmol

---

[1] Ber. 1895, XXVIII., 16 and 224.

are interesting and the want of material has alone prevented me completing their investigation at this time, but I hope to continue the research later. The nitro-compound is also worthy of further inquiry.

On fusing eudesmol with potash at 180° C., the volatile acid obtained on acidifying with sulphuric acid and distilling was acetic acid. No iso-butyric acid was detected.

Theoretical Considerations.

The isolation of eudesmol from several members of the "globulus group" of Eucalypts, (those species whose oils are rich in eucalyptol at time of distillation), the natural alteration of the eudesmol fraction from oils like that of *E. macrorhyncha* with the corresdonding formation of eucalyptol, and the other facts described in the body of this paper, show eudesmol to be intermediate in the formation of eucalyptol in Eucalyptus oils.

Eudesmol has a formula $C_{10}H_{16}O$, is isomeric with camphor, and contains two atoms of hydrogen less than eucalyptol.

The ease with which eudesmol forms a di-bromide as an additive compound (attempts to form a higher bromide were not successful), indicates that the molecule is unsaturated, but that the linking must be different from the double linking of the terpenes is shown by eudesmol not forming a nitrosochloride. The pinenes of Eucalyptus oils readily form nitrosochlorides. Eudesmol not reacting with phenylhydrazine indicates that the oxygen atom is not ketonic, but that it is combined in the molecule in some other way. The non-success in all attempts to introduce hydrogen atoms into the eudesmol molecule by ordinary methods, and its inertness to the action of sodium generally, makes it appear probable that the oxygen atom is combined to more than one carbon atom. It may be that cymene plays some part in the formation of eudesmol. Cymene has been shown to occur in the oil of *E. globulus*[1] and thus in other Eucalyptus oils, because *Eucalyptus globulus* is only one member of a class whose oils are identical in composition.

---

[1] Faust and Homeyer, Ber. VII., 1429.

Cymene is closely connected with the pinenes, and has been shown to contain iso- and not normal propyl.[1] It may be too that dipentene takes some part in this alteration. Eucalyptol, which is identical with cineol,[2] appears not to be either a ketone or an alcohol, as it does not combine with hydroxylamine or phenylhydrazine. It is not attacked by sodium nor by benzoyl chloride below 120°.

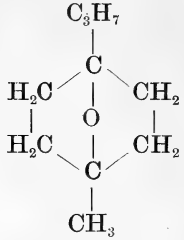
The results of this investigation on eudesmol point to a structure allied to that of eucalyptol, but containing two atoms less of hydrogen. The oxygen atom of eucalyptol enters the molecule during the formation of eudesmol, and if cymene be the structure upon which eudesmol is built, then the two added hydrogen atoms enter the molecule at the same time as the oxygen atom. When those Eucalyptus oils which contain a farly large percentage of high boiling constituents are distilled under atmospheric pressure, the fraction boiling above 250° C. almost in every case splits off a portion of water, and it thus appears that water is present in fairly loose chemical combination with the constituents which compose the high boiling portion of the oils. That it is this water, or its elements, that assists in the formation of eucalyptol appears certain, if it is not so, then it is difficult to account for the formation of eucalyptol in those Eucalyptus oils when kept in their crude condition in a closely stoppered bottle, or to account otherwise for the increase in them of from twenty to thirty per cent. of eucalyptol. That the alteration is from higher boiling constituents to those boiling at a lower temperature is shown in the analyses given, and this must necessarily be so if eucalyptol is the final product as supposed. It has been shown by the investigation on the oil of *E. eugenioides* that oxygen is necessary to start this change. That the increase in eucalyptol content means also a diminution of certain of the terpenes has also been shown.

---

[1] Widman, Ber. xxiv., 439.

[2] The name eucalyptol has been retained in this paper to indicate the precise origin of the material, Eucalyptus oils. It may be that cineol found in the Melaleucas may have a like origin as both genera belong to the N.O. Myrtaceæ.

Cineol, and therefore eucalyptol, was supposed by Brühl[1] to contain no double linkings, and owing to its optical inactivity, and for other reasons, he suggested for it the following formula :



The oxygen atom entering the molecule during the formation of eudesmol, that substance must have a formula corresponding to eucalyptol. Eudesmol has no rotation, so that it probably does not contain an asymmetric carbon atom, or that the molecule has a racemic modification. It is difficult to depict for eudesmol a corresponding structure to cineol, having one double linking on the terpene type, without the presence of an asymmetric carbon atom which would indicate activity.

After arriving at the composition of eudesmol and having determined its close connection with eucalyptol, it appeared to me, on considering its reactions, that the difficulty might probably be met by suggesting the quadrivalence of the oxygen atom, as this appears to be in a different state of combination in both eudesmol and eucalyptol than is found to be the case in any allied substance. The question of the valency of an oxygen atom under certain conditions has also been considered by others.

Brühl[2] advocated the quadrivalence of oxygen in hydrogen peroxide. J. F. Heyes[3] advocated the quadrivalence of oxygen in reference to some peroxides.

In a paper read before the Chemical Society on June 1st, 1899, on "The salts of dimethylpyrone and the quadrivalence of oxygen," by Dr. J. N. Collie, F.R.S. and Thomas Tickle, the authors are

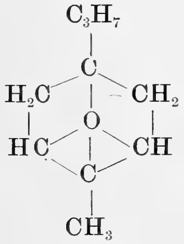
---

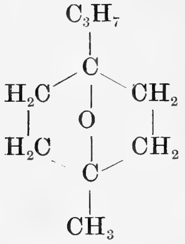
[1] Brühl, Ber. XXI., 461. [2] Brühl, Ber. 1897, XXX., 160

[3] Phil. Mag., 1888, XXV., 221.

inclined to believe that the constitution of these compounds is similar to that of the salts of nitrogenous and other bases. This, however, assumes that oxygen may behave as a quadrivalent element. In favour of this hypothesis, the authors instance such compounds as dimethyl ether hydrochloride, diethyl ether hydriodide, ether peroxide, etc.

If the oxygen atom in eudesmol be depicted as quadrivalent, then by taking Brühl's formula for eucalyptol the following constitutional formulæ might be suggested, considering iso-propyl present as in cymene.

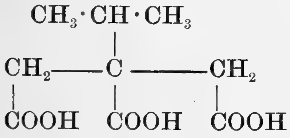

Eudesmol.


Eucalyptol.

This would necessitate the arrangement of the fourth affinity of the carbon atoms of the nucleus on the centric formula.

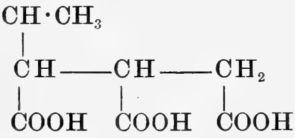
As eudesmol on oxidation with nitric acid gives camphoronic acid as one of its oxidation products, we may perhaps derive some assistance by considering the probable formula for that acid.

Bredt[1] from investigation of its salts considered camphoronic acid to be isopropyltricarballyic acid and to have the formula



$$\begin{array}{ccccc} & & CH_3\cdot CH\cdot CH_3 & & \\ & & | & & \\ CH_2 & — & C & — & CH_2 \\ | & & | & & | \\ COOH & & COOH & & COOH \end{array}$$

or



$$\begin{array}{ccccc} CH_3\cdot CH\cdot CH_3 & & & & \\ | & & & & \\ CH & — & CH & — & CH_2 \\ | & & | & & | \\ COOH & & COOH & & COOH \end{array}$$

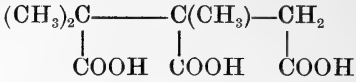
thinking the first of these the more probable.

In an important paper on the synthesis of *i*-camphoronic acid by Perkin and Thorpe[2] it is shown that camphoronic acid has the constitution of a trimethyltricarballylic acid of the formula

---

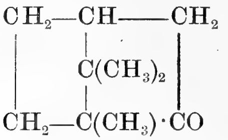
[1] Annalen, 1884, 226, 249 – 261.

[2] Journ. Chem. Soc., 1897, 1169.

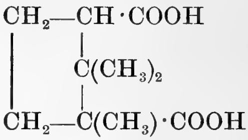


$$\begin{array}{ccc}(CH_3)_2C\text{———} & C(CH_3)\text{—} & CH_2\\ | & | & |\\ COOH & COOH & COOH\end{array}$$

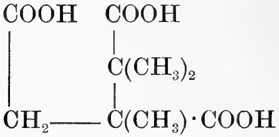
as was first suggested by Bredt[1] who represented camphor, camphoric acid and camphoronic acid as follows:—



Camphor.



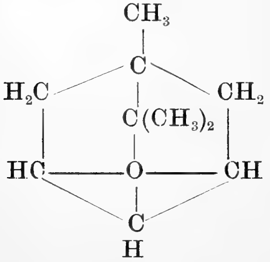
Camphoric acid.



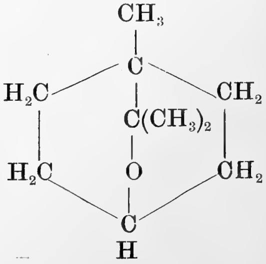
Camphoronic acid.

Eudesmol does not form the intermediate acid (camphoric acid) on oxidation with dilute nitric acid, but camphoronic acid, again indicating that the molecule of eudesmol differs from that of camphor. If we consider eudesmol to be in agreement with Brühl's formula for eucalyptol, the camphoronic acid derived from it would require to be depicted as isopropyltricarballylic acid.

If we accept Bredt's formula for camphoronic acid to be trimethyltricarballylic acid, and which formula is supported by the synthetical production of Perkin and Thorpe, then Brühl's formula for eucalyptol cannot be considered to be correct, and eudesmol will require to be constructed in a form corresponding somewhat with Bredt's formula for camphor, but with the oxygen atom attached to more than one carbon atom, as follows:—



Eudesmol.

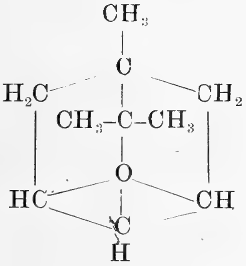


Eucalyptol.

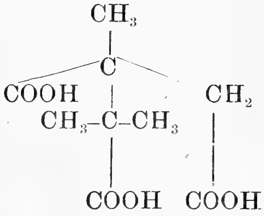
---

[1] Ber. 1893, xxvi., 3049.

The comparative ease with which oxidising agents act upon the eudesmol molecule, together with its instability, denote its susceptibility to attack, the tendency evidently being for the oxygen atom to become divalent, or in its most stable form. If we accept the possibility that the first action of the oxidising agent is to destroy the symmetry of the molecule by attacking it in its weakest point, the oxygen atom becoming attached to one of the three lower carbon atoms, then the chain would be broken and camphoronic acid as trimethyltricarballylic acid could be constructed from eudesmol.



Eudesmol.



Camphoronic acid.

DIVISIONS OF SOME ABORIGINAL TRIBES, QUEENSLAND.

By R. H. Mathews, L.S.

[*Read before the Royal Society of N. S. Wales, August 2, 1899.*]

Last year I contributed two articles to this Society dealing with the social organisation and geographic boundaries of some of the native tribes of Queensland.[1] On the present occasion it is proposed to furnish similar information respecting a few other tribes whose country adjoins that of the communities treated of in my previous papers.

I shall commence with the Wonkamurra, Yandrawontha, Yowerawarrika, and allied tribes, who adjoin the Barkunjee nation on the north. Their hunting grounds are on the Lower Wilson River, Cooper's Creek, and part of the Diamantina, extending some distance within the South Australian frontier. The natives within this area are segregated into two phratries, called Koolpirro and Thinnewa—the males of the former phratry marrying the females of the latter, and conversely—the resulting offspring of both sexes adopting the phratry name of their mother in either case. This can be concisely represented by means of a table.

Table No. 1.

Phratry.	Husband.	Wife.	Offspring.
A.	*Koolpirro*	Thinnewa	Thinnewa
B.	Thinnewa	*Koolpirro*	*Koolpirro*

Along the course of the Mulligan River, Saltpetre Creek, Pituri Creek, and part of the Upper Georgina River, are several tribes, among which may be mentioned the Yoolanlanya, Yanindo, and Yorrawinga. They are divided into sections, among which may

---

[1] Journ. Roy. Soc. N. S. Wales, xxxii., 78 - 84; 250 - 253.

be mentioned Lookwarra, Belthara, Ungella, Drungwarra, Koomara, and Gabala, but my enquiries respecting their rules of marriage and descent are not yet completed.

There is a community of tribes spread over the country drained by the Norman and Yapper Rivers, Spear Creek, Carron Creek, Walker's Creek, the Lower Gilbert, Byerley's Creek, Pelican Creek, Staaten River, Nassau River, and the lower portions of the Einasleigh and Lynd.

The most important of the numerous tribes in this area are the Goothanto, Ariba, Koogobathy, Goongarra, Owoilkulla, Wallungarma, Karantee and Nahwangan. Their territory extends from Woodstock Station on the head of the Norman River to the Nassau River, a distance of about three hundred miles, and having a maximum width of about two hundred miles. Their frontage to the Gulf of Carpentaria reaches from the mouth of the Nassau to the mouth of the Flinders. On the east they are bounded by the Warkeemon nation, whose sectional divisions I reported last year.[1] On the west and south they are bounded by the Mycoolon[2] and Kogai-Yuipera[3] nations respectively. I have named this aggregate of tribes the Goothanto nation after the tribe of that name occupying the country around the junction of the Gilbert and Einasleigh Rivers.

In all the tribes of this nation the people are divided into four sections called Arenia, Arara, Loora and Arrawonga, or else mere variations of these names, with descent in all cases through the mother. To Mr. E. Palmer belongs the credit of first reporting one of the tribes of this organisation.[4] In 1883 he stated that the names of the sections of the Koogobathy tribe, which I have included in the Goothanto nation, as Barry, Ararey, Jury and Mungilly, which are evidently modified forms of the names I have given in Table No. 3. Dr. W. E. Roth, in 1897, referred to

---

[1] Journ. Roy. Soc., N.S. Wales, xxxii., 250, 251. [2] *Ibid.*, p. 82.

[3] Proc. Amer. Philos. Soc., Philad., xxxvii., 331 – 333.

[4] Journ. Anthrop. Inst., Lond., xiii., 304.

another variation of these section names among the natives at Normanton.[1]

The present article, however, is the first in which the geographic range of the aggregate of tribes composing this community has been published, and the descent of the children clearly established. The sections Arenia and Arara correspond to Karpungie and Cheekunjee respectively, and the sections Loora and Arrawonga to Kellungie and Koopungie of the Warkeemon community, reported by me in 1898.[2] The rules of intermarriage among the Goothanto are as shown hereunder:—

Table No. 2.

Phratry.	Husband.	Wife.	Offspring.
A.	*Arenia*	Loora	Arrawongo
	Arara	Arrawongo	Loora
B.	Loora	*Arenia*	*Arara*
	Arrawongo	*Arara*	*Arenia*

The country watered by the Lower Mitchell, Alice, Coleman, Palmer and other rivers is inhabited by the Koonjan, Goonamon, and several friendly tribes, possessing four intermarrying divisions and matriarchal descent, as under:—

Table No. 3.

Phratry.	Husband.	Wife.	Offspring.
A.	*Ahjeereena*	Perrynung	Mahngal
	Arrennynung	Mahngal	Perrynung
B.	Perrynung	*Ahjeereena*	*Arrennynung*
	Mahngal	*Arrennynung*	*Ahjeereena*

On a tract of country at the junction of the Dawson with the Fitzroy, and thence westerly to Arthur's Bluff, extending also north and south for some distance, is a tribe called Kang-ool-lo, having four sections, the names of which are evidently modifications or combinations of those in use among the Dippil and Kooinmerburra nations. The names of the sections, and how they intermarry are as shown hereunder:—

---

[1] Ethnological Studies, Queensland Aborigines, p. 68.

[2] Journ. Roy. Soc., N.S. Wales, xxxii., 250 – 251.

Table No. 4.

Phratry.	Husband.	Wife.	Offspring.
A.	*Keearra*	Banniar	Koorpal
	Banjoor	Koorpal	Banniar
B.	Banniar	*Keearra*	*Banjoor*
	Koorpal	*Banjoor*	*Keearra*

At the junction of the Rankine with the Georgina River—on Barklay's Tableland—and on the sources of the Gregory and its tributaries, are the hunting grounds of the Inchalachee and Warkya tribes—the latter extending westerly as far as Lake Sylvester. They are divided into eight sections, which constitute two phratries, comprising four sections each. The intermarriage of these divisions, and the sections to which the resulting offspring belong, will be easily understood when arranged in tabular form:

Table No. 5.

Phratry.	Husband.	Wife.	Offspring.
A.	*Bolangie*	Kungilla	Belyeringie
	Boonongoona	Belyeringie	Narechie
	Warkie	Narechie	Beneringie
	Thimmermill	Beneringie	Kungilla
B.	Kungilla	*Bolangie*	*Thimmermill*
	Beneringie	*Thimmermill*	*Warkie*
	Narechie	*Warkie*	*Boonongoona*
	Belyeringie	*Boonongoona*	*Bolangie*

Adjoining the Inchalachees and their friends on the north, and reaching thence to the mouth of the Nicholson River, and north-westerly along the Gulf of Carpentaria are the Yangarilla, Wahnyee, Yookala, and friendly tribes, bearing the eight sectional names reported by me to this Society last year.[1]

APPENDIX.

Divisions of Tribes in the Northern Territory.

To the north-west of the Warkya we find the Wombya and several adjoining tribes, who possess the eight divisions which I

---

[1] "Divisions of Some North Queensland Tribes."—Journ. Roy. Soc., N.S. Wales, xxxii., 250 - 255.

gave in tabular form on page 75 of volume XXXII. of the Journal of this Society. This organisation extends, with slight modifications in the names of the sections, over a wide tract of country from Creswell Downs to the Katherine River. Adjoining the Warkya on the south-west are the tribes of what I have called the Ulperra nation, Table No. 8, extending from Tennant's Creek to Alice Springs, and north-westerly therefrom to meet the tribes of the organisation represented in Table No. 7.

Throughout the course of the Victoria River, on the Daly River, and their tributaries, the native tribes are segregated into two principal phratries A and B, each of which is subdivided into four sections, which intermarry as follows :—

Table No. 6.

Phratry.	Husband.	Wife.	Offspring.
A.	*Chamaja*	Chungalla	Chalyerry
	Changarra	Chalyerry	Choolama
	Chanama	Choolama	Chongarry
	Jambajunna	Chongarry	Chungalla
B.	Chungalla	*Chamaja*	*Jambajunna*
	Chongarry	*Jambajunna*	*Chanama*
	Choolama	*Chanama*	*Changarra*
	Chalyerry	*Changarra*	*Chamaja*

On Sturt Creek, and extending thence south-easterly towards the Lander and Barrow's Creek, are the Neening, Jarroo, and Munga tribes, with some others, having the following divisions, or mere modifications of them :—

Table No. 7.

Phratry.	Husband.	Wife.	Offspring.
A.	*Choongoora*	Changally	Chabalye
	Chagarra	Chabalye	Chooara
	Chowan	Chooara	Chowarding
	Chambeen	Chowarding	Changally
B.	Changally	*Choongoora*	*Chambeen*
	Chowarding	*Chambeen*	*Chowan*
	Chooara	*Chowan*	*Chagarra*
	Chabalye	*Chagarra*	*Choongoora*

For the purpose of showing the equivalence of the eight sections represented in Tables Nos. 5, 6, and 7, it is desirable to introduce the eight divisions reported by the Rev. L. Schulze in 1891.[1] I tabulated this gentleman's investigations, with some modifications, last year,[2] but in order to bring the section names mentioned by him into corresponding positions with those under consideration in the present article, I have re-arranged them as under. The A phratries in each table are equivalent to each other, as well as the sections of which they consist; and all the B phratries likewise correspond in the same way.

Table No. 8—The Ulperra Tribe.

Phratry.	Husband.	Wife.	Offspring.
A.	1. *Knurraia*	Ngala	Bultara
	2. *Koomara*	Bultara	Parulla
	3. *Panungka*	Parulla	Pungata
	4. *Mbutjana*	Pungata	Ngala
B.	5. Ngala	*Knurraia*	*Mbutjana*
	6. Pungata	*Mbutjana*	*Panungka*
	7. Parulla	*Panungka*	*Koomara*
	8. Bultara	*Koomara*	*Knurraia*

The names of the sections of the Warramonga tribe are practically identical with those referred to by Mr. Schulze. If we adopt the same numerals as in Table No. 8, the equivalence of the Warramonga divisions will be as follows:—1, Ungarria; 2, Takamara; 3, Taponunga; 4, Ambajona or Jambean; 5, Jungulla; 6, Tapongatee; 7, Joopalla; 8, Cubadgee. The intermarriages of these sections, and the descent of the offspring, follow precisely the same order as those in Table No. 8. In preparing the amended list of names of sections, and rules of intermarriage of the Warramonga tribe, I wish to acknowledge the willing help afforded by Mr. W. Beattie.

Each phratry has perpetual succession, and is sustained entire, by means of its women. In Tables 1 to 8 of this article, the section names of which the phratry consists are in all cases those

---

[1] Trans. Roy. Soc., S.A., xiv., 223 – 227.

[2] Journ. Roy. Soc., N.S. Wales, xxxii., 72.

shown in the column headed "wife." All the members of the A phratry are printed in Roman letters, and those of the B phratry are all in italic. For the purpose of illustrating the order of descent, I will take a few examples from "Phratry A" in each type of social structure. Thus, in Table No. 3, where the phratry consists of only one division, Thinnewa produces Thinnewa from generation to generation. In Table No. 2, which is an example of tribes who have two divisions in the phratry, Loora produces Arrawonga, and Arrawonga produces Loora in the next generation, and so on continually. When there are four divisons in the phratry, of which Table No. 5 is an example, we find in the column headed "wife," that Kungilla has a daughter Belyeringie; Belyeringie produces Narechie; Narechie is the mother of Beneringie; Beneringie has a daughter Kungilla, the same name we commenced with; and this order of succession is repeated for ever. If our examples had been selected from "Phratry B," an analogous result would have been obtained. In all the Tables herein given, the sons of the women of one phratry marry the daughters of the women of the other; therefore, the men and women of the same generation in each phratry respectively stand in the mutual relationship to each other of brothers-in-law and sisters-in-law.

Let us suppose a line drawn from Anson Bay, at the mouth of Daly River, to Limmen Bight in the Gulf of Carpentaria, and then take the portion of the Northern Territory of South Australia bounded on the north by the said line; on the west by Western Australia; on the east by Queensland, and on the south by South Australia proper. Throughout this immense tract of country I have described the divisional systems of the principal native communities sparsely distributed over it. For particulars of my work the reader is referred to the tables at pages 72, 73 and 75 of the thirty-second volume of the Journal of this Society, and to Tables 1, 5, 6, 7, and 8 of the present article. The divisions shown in Table No. 7 also extend a long way westerly into West Australia, reaching from Termination Lake northerly to Wyndham, a distance of about three hundred miles.

THE INITIATION CEREMONIES OF THE ABORIGINES OF PORT STEPHENS, N. S. WALES.

By W. J. ENRIGHT, B.A. *Syd.*

(Communicated by R. H. MATHEWS, L.S.)

[*Read before the Royal Society of N. S. Wales, July 5, 1899.*]

THE male aboriginal, on attaining the age of puberty, reaches the most eventful period of his life. Hitherto his place has been amongst the women and children, but he now passes through a ceremony admitting him to a brotherhood whose secrets are inviolable and whose power is more dreaded than any Vehmgericht. Now filled with a sense of the dignity of manhood, he becomes entitled to greater privileges than previously enjoyed.

This ceremony of admission is known by various names in different parts of the colony, but amongst the Kutthung[1] and other tribes of the north-east coast it is called the Keeparra: I believe that the first detailed account[2] of it, and its sister ceremony "the Dalgai," was one written by Mr. R. H. Mathews.

In December 1896 and again in December 1897, I sojourned among the remnant of the Kutthung tribe at Port Stephens without being able to elicit from them anything more valuable than the reluctant admission that at the present time the youths are initiated at Forster.

I mentioned the difficulties I encountered in obtaining particulars of their secret ceremonies to my friend Mr. R. H. Mathews, from whom I have always received encouragement and assistance in all ethnological work, and on his next visit to Maitland he drove out with me to the native camp at Sawyer's Point on the Karuah River. He was personally known to some of the men present

---

[1] Pronounced Kut-thung.

[2] Journn. Anthrop. Inst., XXVI.. 320 – 340. Proc. Roy. Soc. Vic., IX., N.S. 120 – 136.

there, and was at once received by them as one of the initiated. I remained in the camp "with the women and children," as they jocularly expressed it, while Mr. Mathews took all the initiated men into a secluded place in the bush near by, where a Winggerah[1] was held, at which he explained that he had told me all the secrets of the keeparra and had imposed upon me the usual obligations of secrecy. As soon as they were satisfied, I was summoned and shown the sacred goonanduckyer[2] and was formally admitted as a member of the tribe entitled to all the privileges of an initiate.

With the help of Mr. R. H. Mathews, I have been able to obtain the following information, though not without considerable difficulty:—The place of initiation at Forster, New South Wales, consisted of a large circular space called "boolbung," about thirty feet in diameter, resembling a circus ring. This is connected with another smaller circle called "goonambung" situated in a very secluded part of the bush, by a pathway (goolga) about a quarter of a mile in length; the trees along which for some distance from the goonambung have geometrical figures and representations of various animals carved on their trunks. In the centre of the goonambung a fire was lighted, and was kept burning. My enquiries proved that the ground at Forster differs but little from that described by Mr. Mathews in "The Keeparra Ceremony of Initiation,"[3] to which I would refer my readers for more minute details.

When a tribe has a number of youths who have attained the proper age for initiation, a messenger[4] is sent out to summon the neighbouring tribes to assist in the creremony. The messenger

---

[1] A secret council ot initiates.

[2] Bullroarer used in the keeparra.

[3] Journ. Anthrop. Inst., xxvi., 321 – 323.

[4] The person of this messenger is quite sacred, and whatever differences there may be between the tribe summoning and the tribe summoned, the utmost amity must outwardly prevail at this time, and any interference with the person of the messenger would be promptly resented and avenged, not only by the tribe to which he belonged, but also by the neighbouring tribes.

who is an initiate, carries with him as symbols of authority the bullroarer (goonanduckyer), the message-stick, some tails and pieces of colourless stone.[1] The goonduckyer and message-stick must never be seen by a women or an uninitiated person, and I have been assured that instant death would overtake a female or boy unfortunate enough to see one of these implements.[2]

When a messenger approaches a camp, he swings the goonanduckyer so that it may be heard by some of the older men, who immediately recognise the significance of the sound as soon as they hear it, and coming out of their camp they meet the messenger and conduct him into the camp, where he is entertained until the following day, when a winggerah is held to which his invitation is delivered.

If the invitation is, as usual, accepted, the whole tribe gets ready for the march, the women and boys however, being kept in ignorance of the object of the journey. When the tribe arrives near the ground they halt, and the initiates proceed to paint their bodies in squares and circles with white and red colours, and go to the goonambung ring, which they enter in Indian file, and marching round take their seats on the wall, in such a position that they look towards the burri or country whence they have come.

Each man, who has a son to be initiated, bears a blotch of red ochre on his forehead, and by this means they indicate the number of youths they have brought to be initiated.[3]

The tribe which has issued the invitation are then summoned by the swinging of the goonanduckyer, at the sound of which they form in single file and march into the goonambung, thus making themselves known to the new arrivals, who arise and march to the boolbung circle, each carrying a small branch or bough of a tree in each hand. Here they dance with the women of the tribe to whom the ground belongs, and at the conclusion of it the men belonging to that tribe go into the ring and salute the newly

---

[1] Usually crystalline quartz.

[2] This appears to apply only to a message-stick relating to the Keeparra.

[3] Proc. Roy. Soc. Vic., ix., N.S., 124.

arrived women by dancing around them. All the men then strip the leaves off the branches they carry and scatter them over the ground. This portion of the ritual appears to be meaningless now, but it may perhaps have formerly symbolised the stripping of the youth of his old character preparatory to confering on him the *toga virilis.*

The day for commencing the initiation having arrived, the men who are to act as the stewards go to the goonambung and assume the symbols of office in the shape of a smearing of grease and charred bark of the apple-tree (goondary).[1] The boys are prepared by their female relations, who cover them all over with a mixture of red ochre and grease, and they are also adorned with a belt from which is suspended two tails.

The youths when their preparations have been completed proceed to the boolbung in company with the women and children. The latter, however, do not enter the ring but take their places outside, close to the youths belonging to their respective tribes; the youths standing inside the ring at the points nearest their respective burris.

The women and children who have been previously made to lie down with their faces to the ground are then covered with rugs and bushes, and the proponents for initiation with their heads enveloped in rugs are taken some distance along the goolga out of sight of the women, and then made to lie down with the rugs still covering them. Whilst in this position, the awful sound of the goonanduckyer, the voice of Goolumbra further impresses them with the solemnity of the occasion and serious nature of the step they are taking, and renders their minds better fitted to receive the lessons of the keepara.

The youths having been taken out of sight as just stated, the women and children are permitted to rise, and are conducted to another camp, the site of which has previously been selected at a winggerah held prior to the commencement of the proceedings.

---

[1] Not the fruit tree, but the so-called apple-tree of Australia (*Angophora*) Eds.

Before leaving for the new camp a doolbhi[1] is erected outside the ring to indicate to any other tribes who arrive later on, the direction in which it is situated. Near this new camp, which is called Ulrà,[2] a piece of ground is neatly swept and two fires are lighted thereon some distance apart. On this playground which has been thus prepared, the women and girls dance every evening during the absence of the boys.

The women having been taken away as just described, the novices whom we have left lying down at the goolga are ordered to stand up and the rugs are then placed over their heads in the form of cowls. They are then taken along the goolga towards the goonambung, and on the way they are shown by the elders the teeroong or various geometrical and other figures carved on the trees. As far as I can learn, there are no figures carved on the earth at the keeparra ground used by the Kutthung. None of the aboriginals from whom I drew my information knew the meaning of the teeroong.

When the youths arrive at the goonambung they are taken around it, and then marched towards the bush, the boys alongside of their guardians, with their eyes intently fixed upon the ground until they reach a suitable place, where a camp is formed in the shape of a crescent or semicircle with two fires in front of it, and also a level space carefully cleared and swept. On this place every night the men mimic the actions of various native animals, and the goonanduckyer is sounded occasionally to impress the novices who are informed, that it is the voice of Goolumbra, of whose terrible powers they are warned. During their stay at this camp which is called the keelaybang, the novice who is kept either in a lying or sitting position, must not communicate by word with his guardians, and is threatened with severe penalties if he does so.

---

[1] "Doolbhi" consists of a forked piece of timber inserted in the ground with another piece tied at right angles to it a little distance from the ground pointing in the direction of the new camp. If there are any streams between the boolbung and the new camp, they are represented by twigs fastened across the pointer equal in number to the streams.

[2] Ulrà appears to be a name given to any kind of camp.

Should he desire anything he must touch one of the men who continues to question until he gets an affirmative nod from the boy. Often the man who has charge of the boy will at once know what is the novice's desire, but in order to test him will refrain from putting the proper question. During their stay in the keelaybang no meat is given to the boys until it has been cut into small pieces and the bone and sinew carefully removed. In some tribes the boys are given human urine to drink and excrement to eat, but at the present time this is not practised amongst the Kutthung, nor have I been able to discover whether it was ever in vogue, but the name goonanduckyer[1] hints at its existence.

Should a boy desire to micturate he is allowed to do so at one of the fires, alternating the operation at each fire. Any other call of nature is obeyed outside the camp, one of the initiates all the time keeping guard over him. After some days spent in this camp, the cry of a dingo (mirree), will be heard near it. This noise or howl is uttered by men who have come from the women's camp, and is answered by a shout from the keelaybang. When the new arrivals get in sight they march in single file towards the camp, with bushes in front of them which they throw down on their arrival and execute a dance. The men who have charge of the boys pick up these bushes and commence dancing with them in their hands, all the while stripping off the leaves. The object of this visit appears to be to ascertain when the novitiate will be completed and a return made to the camp. Several of such visits may possibly have to be made before the initiation is accomplished. During their stay the boys are taught the sacred songs of the tribes and the laws relating to the class system; they also commence to learn an entirely new language. In this new language the returning boomerang (barrakun) is known as dulla, and the woomera (yukri) is called burrumba. The learning of this language is a matter of time, and the knowledge acquired of it is useful in ascertaining whether a man is an initiate.

---

[1] *Stercus humanum edens.*

On the morning before they depart to the women's camp the boys are made to stand in a row, their heads remaining covered, and then the men form in line in front of them, and two of them swing the goonanduckyer. After it has been sounded sufficiently the coverings are removed from the boys heads, and they are permitted to see for the first time the instrument whose sound has so impressed them. Some old men who are strangers to the boys then step forward and threaten them, that, if ever they reveal anything that has been shown them or taught them, they will be killed, and this is quite sufficient to deter them from revealing the secrets of the keeparra. This concludes the ceremony in the bush, and a start is made for the camp where the women have been left, but on the way the whole party go into a waterhole or at some point along a stream of water previously agreed upon and wash themselves. At the conclusion of their ablutions they singe the hair off the bodies of the novices, and then cover the whole of the party from head to foot with pipeclay before resuming their journey to the women's camp. On their way they are met by a number of men from the women's camp, who announce their arrival by howling like dingos, and this howling is answered by one of the men with the guardians swinging a goonanduckyer. Each member of the party from the women's camp carries a green bough in his hand which is thrown down, when they form into line in front of the novices and a short dance is gone through. The men with the novices then pick up the bushes and strip them of their leaves which are scattered about on the ground. The new arrivals then return to the women's camp and prepare for the return of the novices by making all the women lie down and covering them with bushes. After sufficient time has elapsed for these preparations to be completed, the novices and men, divested of all incumbrances, make a start for the camp, their approach to which is heralded by the sound of the barroway[1] by a man who has previously gone out of the camp. On the arrival of the novices with their guardians at the camp they form a complete circle around it, and then the

---

[1] A large bullroarer.

women are permitted to rise and greet their sons whom in their disguise they have considerable difficulty in recognising. On discovering their sons the mothers go forward to them and raise their breasts which the sons take hold of and pretend to suck. Amongst other tribes the sisters of the novices greet them by rubbing their feet on the feet and ankles of the novices, but this custom did not appear to prevail amongst the Kutthung. After each mother has greeted her son in this fashion, the women pass out of the ring under the arms of the men who then throw bushes on the fires causing them to smoke. Each guardian then takes hold of the novice under his care and holds him for a time in the smoke, after which all the novices take their departure together with their hands linked, to the place where they have left their belongings, and they are soon followed thither by their guardians who remain with them for the night.

The next day the visiting tribes make preparations for departure, and on their journey the novices must not camp with the elders, but like those whom they have left behind they are kept in a "bachelor's camp" until their initiation is completed. Each night however, they are allowed to approach a little nearer to the general camp, and at last are finally admitted into it. Before being allowed the privilege of marriage, they must attend more keeparras, the number of which, as far as I can ascertain is five, but it is possible that more regard is paid to the age of the youth than to the number of keeparras he has attended. A new name is also given to him now which must never be used within the hearing of women; the raised scars (bheerammer), are made on his body.

Prior to being initiated he was permitted to use as food all kinds of fish, honey, and the female of all land animals, but certain birds and the male of all land animals were forbidden him. After his first keeparra he is entitled to partake of the flesh of the male kangaroo-rat, and after the second he is permitted to eat the male opossum, and each succeeding keepara increases his privileges in this respect.

The custom of knocking out one of the front teeth during the ceremony is not now in vogue amongst the Kutthung, nor is it certain that it ever existed amongst them, and of late years the practice of ornamenting the bodies with scars has fallen into disuse. It is more than probable that the last keeparra has been held by them; for as each year goes by their numbers dwindle, and in January 1899, they were not able to get a sufficient number of aborigines together to enable them to celebrate the ceremony. Many of those I have met along the coast had never gone through the keepaara, but had been merely initiated into the dhalgai, a sister ceremony, much shorter however than the keeparra, and needing for its practice no assemblage of adjoining tribes nor any prepared ground; in fact it requires but a half dozen men who have passed through the keeparra, and the use of a goonanduckyer, to enable the youth to be initiated. As the dhalgai ceremony amongst the Kutthung does not differ from that already described by Mr. R. H. Mathews, I will refer my readers to his work[1] for an account of it.

The burri[2] of the tribe whose initiation ceremony I have here described, extended along the Karuah River's southern bank and the southern shore of Port Stephens to Pipeclay Creek, whose western bank formed the eastern boundary of their territory; but the southern and western boundaries were uncertain or rather I received varying accounts from different individuals. These boundaries were no doubt strictly adhered to before the advent of Europeans, but afterwards when tribes were killed off or driven from their territories the boundaries of adjoining burris would be changed, and this would account for the discrepancies in the statements I have received. The country on the north side of Port Stephens and the Karuah extending down to the right bank of the Myall River belonged to the Gummipingal;[3] the land lying

---

[1] Journ. Anthrop. Inst., XXVI., 338 - 340.

[2] District belonging to a tribe.

[3] "People of the Spear." Gummi a spear, and gal people. The grass trees from which the material for spear handles was obtained grew abundantly in this district.

between the Myall River, the Myall Lakes and the sea, was occupied by the Grewigerigal,[1] and the district lying between Pipeclay and Tellegherry Creeks was occupied by the Doowalligal.[2]

Amongst the Kutthung and neighbouring tribes there was no code of signs in use, as some believe amongst the initiates, and in a community such as that in which the aboriginals lived, where every male on attaining the proper age would be initiated, and in which all initiates would be known to the older men who played a leading part in the keeparra, the use of such signs for the purpose of distinguishing initiates except from adjoining tribes would be utterly unnecessary, and in the latter case the language previously referred to would furnish an infallible test.

In conclusion, I wish to refer to a description of the "Gaboora" ceremony[3] published in the Australian Anthropological Journal a year or two ago. Mr. Cohen, the writer of the article says that "the youths to be initiated were kept apart from the other members of the tribe for a month previous to the inauguration ceremonies, and that if any female was detected holding conversation with them or touching them she would be put to death." According to my investigations the novices remain in the general camp with their female friends until the final morning on which they are taken away by the old men. It is also stated that the "gaboora ceremonies invariably occupied two days." From ten days to a fortnight is the shortest time employed for this purpose among all the tribes of the north east coast. Mr. Cohen's description of the scenes in the bush, while the novices are away with the chief men undergoing the ordeal of initiation, are to say the least disjointed and fragmentary. Moreover some of the scenes which he narrates were never heard of by my native imformants; whilst others were stated to be merely portions of ordinary corroborees, and in no way connected with the rites of the keeparra or "gaboora," as it is called by the writer of the article in question.

---

[1] "People of the Sea." Grewi the sea, and gal people.

[2] "People living between the two"; but whether the name is given them from the fact that they lived between two streams or between two tribes I could not ascertain.

[3] "Description of the Gaboora Ceremony."—Aust. Anthrop. Journ., Vol. I., pp. 83 - 84, 97, 98, 115 - 117; Vol. I., N.S. pp. 7 - 10.

SAILING BIRDS ARE DEPENDENT ON WAVE-POWER.

By L. HARGRAVE.

[*Received Aug. 24. Read before the Royal Society of N.S. Wales, Sept. 6, 1899.*]

THERE are many birds frequenting the southern oceans beyond the limits of the S.E. trade winds that are not adapted for soaring, and yet they circle, glide and swoop around without flapping their wings. These have been well called sailing birds; and it is one of their oft repeated evolutions that shows me, and I hope you, that sailing flight is not at all incomprehensible.

I will first point out that the tropics are the home of heavy short-winged birds, such as gannets, boobies, divers and small gulls. These seldom make any attempt to glide, much less sail or soar. The only exceptions I know are the frigate bird, and the boatswain bird; these two soar at high altitudes for long distances on motionless wings.

It is worthy of remark that large flocks of sailing birds accompany vessels running down their easting, and this gives an opportunity for observing whether sailing birds really can work to windward, this point can only be determined from on board a steamer going westward, and south of what I believe is the usual track from Australia to the Cape.

My own opinion is that sailing birds cannot make anything to windward except during the limited time that the sea is running in an opposite direction to the wind: and as an argument I call attention to the absence of sailing birds in the S.E. trades and attribute the scarcity to their inability to get out of the trades by standing to the S.W. if they get too far to leeward.

The most ordinary conditions for observing sailing birds are when the wind and sea are both aft. The waves are probably overtaking the ship and passing at about six knots. Large numbers of birds follow the vessel and make wide circuits on either side of the wake; their interest is centered on garbage, and their efforts are directed to keeping astern, their weight and area are such that they must keep moving through the air at a nearly uniform speed in order that they may be supported; this velocity I estimate at forty miles per hour.

If you direct your attention to the position of a bird *with regard to the wave surface*, it will speedily be noticed to be nearly always on the rising side or face of the wave and moving *apparently* at right angles to the wave's course, but really diagonal to it.

The bird is going to leeward as fast as the wave is; and, if that speed is too great for its requirements it turns towards the crest, points one wing to the sky and uses its velocity to shoot upwards high above the back of the wave, and then descends to the trough of the following wave along the face of which it glides: the back of the wave is its peculiar aversion. Now there has been no flapping and the performance takes place with or without wind, all the bird requires is the wave.

As to the effect of the wave on the air, we will suppose the water to be quite flat and the air motionless, a heavy undulation comes on the scene, it has to pass, so it pushes the air up with its face, letting it fall again as its back glides onwards. The air on the face is slightly compressed, that on the back lowered in pressure, both operations taking power out of the wave and eventually largely contributing to its extinction.

The closer the bird is to the surface of the water, the firmer and more inelastic is the uplift of the rising air. The bird appears to almost feel the surface with the tip of its weather wing.

The case I wish you to consider is that of a sea-wave, for example one hundred and eighty feet long and ten feet high, travelling at eighteen knots, or say, thirty feet per second under *calm* air. This wave will raise all the air as it passes ten feet, at the mean rate of three and one-third feet per second.

The rate will vary from zero in the trough, attaining its maximum velocity at half the wave height, or where the wave is steepest, and falling to zero at the crest. Let us suppose the maximum velocity of uplift of the air to be about four feet per second and the steepest part to be 10° slope.

Now according to Prof. S. P. Langley, a plane surface 30″ × 4·8″, weighing 1·1 lbs. will glide on air, without losing its elevation, at a speed of 49·8 feet per second, if sloped 5°. That is, the plane pushes 4·33 feet of air vertically downwards whilst it is translated 49·8 feet in 1 sec.

The same effect with regard to the position of the plane at the end of its journey of one second's duration is produced if the plane be sloped 5° downwards, and the air through which it passes be pushed bodily upwards 4·33 feet in one second.

Now the air over our wave is being lifted about four feet per second; so if the 1·1 lb. plane were launched with 5° downward slope in the same direction the wave is travelling, from one foot above the steepest part of the wave, it would overrun the wave which has only a velocity of thirty feet per second. It would thus get out of the air that is being lifted and shoot into the water in the trough. But if the aspect of the plane be changed so that it face 53° either to the right or left of the track of the wave, its position above the mean sea level, and situation on the wave slope will be unaltered: and, if the wave was of unlimited width the plane would continue on its course till dashed ashore.

The plane is simply abstracting the power stored in the wave by a distant gale, and using it to counteract gravity. And if the work be continued long enough, or a multitude of planes be continually drawing on the reservoir of power, the wave must inevitably be flattened.

The velocity of 49·8 feet per second is sufficient to raise the plane to an elevation of thirty-eight feet in one and a half seconds, if its course be changed from horizontal to vertical, it there comes to rest. And from a poise at this station the plane may swoop down, at great disadvantage if close to the back of the wave, at various slopes and directions till it cuts into the air that is being raised by the face of the following wave, which again enables it to resume its velocity.

Observe that the wave I instance in this example, is one of the low round topped sort that prevail in calm weather. If we were to base our calculations on a wave with a sharp crest approaching to the breaking dimensions, our plane would be travelling on its course through air having a velocity of uplift of 30 instead of 4·3 feet per second, if the wave slope were 45°; and would need loading approximately to $\frac{30}{4 \cdot 3} \times 1 \cdot 1 = 76$ lbs. per square foot to keep it down to its original mean height, and could be made of seven gauge wrought iron.

If we figure out the result with 2° angle of incidence, and a horizontal velocity of 65·6 feet per second, we find that the 1·1 lb. plane will be supported where the wave face is only $4\frac{1}{2}°$ slope, giving a velocity of uplift of 2·289 feet per second, and will make a course 62° 40′ to the right or left of that of the wave. Couple this with the fact that the head resistance of a sailing bird's form and the delicate arch of its wings are the survivals of untold numbers of cruder types, and no surprise should be felt at any intricate tactics pursued when further aided by the power derived from the wind and roughened sea.

This is the solution of the problem of a sailing bird's progression totally denuded of complications. It becomes a giant's task to compute the result when the effect of cross seas, wind at all angles and ever varying force, arched surfaces, head resistance, ratio of weight to area, and the intelligence of the guiding power crop up. These questions all combined, have been considered in the evolution of a sailing bird and must be reckoned with by the designer of a wave driven flying machine. I am not aware that anyone has attempted to show that sailing flight by wave-power alone is a practicable art, but even if some one else has done so, an observation from an independent source confirming old work cannot fail to be of interest.

SOME APPLICATIONS AND DEVELOPMENTS OF THE PRISMOIDAL FORMULA.

By G. H. Knibbs, F.R.A.S.,

Lecturer in Surveying, University of Sydney.

[*Received Aug. 29. Read before the Royal Society of N. S. Wales, Sep. 6, 1899.*]

---

1. The prismoidal formula and the limit of its application.
2. The prismoidal formula applied to solids with ruled surfaces
3. Skew, warped, or ruled quadric surfaces.
4. Volumes of warped-surface solids.
5. Solids of trapezoidal section with two warped surfaces.
6. Solids of quadrilateral section with plane surfaces.
7. Solids of quadrilateral section with one warped surface.
8. Solids of pentagonal section with two warped surfaces.
9. Solids of heptagonal section with four or six warped surfaces.
10. Approximate estimate of volume from profile of centre-line of m longitudinally contiguous solids.
11. Solids whose longitudinal axes are curved.
12. Solids whose longitudinal axes are tortuous curves.
13. Solids of curved longitudinal section with circularly warped surfaces.
14. Centre of gravity of various sections.
15. Prismoidal formula applicable to circularly warped solids.
16. Prismoidal formula not applicable with variable radius of curvature.
17. Suggestions respecting the use of the preceding formulæ.

1. *The prismoidal formula and the limit of its application.*— Consider the solid generated by parallel motion in the direction z, of any figure in the plane xy, whose area is connected with its z coördinate by the relation

$$A_z = f(x.y.z) = A + Bz + Cz^2 + Dz^3 \ldots\ldots\ldots\ldots (1);$$

i.e., a solid whose xy section is a *cubic* function of its z coördinate. Since the origin of z does not affect the *degree* of the equation, but alters only the values of the *constants*, we may analytically treat A as the area of one of the terminal planes of the solid, and express its volume as

$$V=\int_0^z f(z)\,dz = Az+\tfrac{1}{2}Bz^2+\tfrac{1}{3}Cz^3+\tfrac{1}{4}Dz^4\ldots\ldots\ldots\ldots(2);$$

that is

$$V=\tfrac{1}{6}z(6A+3Bz+2Cz^2+1\tfrac{1}{2}Dz^3)=\tfrac{1}{6}z(A+4A_m+A')\ldots\ldots\ldots(3)$$

A_m denoting the middle area, or the area for $z_m=\frac{1}{2}z$; and A' the area of the other terminal plane: which may be readily verified. We thus see that this last expression (3), viz., the '*prismoidal formula,' is true for any solid whose sectional area is a cubic or lower function of the distance from either of its terminal planes;* a proposition due really to Newton.[1]

2. *The prismoidal formula applied to solids with 'ruled surfaces.'* Consider further the 'ruled surface' formed by the motion of a straight line as *generator*, the terminals making a complete circuit of two parallel planes serving as *directors;* the areas of the latter being

$$f(x.y)=A;\quad f'(x'.y')=A';$$

and the velocities of the generator-terminals, viz., their contact-points on the directors, being unrestricted. If now ds and ds' be corresponding infinitesimal elements of the director curves, projected in Fig. 1 on the one plane, and if g and g' denote the projections of successive positions of the generator on the same plane; it is evident that any intermediate parallel plane A_1 will cut the generators and their projections in a constant ratio; and that any infinitesimal increment of area dA_1 say, see the shaded portion of the figure, may therefore always be represented by a quadratic function of z. That is to say, if $d\theta$ be the infinitesimal angle between the projections of the successive positions of the generator, the increment of area will always be of the form

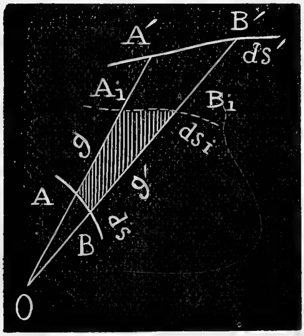


Fig. 1.

$$dA_1=(a+bz+cz^2)\,d\theta\ldots\ldots\ldots\ldots(4),$$

---

[1] "Methodus differentialis," 1711.

and this property depends merely upon the fact that the generator is cut in a constant ratio.[1] And since the total difference of area between any two planes is made up of terms similar to (4), that is differing only with respect to the value of the constants, it follows that the xy sectional-area, in *a solid whose mantle is a 'ruled surface,' is merely a quadratic function of the* z *coördinate.* Hence without restriction, the volume of such a solid is also expressed by the prismoidal formula, as shewn in § 1.

3. *Skew, warped, or ruled quadric surfaces.*—If the directors are dissimilar polygons whose sides are neither necessarily parallel nor equal in number, the prismoidal formula still applies, as the last section, § 2, demonstrates; and the middle-area may readily be found, provided the scheme of generating the '*mantle*'[2] be specified. If the generator-terminals move simultaneously with uniform velocities over any two sides S and S' of the polygons, starting from the initial and reaching the terminal points of those sides at the same instant; then if the sides are parallel a plane is generated, but if not, the 'ruled surface' formed is a 'skew,' 'warped' or 'ruled quadric surface';[3] that is a surface upon which a straight line will lie wholly on the surface in two directions, and only in two directions. From projection it is evident that the corresponding side of the middle-section is the straight-line

$$S_{\mathrm{m}} = \tfrac{1}{2}\,(S + S')$$

if S and S' are parallel,[4] and similarly in regard to the coördinates of the terminals, but without that restriction: that is,

$$x_{\mathrm{m}} = \tfrac{1}{2}\,(x + x')\ \text{etc.}\ \ldots\ldots\ldots\ldots(5).$$

---

[1] In Fig. 1 let arcs be drawn from the points A, A_{i}, A', and from B, B_{i}, B' with O as centre. It is evident that in the limit, the triangular areas on opposite sides of the curves, of which these arcs, the curves, and the radii form the boundaries, become equal, both approaching zero as $B\,B'$ approaches $A\,A'$; thus every elementary area is expressible by a quadratic function (4).

[2] The 'ruled surface' bounding the solid between its terminal planes may be called its 'mantle.'

[3] Throughout this article 'warped' means skew or plane-warped unless otherwise specified. A skew surface is one on which the successive positions of the generator do not intersect.

[4] Added 21 Sept. This restriction was erroneously omitted in the paper as read.

4. *Volumes of warped-surface solids.*—The area of any polygon of n sides, expressed in terms of the coördinates of its angular points, is

$$A = \tfrac{1}{2}\Sigma_1^n \left[(x_{k+1} - x_{k-1})y_k\right] \ldots\ldots\ldots\ldots (6);$$

consequently the volume of a solid whose parallel end-planes, the perpendicular distance l apart, are polygons of the same number of sides, and whose mantle consists of warped surfaces, is:—

$$V = \tfrac{1}{12}\, l\, \{\Sigma_1^n \left[(x_{k+1} - x_{k-1})\,(2y_k + y'_k)\right] + \Sigma_1^n \left[(x'_{k+1} - x'_{k-1})\,(2y'_k + y_k)\right]\} \ldots\ldots\ldots\ldots (7)$$

as may easily be seen by forming the area of the middle section. When a series of such solids are contiguous, so that the end planes are common to the adjoining solids and the distances between those planes are equal, this formula, (7), may be thus extended:—Put for brevity

$$X_k = (x_{k+1} - x_{k-1})\ ;\ X'_k = (x'_{k+1} - x'_{k-1})\ ; \ldots\ldots\ldots\ldots (8)$$

and so on: then omitting the suffixes since no confusion can arise, and omitting also the limits as they are obvious, we have

$$V_m = \tfrac{1}{12}\, l\, \{\Sigma\left[X(2\,y + y')\right] + \Sigma\left[X'(y + 4\,y' + y'')\right] + \ldots + \Sigma\left[X^L(y^K + 4\,y^L + y^M)\right] + \Sigma\left[X^M(y^L + 2\,y^M)\right]\} \ldots\ldots (9)$$

in which K L M are to be understood as accents merely: V_m is the total volume of the m solids. The initial and final terms are identical in form, and all interior terms are also identical with one another. This last expression reduces the scheme of computation to its simplest form, : its prismoidal character is apparent.

5. *Solids of trapezoidal section with two warped surfaces.*—In certain cases which present themselves practically for solution, the formula may be greatly simplified, In Fig. 2 let the heavy lines denote the parallel end areas of a prismoidal figure, the sides AB = a, A′B′ = a', CD = b, and C′D′ = b' being parallel to one another. The surfaces AA′C′C and BB′D′D will be warped,

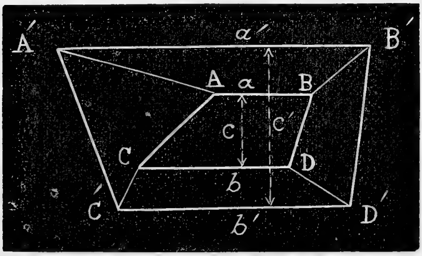


Fig. 2.

and the other two surfaces will be planes. Then, l denoting, as in § 4, the perpendicular distance between the parallel terminal planes, the volume will be

$$V = \tfrac{1}{12} l \left\{ c\left[2(a+b)+(a'+b')\right] + c'\left[2(a'+b')+(a+b)\right] \right\} \ldots\ldots (10)$$

c and c' being the rectangular distances between the parallel sides of the trapezoids. If a and a' become zero, we have a solid whose end planes are triangles, with the bases b and b', parallel, and altitudes c and c', the mantle of the solid consisting therefore of one plane and two warped surfaces; its volume will be

$$V = \tfrac{1}{12} l \left\{ c(2b+b') + c'(2b'+b) \right\} \ldots\ldots\ldots\ldots (11).$$[1]

6. *Solids of quadrilateral section with plane surfaces.*—In earthwork computations, the data are to hand in a form which requires special consideration. In a roadway it is usual to make the bed, or formed surface of the road, a constant width, AB $= w$ say, and to keep the sides AF, BG to a constant slope; see Fig. 3. This slope is defined by the cotangent (r) of the angle which the sides make with the horizontal bed; that is to say its *grade* is expressed as r horizontal units to 1 perpendicular. The side planes will consequently intersect one another at the distance CD $= w/2r$, *beneath* in the case of 'cuttings,' or *above* in that of 'embankments,' the centre of the road-bed AB; and the area of the triangle ABD thus formed is $w^2/4r$. The 'centre height,'

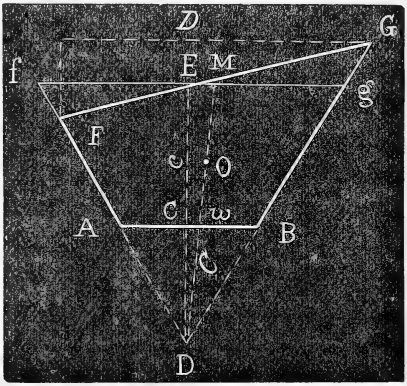


Fig. 3.

---

[1] If the factor be made $\frac{1}{6} l$, the expression will give the volume of a solid whose parallel ends are rectangles with the sides b, c and $b'c'$; as was shown by Hutton in 1770.

CE $= c$, is ordinarily determined by measurement,[1] so that if the 'augmented centre height' DE be denoted by C, we shall have

$$C = c + \frac{w}{2r} \ldots\ldots\ldots\ldots(12)$$

If the surface, fg Fig. 3, is level across, in which case all the sides are planes, and the area of any triangle fDg is rC^2, the volume of m longitudinally contiguous solids will be

$$V_{\mathrm{m}} = \tfrac{1}{3}\,lr\,\left\{ C_{\mathrm{o}}^2 + C_{\mathrm{m}}^2 + 2\sum_{\mathrm{k}=1}^{\mathrm{k}=\mathrm{m}-1} C_{\mathrm{k}}^2 + \sum_{\mathrm{k}=\mathrm{o}}^{\mathrm{k}=\mathrm{m}-1} C_{\mathrm{k}}C_{\mathrm{k}+1} - \tfrac{3}{4}m\frac{w^2}{r^2} \right\} \ldots\ldots\ldots(13)$$

the negative term $lmw^2/4r$, being the volume of the prism, whose constant section is ABD, beneath or above the road-bed.

7. *Solids of quadrilateral section with one warped surface.*—If in Fig. 3, the upper line fg instead of being horizontal, *i.e.*, parallel to AB, makes an angle therewith whose cotangent is s; that is takes up some such position as FEG the slope of which is s horizontal units to 1 perpendicular; then the projections of EG, EF, on fg produced if necessary, are

$$D = rC\left(\frac{s}{s-r} + \frac{s}{s+r}\right) = rC\frac{2s^2}{s^2 - r^2} \ldots\ldots\ldots\ldots(14)$$

r and s being regarded as always positive: consequently the area of the triangle FDG is

$$A = rC^2\,\frac{s^2}{s^2 - r^2} \ldots\ldots\ldots\ldots(15);$$

that is to say $s^2/(s^2 - r^2) = q$, is the factor,[2] which multiplied into the area fDg, gives the area FDG. Since s is necessarily greater than r, this factor q is generally greater, and can never be less than unity, that being the limit for $s = \infty$.

In a figure like DFEGD, Fig. 3, the area will always be $\frac{1}{2}CD$ whether FE and EG be in the same straight line or not; or the

---

[1] For example by 'levelling' the profile of the 'centre-line' of the road, and determining the levels for the formed road by a general consideration of the best grade, having regard to all relevant circumstances.

[2] It is sometimes convenient to express this factor as a series

$$1 + \frac{r^2}{s^2} + \frac{r^4}{s^4} + \text{etc.} = 1 + r^2\tan^2\epsilon + r^4\tan^4\epsilon + \text{etc.}$$

ϵ being the angle which the sloping line makes with the horizontal.

area included within the heavy lines,

$$A = \tfrac{1}{2}\left(CD - \frac{w^2}{2r}\right) \ldots\ldots\ldots\ldots (16).$$

Thus the volume of a solid, in which the parallel terminal planes are identical except as regards the position of the line FG, and in which therefore the FG surface only is warped, is

$$V = \tfrac{1}{3}\, lr \left\{ q_0 C_0^2 + \tfrac{1}{2}(q_0 + q_1)\, C_0 C_1 + q_1 C_1^2 - \tfrac{3}{4}\frac{w^2}{r^2} \right\} \ldots\ldots\ldots (17)$$[1]

For practical purposes q may be taken from tables of double entry constructed with r and s as arguments. The formula for the volume of m contiguous solids will be of the same type as (13) § 6. If q be regarded as unity, and two longitudinal sections be taken as forming one prismoid, (17) becomes simpler, and in general sufficiently accurate for mere estimates of volume from profile.

8. *Solids of pentagonal section with two warped surfaces.*—Reverting to (16) in the preceding section, it is immediately evident that the volume of m longitudinally contiguous solids, with two warped surfaces in each, viz., the FE and EG surfaces, is expressed by

$$V_m = \tfrac{1}{12}\, l \left\{ C_0(2D_0 + D_1) + \ldots + C_k(D_{k-1} + 4D_k + D_{k+1}) + \ldots \right.$$
$$\left. \ldots + C_m(D_{m-1} + 2D_m) - 3m\frac{w^2}{r} \right\} \ldots\ldots\ldots\ldots (18)$$

in which k has all values from 1 to $m-1$. The quantity $lmw^2/4r$ is the volume of the extended prism on ABD and lying under the whole of the m sections.[2] The algorithm in practical computations is simple and convenient.[3]

---

[1] In earthwork such solids present themselves in what is called 'two-level ground,' that is ground where the natural surface on a 'cross-section' may be regarded as of uniform slope on each side of the 'centre-line.'

[2] If the base of the solid ABB_1A_1 is a parallelogram but not rectangular, r is not the measure of the slope of the side planes with reference to the base but only of their line of intersection with the parallel end planes ABGEF.

[3] When FE and EG are not in the same straight line, the section is known as a 'three-level section.' The data necessary for computation are the horizontal distances of $FG = D$ and the vertical heights $DE = C$.

9. *Solids of heptagonal section with four or six warped surfaces.* Another case of practical importance is that illustrated by Fig. 4, shewing a section of the solid: AB, and the angles GAB, ABH are constant for each terminal polygon: this constancy of the angles however is unessential, and the surfaces standing on GA, and on HB, may be also warped. It is essential, however, that the points E and F be vertically over A and B. Let as before $AB = w$, $CD = c$, $AE = e$, $BF = e'$, and the sum of the projections of $GE + ED = d$, and of $DF + FH = d'$, so that d and d' will be the total horizontal distance between the 'centre line' and the points where the sides of the road meet the natural surface. The area of a section is evidently

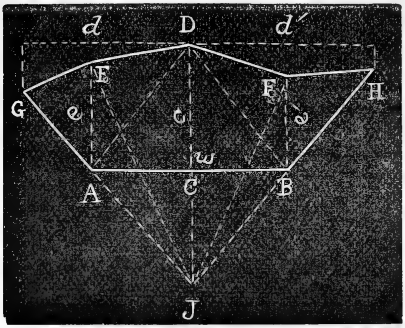


Fig. 4.

$$A = \tfrac{1}{2}\,(cw + de + d'e') \dots\dots\dots\dots (19)$$

consequently the volume of m longitudinally contiguous solids whose parallel faces are the rectangular distance l apart is[1]:—

By writing these in columns I. and IV. as hereunder, column II. is obtained by multiplying the first and last D by 2, and the intermediate ones by 4. Diagonal addition gives the numerical values required in column III.: the products $C\,\Sigma(D)$ can then be formed or taken out of suitable tables. For earthwork computations these may be constructed so as to give, not the products of C and D, but those products not only multiplied by $\frac{1}{12}\,l$, but also reduced to any required unit, as for example cubic yards in English practice. See for example, Table XI., Theory and Practice of Surveying.—J. B. Johnson, 1887, pp. 672 – 681.

I.	II.	III.		IV.
D_0	$2\,D_0$	$2\,D_0 + D_1$	×	C_0
D_1	$4\,D_1$	$D_0 + 4\,D_1 + D_2$	×	C_1
D_2	$4\,D_2$	$D_1 + 4\,D_2 + D_3$	×	C_2
:	:	: : :	:	:
D_m	$2\,D_m$	$D_{m-1} + 2\,D_m$	×	C_m

[1] The case considered is for 'five-level sections,' where the 'intermediate heights' e and e' are taken over the sides of the road-bed: this simplifies the computation of the area, see (19).

$$\left.\begin{aligned}V_m = \tfrac{1}{12}\, l \Big\{ & w\,(3c_o + 6\,c_1 + \ldots + 6\,c_k + \ldots + 6\,c_{m-1} + 3\,c_m) + \\ & e_o(2d_o + d_1) + \ldots + e_k(d_{k-1} + 4\,d_k + d_{k+1}) + \ldots + e_m(d_{m-1} + 2d_m) + \\ & e'_o(2d'_o + d'_1) + \ldots + e'_k(d'_{k-1} + 4d'_k + d'_{k+1}) + \ldots + e'_m(d'_{m-1} + 2d'_m)\end{aligned}\right\}(20)$$

in which the values of k are 1 to $m - 1$. The scheme of numerical computation is obvious: the process cannot be further abbreviated.[1]

10. *Approximate estimate of volume from profile of centre-line of* m *longitudinally contiguous solids.*—If the centre-heights of the end planes, of the form ABGF Fig. 3, be given, the values of r and w being constant, the error of treating two adjoining solids as a prismoidal figure of the length $2\,l$ will in general be small, so that approximately, m being an even number, the total volume is

$$V = \tfrac{1}{3}\, lr \left(q_o C_o^2 + 4\,q_1 C_1^2 + 2\,q_2 C_2^2 + 4\,q_3 C_3^2 + \ldots + q_m C_m^2 - \tfrac{3}{4}\, m\, \frac{w^2}{r^2}\right) \ldots (21)$$

in which q is unity if the surface is level across, see § 7, and C is formed as indicated in (12).

11. *Solids whose longitudinal axes are curved.*—Let OY be the line of intersection common to three planes OX, OP, OQ; to one of which—OX say—the axis of a prism, whose right section thereon is any closed curve whatsoever, is vertical; the prism being cut also by the other two planes, making the angles θ_1 and θ_2 with the plane YOX. Then the intercept between the PQ planes, of any line parallel to the axis of the prism, is

$$l = z_2 - z_1 = x\,(\tan\,\theta_2 - \tan\,\theta_1) = \mu x \text{ say} \ldots\ldots\ldots\ldots (22):$$

OX and OY being the axes of the abscissæ and ordinates, to the plane of which z is perpendicular, hence the volume of the portion of the prism intercepted between the P and Q planes is

$$V = \iint \mu x\, dx\, dy \ldots\ldots\ldots\ldots (23),$$

and since the area of the right section of the prism is

$$A = \iint dx\, dy \ldots\ldots\ldots\ldots (24)$$

---

[1] See the suggestions in the footnote to the previous section, § 8, relating to diagonal additions, etc. There is no advantage to be derived from continuing the lines GA, HB to J as in the previous case. The expression for the total area merely requires that c in (19) be replaced by C = DJ; see § 14 hereinafter.

the *mean height*[1] of the intercepted volume is

$$l_0 = \mu\bar{x} = \frac{V}{A} = \mu\,\frac{\int\!\!\int x\,dx\,dy}{\int\!\!\int dx\,dy} \;\ldots\ldots\ldots\ldots(25).$$

The quantity into which the factor μ is multiplied is obviously the abscissa of the 'centre of gravity' of the right-section of the prism; and hence the volume of any prism with plane ends, is equal to the area of its right section, multiplied by a line perpendicular thereto, passing through its centre of gravity and intercepted by its terminal planes. Since the solid generated by any plane figure rotating about an axis lying wholly in its plane *produced*, is made up of the infinitesimal or elementary volumes $\bar{\rho}\,d\theta\,A$, in which $\bar{\rho}$ is the perpendicular distance between the rotation-axis and the centre of gravity of the plane area, and θ is the angle of rotation, its volume is

$$V = A\int\bar{\rho}\,d\theta = A\bar{\rho}\theta = l_0 A \;\ldots\ldots\ldots\ldots(26)$$

that is to say, the volume of a solid so generated is equal to the area of the right-section multiplied by l_0, the distance traversed by its centre of gravity: a theorem due to Pappus[2] and rediscovered over one thousand years later by Guldinus.[3] The rotation at a finite rate of the generating plane figure in its own plane about its centre of gravity, while it moves at a finite rate along the curve $\bar{\rho}d\theta$, is immaterial, and does not modify the result with respect to the generated volume, unless the curve be such that the generator returns on itself, *i.e.*, repasses over any portion of its path: this is evident since the infinitesimal element of the generated solid is always $A\bar{\rho}d\theta$.

12. *Solids whose longitudinal axes are tortuous curves.*—Let the radius of the osculating circle, the circumference of which contains and is determined in position by three consecutive points

---

[1] That is the height which multiplied by the area of the right section gives the volume.

[2] "Mathematical collections."—Born about 340 A.D.

[3] "Centrobaryca,"—Born 1577, died 1643.

on a *tortuous curve*,[1] be denoted by ρ; and let the tangent to this circle at the middle point be called the tangent to the curve. If then the centre of gravity of any plane figure, as generator, move along this curve in such a manner that the plane is continually perpendicular to the tangent of the curve as defined, the volume of the generated solid will be equal to the length of the curve intercepted between the terminal planes, multiplied by the area of the generator, provided that it does not return on itself; and that the centre of the osculating circle as defined, is always outside the boundary of the generator.[2] For if ds denote an element of the curve, subtending at the centre of the osculating circle the angle $d\theta$, the volume will be

$$V = \int A\rho d\theta = \int A ds = As \text{...........} (27).$$

With reference to the curve itself, the plane generator may be regarded as not rotating, if the radius ρ of the osculating circle does not change its position with reference to the axes thereof: as in the preceding section however, the rotation of the generating plane does not affect the volume of the generated solid, since the relations expressed in (27) still hold good.

13. *Solids of curved longitudinal section with circularly warped surfaces.*—In Fig. 5, let O be the centre of the concentric arcs B_0B_1, C_0C_1, representing in plan a half-width of roadway as in

---

[1] That is a curve of 'double curvature' or one that will not lie in a plane. Let O_0, O_1, O_2 be the centres of circles of which the very small arcs PP_0, P_0P_1, P_1P_2 form part. Then if O_1 be in the plane PO_0P_0 the curve is a plane curve, but if not it is tortuous. Let the radius P_0O_0 rotate through the angle $d\phi_0$ about the point P_0 in a plane perpendicular to that of the circle containing PP_0, and then change its length to the radius of the curve P_0P_1 by the point O_0 moving to O_1: and similarly let P_1P_1 rotate laterally $d\phi_1$, and the point O_1 extend to O_2: these rotations may be made to measure the tortuosity: the curve $O_0O_1O_2$ contains the centres of the osculating circles as defined, and denoting the arcs when infinitesimal by ds_0, ds_1 etc., and the radii O_0P_0, O_1P_1, etc., by ρ_0, ρ_1 etc., we have $\rho_0\, d\theta_0 = ds_0$, $\rho_1\, d\theta_1 = ds_1$ etc. It is obvious that in a curved so developed the tangent at P_0 is common to the arcs ds_0, ds_1 and so on: $d\theta/ds$ measure the curvature, $d\phi/ds$ the tortuosity.

[2] This condition is necessary, otherwise negative volumes would have to be considered.

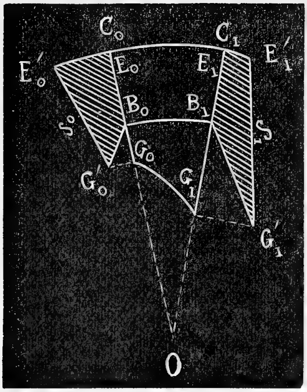


Fig. 5.

Fig. 3, CB being $\frac{1}{2}w$: and let also the shaded figures CBG′E′C represent the vertical sections on OC_0 and OC_1, so that the point E is vertically over C, and similarly the point G vertically over the line OC. Let y_c denote an ordinate on the line C_0C_1 perpendicular to the plane C_0B_1: if then the angle C_0OC_1 be denoted by θ, and $dy_c/d\theta$ be constant, the curved surface-line E_0E_1 will be a *spiral* with a uniform rise. Let also y_g be similarly the ordinate of any point on the curved surface-line G_0G_1, measured from its projection on the CB plane; then if $dy_g/d\theta$ be also constant, the surface-height at the centre line of a right section of the solid between the terminal BCEG planes (see Fig. 3), the 'side height'—or height where the uniformly sloping side of the road-cutting[1] meets the natural surface—and the horizontal projections of the lines EG or BG will together change uniformly,[2] that is as a linear function of θ, or of z the distance on the curved centre line, C_0C_1. This is the analogue of the case already considered in § 7, § 8, etc.; and since if the radius of curvature become infinite the surface $E_0G_0G_1E_1$ becomes an ordinary warped surface, we may call the similar surface in the case now considered, a 'circularly warped surface.' Such a solid as is here considered, viz., one whose longitudinal axis is curved, and the terminals of whose cross-sectional surface lines together change their height uniformly, may be taken as defining a class of solids which often present themselves in engineering practice, as in road and railways; and to find its volume it is necessary only to take account of the changing position of the centre of gravity of its right section as it moves along the longitudinal axis; as will hereinafter be shewn.

---

[1] As before a similar statement applies to embankments.

[2] It is not essential that the slope (r) of the cutting should be constant but it must change uniformly with θ, *i.e.*, $dr^{-1}/d\theta$ must be constant.

14. *Centre of gravity of various sections.*—If the line perpendicular to the axis of rotation, by which a solid is generated, be taken as the axis of abscissæ, we shall require only the abscissa of the centre of gravity of each section previously discussed. The triangular section shewn in Fig. 3 is first considered. Let the line FG be bisected in M; then since the centre of gravity of the triangle DFG is on the line DM, and at the point O so taken that DO = 2·OM; or what is the same thing, since the abscissa of O is $\frac{2}{3}$ that of M, reckoned from the axis DE; or still more generally since the coördinates of O are the mean of those of the three points of the triangle:

$$x_0 = \tfrac{2}{3}\, s\, C \frac{r^2}{s^2 - r^2} \ldots\ldots\ldots\ldots (28)$$

as may easily be verified, see (14). If the perpendicular distances d and d' of F and G from the line DE be given, then whether FE and EG are in one line or not, the centre of gravity is one-third their difference: that is

$$x_0 = \tfrac{1}{3}\,(d' - d) \ldots\ldots\ldots\ldots (29)$$

the identity of which with (28) is easily shewn. The expression for the centre of gravity of sections like that illustrated in Fig. 4 is not so simple. By equating the moments of the several triangles composing the figure about the y axis, parallel to CD, it will be seen that

$$x_0 = \tfrac{1}{3}\, \frac{d'e'(\frac{w}{2} + d') - de\,(\frac{w}{2} + d)}{cw + d'\epsilon' + de} = \tfrac{1}{3}\, \frac{E'(\frac{w}{2} + d') - E\,(\frac{w}{2} + d)}{A} \ldots (30)$$

E' and E denoting the areas of the pairs of triangles standing on the lines e' and e respectively, and A the area of the whole figure. If in Fig. 4, the centre of gravity be required for the whole figure including the triangle ABJ, it is merely necessary to substitute C for c in formula (30), and A must include this triangular area. More generally, if A, A' etc., be contiguous areas the abscissæ of whose centres of gravity are x, x' etc. from any arbitrarily chosen axis, then the abscissa of the centre of gravity of the total area ΣA is

$$x_0 = \frac{\Sigma(xA)}{\Sigma A} \ldots\ldots\ldots\ldots (31)$$

from which formulæ for particular cases may be readily deduced.

15. *Prismoidal formula applicable to circularly warped solids.*—Since the projections of EF, FG, change linearly in proceeding along the centre-line C_0C_1, see Fig. 3, not only in solids with warped surfaces, but also when the surfaces are circularly warped, as shewn in § 13, the relation

$$x_z = x_0 + (x_1 - x_0)\frac{z}{l} \text{ ....} (32)$$

always holds good, if x_z denote the abscissa of the centre of gravity on the right section, distant z, measured curvilinearly on the centre-line C_0C_1 Fig. 5, from section 0. The length l is the total distance to section 1, also measured on the curve; and x_0 and x_1 are the abscissæ of the centres of gravity on the initial and terminal sections.

Let R denote the constant radius of curvature of the centre-line C_0C_1, ρ_z that of the centre of gravity of section A_z; then since x_z may be written $x + \lambda z$, see (32), and remembering that the area of a circularly warped figure is a quadratic function of z, and that not $\rho_z d\theta$ but $R d\theta = dz$; the volume of a solid, of the type illustrated in Fig. 5, will be

$$V = \int A_z \rho_z \, d\theta = \int \left\{ (A + Bz + Cz^2)(R + x + \lambda z) \right\} \frac{dz}{R}$$

$$= z \left\{ A' + B'z + C'z^2 + D'z^3 \right\} \text{ ....} (33)$$

in which the constants have the following values, viz.,

$$A' = A(1 + \frac{x}{R}); \; B' = \tfrac{1}{2} \left\{ \frac{A\lambda}{R} + B(1 + \frac{x}{R}) \right\}; \; C' = \tfrac{1}{3} \left\{ \frac{B\lambda}{R} + C(1 + \frac{x}{R}) \right\};$$

$$D' = \tfrac{1}{4} \frac{C\lambda}{R} \text{ ....} (34)$$

that is, the volume is a *quartic*, and the area of the right-section therefore a *cubic* function of z,[1] the length on the centre-line. Consequently, see § 1, the prismoidal formula is *rigorously* applicable. Remembering that $\lambda = (x_1 - x_0)/l = \Delta x/l$ say, and that the limits of z are 0 and l, equation (33) may be written in full in the form

$$V = l \left\{ A \left(1 + \frac{x}{R} + \tfrac{1}{2} \cdot \frac{\Delta x}{R}\right) + \tfrac{1}{2} Bl \left(1 + \frac{x}{R} + \tfrac{2}{3} \cdot \frac{\Delta x}{R}\right) + \right.$$

$$\left. + \tfrac{1}{3} Cl^2 \left(1 + \frac{x}{R} + \tfrac{3}{4} \cdot \frac{\Delta x}{R}\right) \right\} \text{ ....} (35)$$

---

[1] Since $A = dV/dz$: or as is immediately obvious from (33) itself.

x denoting the abscissa of the centre of gravity on the initial plane, *i.e.* for $l = 0$. As may easily be verified, this expression is identical with

$$V = \tfrac{1}{6} l \left\{ A_0 \left(1 + \frac{x_0}{R}\right) + 4 A_m \left(1 + \frac{x_m}{R}\right) + A_1 \left(1 + \frac{x_1}{R}\right) \right\} \text{............(36)}$$

in which x_m is the abscissa of the centre of gravity of the 'mid-section'; x is positive when it is on that side of the centre line, or axis of reference, which is *opposite* the centre of rotation.[1] Since the triangle beneath the line AB, Fig. 3, is symmetrical, its centre of gravity is in the line CD and its volume to be subtracted from (36) say, is $lw^2/4r$. The general result above indicated is, that the prismoidal formula may be applied to circularly warped solids of triangular section; it being necessary only to multiply their end and middle areas by the ratio ρ/R, ρ being the radius of the centre of gravity, and R of the 'centre line,' since $\rho/R = 1 + x/R$.

By considering formulæ (31) and (36) it is evident that the latter is true for any 'circularly warped solid': for let the right section of such a solid be divided into a series of triangles, whose areas are A, A' etc., the abscissæ of the centre of gravity of these being x, x' etc., measured from the curved axis, of radius R, of the solid; then for any section we have from those formulæ

$$\Sigma \left\{ A \left(1 + \frac{x}{R}\right) \right\} = \Sigma A \left\{ 1 + \frac{1}{R} \cdot \frac{\Sigma(xA)}{\Sigma A} \right\} = \Sigma A \left(1 + \frac{x_0}{R}\right) \text{......(37)}$$

x_0 being the centre of gravity of the whole figure and ΣA its area. Consequently formula (35) may be applied to any 'circularly warped solid' of polygonal section. It is moreover obvious from (33) that the formula is true for any circular solid the centre of gravity of whose right section changes linearly with the z curved-coördinate continually perpendicular to the section.

16. *Prismoidal formula not applicable with variable radius of curvature.*—It may however be shown from (33) that if R be not constant, the prismoidal formula will not apply generally, since on

---

[1] In earth-work computation it is more often negative than positive in cuttings, since on hill sides the rising ground is usually on the same side as the centre of the curve. The values of x/R can be obtained from tables of double entry in practical calculation.

integration the expression for the volume will be higher than a quartic function of z, or will contain logarithmic functions. For example, if in (33) R be a function of z,[1] that is if the centre-line be not a circular curve, let

$$R_z = R_0\,(1 + \alpha z + \beta z^2 + \text{etc.}) \ldots\ldots\ldots\ldots (38);$$

then remembering that $R_z d\theta = dz$, the expression for the volume will become, including also a non-linear variation of the abscissa of the centre of gravity of the right-section

$$V = \int \left\{ (A + Bz + Cz^2) \left[1 + \frac{x + \lambda z + \mu z^2 + \text{etc.}}{R_0(1 + \alpha z + \beta z^2 + \text{etc.})} \right] \right\} dz \ldots\ldots (39)$$

For the purposes of practical computation there is no special difficulty in integrating this for particular cases: in general it may be said that it will be convenient to expand the expression in the square brackets in the form of a convergent series, and thus to integrate only the terms of sensible magnitude. Thus the above expression can, in practical cases, always be put in the form

$$V = \int \left\{ (A + Bz + Cz^2) \left[1 + \frac{1}{R_0} (x + az + bz^2 + \text{etc.}) \right] \right\} dz \ldots (40)$$

in which with the above coëfficients

$$a = (\lambda - \alpha x)\,;\; b = \left\{ \mu - \alpha\lambda + (\alpha^2 - \beta)\, x \right\} \text{ etc.} \ldots\ldots\ldots (41).$$

The value of the integral is obvious.

17. *Suggestions respecting the use of the preceding formulæ.*—By the use of suitable tables, the calculation of which is very simple, and the nature of which has already been sufficiently indicated—see §§ 7, 8, 15 and footnotes—the applications of the preceding formulæ can generally be made to involve nothing more than simple additions and subtractions; as will at once be evident to any computer: it is unnecessary to enter into details.

In respect of corrections for the positions of the centre of gravity, formula (36) it may be observed that if x_0 and x_1 are approximately equal, the factor

$$1 + \frac{x_0 + x_1}{2R}$$

---

[1] As it is for example in so-called 'curves of adjustment' in railway location.

may be applied to the whole volume, in lieu of multiplying each terminal and mid-section by its own correction factor, this will lead only to small errors, especially if the areas of those sections are approximately equal; and similarly if those areas, *i.e.*, A_0 and A_1 etc., are sensibly equal, the same proceeding may be followed even if x_0 and x_1 differ greatly. By attention to matters of this kind the practical computer is often able greatly to abbreviate the process involved in rigorous formulæ, without introducing appreciable error, or vitiating the precision of the practical result.

CURRENT PAPERS, No. 4.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Plates V., VI.]

[*Read before the Royal Society of N. S. Wales, October 4, 1899.*]

In a paper which I read before the Royal Society of N. S. Wales in 1896 on this subject, I called attention to the fact that during the prevalence of strong north-west winds over the Indian Ocean and the main land of Australia, the arrival of current papers in the Australian Bight almost ceased, and I expressed the opinion that the north-west wind altered the direction of the drifting bottles, so that they passed to the south of Australia, Tasmania, and New Zealand, instead of landing on Australia. Now I have to report in the absence of north-west winds and the prevalence of southerly winds, which has been marked during the year, current papers have come in unusually fast; often two per day, and on two occasions three have arrived in each day, and I have found it necessary to publish this list of one hundred and twenty-four current papers, after an interval from list No. 3 of twelve months; the intervals between the earlier lists being two years.

THE "PERTHSHIRE."

The suggestion made in list No. 3, that papers thrown over on the east coast, especially south of Sydney, drifted first to the east in Tasman Sea, and then northwards until they reached the great current from the east which passes south of New Caledonia on to the Australasian coast is again supported by several current papers herein recorded, and also in a very remarkable way by the drift of the *Perthshire* after she was disabled in Tasman Sea; her general direction for six hundred and forty miles was north-east by north, traversed in forty-seven days, and the average daily rate in that direction was 13·6 miles. The effect of the wind causing deviations from the mean direction, seems to have balanced itself. Towards the end of the drift the *Perthshire* travelled rapidly to the west as if she had got into the great oceanic current setting on to the coast of Australia. Three weeks before the *Perthshire* was picked up I expressed the opinion to a reporter that she would pass about midway between Lord Howe and Norfolk Islands, a statement which is confirmed by the actual track, which shews that she passed that point between June 1st and 2nd. The daily positions of the *Perthshire* have been plotted on the chart and connected by lines. The positions as supplied by the Captain of the *Perthshire* will be found in tabular form at the end of this pamphlet. The direction of the drift of the *Waikato* is also in accordance with the tracks shewn by bottle papers, but I regret that my application for a copy of the log has not yet been granted.

REMARKABLE RAPID DRIFT.

Five current papers floated on the east coast of Australia: Nos. 384, 405, 406, 431, and 442, indicate by the rapidity of their drift to the north, the force of the southerly winds during the Winter and Spring of 1899.

In the following list of rates, the usual assumption, viz., that current papers take a straight course, has been made:—

No. 384 put over April 27, found Aug. 6; rate per day 9·3 miles
„ 405 „ April 17, „ Aug. 25; „ 5·2 „

No. 406 put over May 1, found June 17; rate per day 12·7 miles
„ 431 „ June 30, „ Aug. 6; „ 11·5 „
„ 442 „ March 16, „ July 13; „ 5·9 „

These papers have reversed the usual direction and gone faster to the north than the usual rate to the south, and it is shewn on the charts that papers have this year been carried much farther north along the Queensland coast than is usual. This is only a part of the general increased rate of drift which is here shewn. For instance, two papers floated near Cape Horn came over to Australia at the rates of 12·2 and 9·5 miles respectively, with a mean rate of 10·85 miles, which is 19% greater than previous rates over this ocean. In the Indian Ocean the same feature is manifest in 1899, the average drift was 15·2 miles per day, which is 25½% greater than that previously measured. Again, between the Crozets, the Australian Bight and New Zealand, the average drift has been 7·9 miles, and in 1899 it has been 9·9 miles, or 25% greater than it was before.

But looking at the greatly increased rate of drift in the Southern Ocean and Tasman Sea, there must I think have been a greater velocity of wind, and as a consequence much greater strains upon shipping, and probably some broken shafts may be traced to these conditions. I know the number of steamers is increasing fast, and there is no doubt about the recent increased wind effects, but few know how much faster the pressure of wind increases than its velocity; thus, a wind blowing thirty miles per hour has a pressure of 4½ ℔s. on the square foot, and if the velocity is doubled the pressure is quadrupled, for a velocity of sixty miles per hour has a pressure of 18 ℔s. on the square foot. Certain it is, that the amount of damage that has been done inland by winds—covering up fences, tanks, etc., unquestionably proves the severity of wind storms in 1899, compared with other years.

It will be observed that the papers received during the past year number one hundred and twenty-four, and are more evenly distributed through the year than those in the two previous years

(Current Papers, No. 3) during which one hundred and forty-four papers were received.

NUMBER OF CURRENT PAPERS FOUND IN EACH MONTH.

Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	
/	/	/	/	/	/	/	/	/	/	/	/	/	/	
/	/	/	/	/	/	/	/	/	/	/	/	/	/	
/	/	/	/	/	/	/	/	/	/	/	/	/	/	
/	/	/	/	/	/	/	/	/	/	/	/	/	/	
...	/	/	/	/	/	/	/	/	/	/	/	/	/	
...	...	/	/	/	/	/	/	/	/	/	/	/	...	
...	...	/	/	/	/	...	/	/	/	/	...	/	...	
...	...	/	/	/	/	..	/	/	/	/	...	/	...	
...	...	/	/	/	/	...	/	/	/	/	...	/	...	
...	...	/	/	/	/	...	/	...	...	/	...	/	...	
...	...	/	/	/	/	.	/	...	...	/	...	...	..	
...	...	...	...	...	...	...	/	...	...	/	...	...	...	
...	...	...	...	...	...	...	...	...	...	/	...	...	...	
...	...	...	...	...	...	...	...	...	...	/	.		...	Total
4	5	11	11	11	11	6	12	9	9	14	6	10	5	124

It is noteworthy that the papers recorded in this pamphlet are more evenly distributed amongst the months than any previous papers that I have received, and one feature noted in list No. 3 is very marked in this list, and that is: the relatively small number of papers received in April and September. The fact suggests some connection with the Equinox, as if the stormy weather then prevalent disturbed the ordinary currents which bring the papers on shore. It would be very interesting to know if similar relation of the number of current papers with the months of the year obtain in other parts of the world.

It will be seen that there are some very interesting bottle tracks in the Atlantic Ocean, No. 425 made a run of 6,300 miles; the longest in the Atlantic that I have so far recorded, and the first from the direct steamer track from Cape Verde to the Cape. It is much to be desired that the captains of the regular steamers running in that track, would put current papers afloat regularly. This No. 425 is the first paper I have had from it.

PERCENTAGE OF RETURNS.

In list No. 3, I asked for the number of bottles that were put afloat from each vessel and the result is as follows: I hope more of those who are helping so much in this work will notify the number of bottles they put afloat.

Ship.	Number of Bottles.	Received.
S.S. *Australasian*	9	1 = 1 in 9
S.S. *Gulf of Bothnia*	48	1 = 1 in 48
S.S. *Clitus*	41	6 = 1 in 7
S.S. *Hawkesbury*	24	1 = 1 in 24
R.M.S. *India*	96	9 = 1 in 10½
S.S. *Yarrawonga*	4	0 = 0 in 4

If this is a fair guide as to the percentage of the current papers floated, which come back, I must confess that I am disappointed ; at the same time, it is perhaps, not surprising when we consider all the risks which a floating bottle runs on rock bound shores, on unknown and on uninhabited shores, or the number that sink from shells and vegetation that grow on them, or owing to imperfect corks.

ICEBERG.

NOTE.—Captain Brown of the ship "*Yallaroi*" from London to Melbourne, reported that on 17th August, 1899, when crossing the Australian Bight, and in Latitude 41° 30′ south, and Longitude 122° east, that is in line between the Leuwin and Tasmania, he saw an iceberg. No other report of this iceberg has reached me, although it was in the track of vessels from the Cape of Good Hope to Melbourne.

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over.		Where Found.		Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day,	Ref. No.
				Lat. ° ′	Long. ° ′	Lat. ° ′	Long. ° ′						
368	Dec. 3-97	R.M.S. ‘Alameda’	Captain Van Oterendorp ...	34 9 S.	162 55 E.	25 15 S.	153 20 E.	Mar. 14-99	Tasman Sea	466	855	1·8	368
369	Aug. 6-98	,, ...	R. Mikkleson, Commander	33 42 ,,	155 59 ,,	28 50 ,,	153 30 ,,	April 2-99	East Coast ...	239	365	1·5	369
370	Oct. 11-98	R.M S. ‘Aorangi’	C. Hepworth, R.N.R., Comd.	39 18 ,,	168 52 ,,	38 30 ,,	174 40 ,,	Nov. 23-98	New Zealand	43	320	7·4	370
371	Oct. 9-98	,, ...	,, ...	34 58 ,,	155 18 ,,	35 42 ,,	150 15 ,,	Feb. 2-99	East Coast ...	142	295	2·1	371
372	Dec. 3-98	,, ...	,, ...	15 52 ,,	178 42 W	18 15 ,,	178 53 ,,	...	South Pacific	...	165	...	372
373	March 7-99	,, ...	,, ...	40 14 ,,	172 12 E.	39 37 ,,	174 6 ,,	May 17-99	New Zealand	71	110	1·5	373
374	July 6-97	R.M.S. ‘Austral’	A. J. Coad, R.N.R, Comd...	35 40 ,,	131 1 ,,	34 12 ,,	137 27 ,,	Feb. 13-99	South Coast	587	430	0·7	374
375	July 11-97	,, ...	,, ...	35 0 ,,	151 7 ,,	20 10 ,,	169 40 ,,	Feb. 9-99	Tasman Sea	578	1,575	2·7	375
376	Nov. 17-98	,, ...	,, ...	35 11 ,,	119 24 ,,	33 50 ,,	121 55 ,,	Dec. 3-98	South Coast	16	175	10·9	376
377	Dec. 16-98	,, ...	,, ...	35 29 ,,	132 38 ,,	32 15 ,,	126 20 ,,	Feb. 28-99	,, ...	74	425	5·7	377
378	Dec. 19-98	,, ...	,, ...	33 53 ,,	114 33 ,,	34 20 ,,	115 10 ,,	Jan. 15-99	,, ...	27	45	1·7	378
379	Feb. 20-97	R.M.S. ‘Arcadia’	A. C. Loggin, R N.R., Comd	35 29 ,,	130 58 ,,	37 30 ,,	140 0 ,,	Jan. 18-99	,, ...	698	525	0·8	379
380	Dec. 6-98	M.M.S.S. ‘Armand Behic’	A. Poydenot, Commander	38 16 ,,	138 39 ,,	38 15 ,,	141 20 ,,	Dec. 17-98	,, ...	11	145	13·2	380
381	Sep. 8-98	,, ...	,, ...	38 1 ,,	138 14 ,,	38 13 ,,	141 18 ,,	Mar. 12-99	,, ...	185	170	0·9	381
382	Mar. 28-99	,, ...	,, ..	36 29 ,,	136 23 ,,	36 20 ,,	139 40 ,,	May 6-99	,, ...	39	185	4·7	382
383	Oct. 9-98	M.M.S.S. ‘Australien’ ...	— Vernon, ,, ...	35 36 ,,	131 28 ,,	34 30 ,,	137 25 ,,	Jan. 4-99	,, ...	87	400	4·6	383
384	April 27-99	,, ...	,, ,, ...	38 5 ,,	149 5 ,,	25 54 ,,	153 12 ,,	Aug. 6-99	East Coast ...	101	944	9·3	384
385	Nov. 20-97	S.S. ‘Bungaree’	Captain Lingham	46 10 ,,	82 30 ,,	46 50 ,,	167 50 ,,	Nov. 21-98	South. Ocean	366	4,100	11·2	385
386	May 21-97	,, ‘Burrumbeet’... ...	W. Hipgrave, Commander	39 4 ,,	146 14 ,,	39 5 ,,	146 25 ,,	Aug. 10-99	South Coast	142	36	0·3	386
387	Nov. 25-98	,, ‘Culgoa’	Captain Lingham	8 46 N	130 0 ,,	3 35 W	125 40 ,,	Mar. 4-99	North Pacific	99	460	4·6	387
388	April 6-99	,, ‘Clitus’	J. R. George, Captain ...	39 54 S.	143 5 ,,	38 23 S.	142 14 ,,	April 10 99	South Coast	4	55	14·0	388
389	April 7-99	,, ...	,, ...	38 15 ,,	138 50 ,,	38 15 ,,	144 0 ,,	Aug. 18-99	, ...	133	108	0·8	389
390	April 8-99	,, ...	,, ...	37 41 ,,	134 16 ,,	37 5 ,,	139 50 ,,	June 17-99	,, ...	71	322	4·5	390
391	July 28-29	,, ...	,, ...	31 23 ,,	153 1 ,,	32 32 ,,	152 32 ,,	Aug. 10-99	East Coast...	13	82	6·3	391
392	Aug. 2-99	,, ...	,, ...	16 25 ,,	145 40 ,,	15 10 ,,	145 15 ,,	Aug. 8-99	,, ...	6	80	13·3	392
393	Aug. 24-98	S.S. ‘Damascus’	A. Douglas, R.N.R., Comd...	43 16 S	100 36 ,,	38 17 ,,	141 21 ,,	May 24-99	South. Ocean	273	2,170	7 9	393
394	Oct. 25-98	S-S. ‘Darius’	W. Firth, Master	37 31 ,,	132 18 ,,	34 20 ,,	138 0 ,,	Mar. 17-99	South Coast	143	500	3·5	394
395	Sept. 3-98	N.D.L. ‘Darmstadt’ ...	A. von. Collen, Captain ...	12 49 N	47 3 ,,	11 10 N	48 20 ,,	Dec. 10-98	Gulf of Aden	98	135	1·4	395
396	Dec. 18-98	H.M S. ‘Dart’	J. F. Parry, Lieut. Comd...	25 56 S.	153 33 ,,	25 0 S.	153 20 ,,	Jan. 16-99	East Coast ...	29	70	2·4	396
397	Dec. 21-98	,, ...	,, ...	33 11 ,,	151 52 ,,	33 17 ,,	151 33 ,,	July 21-99	,, ...	212	19	0·1	397
398	Jan. 8-99	,, ...	,, ...	34 57 ,,	150 56 ,,	35 24 ,,	150 30 ,,	Feb. 17-99	,, ...	40	40	1·0	398
399	June 15-99	,, ...	,, ...	28 42 ,,	153 29 ,,	27 8 ,,	153 45 ,,	July 1-99	,, ...	16	131	8·2	399
400	June 23-99	,, ...	,, ...	25 20 ,,	153 43 ,,	26 5 ,,	153 12 ,,	Aug. 1-99	,, ...	39	63	1·6	400
401	June 25-99	,, ...	,, ...	22 9 ,,	150 54 ,,	23 30 ,,	150 58 ,,	Octr. 20-99	,, ...	117	96	0·8	401
402	Feb. 20-97	Ship ‘Derwent’	J. R. Andrew, Master ...	0 30 N	28 14 W.	13 0 N	60 22 W	Feb. 13-99	N. Atlantic...	723	2,312	3·2	402
403	Aug. 18-99	Ketch ‘Envy’	W. Champion, ,, ...	36 13 S.	175 2 E.	36 13 S.	175 34 E.	Aug. 21 99	New Zealand	3	30	10·0	403

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over.		Where Found.		Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day,	Ref. No.
				Lat. ° ′	Long ° ′	Lat. ° ′	Long. ° ′						
404	Mar. 24-99	Brigantine 'Ethel'	F. Limschon, Master	39 15 S.	146 25 E	37 50 S.	148 15 E.	April 7-99	South Coast	14	140	10·0	404
405	April 17-99	,,	,,	38 55 ,,	147 55 ,,	30 45 ,,	153 1 ,,	Aug. 25-99	East Coast ...	130	680	5 2	405
406	May 1-99	S.S. 'Futami Maru'	H. Hillcoat, Commander	38 30 ,,	148 2 ,,	32 50 ,,	151 50 ,,	June 17-99	,,	40	506	12·7	406
407	Aug. 14-98	N.D.L. 'Gera'	F. Meissell, Captain	35 34 ,,	134 30 ,,	34 10 ,,	138 5 ,,	Jan. 1-99	South Coast	140	300	2·1	407
408	Jan. 20-99	S.S. 'Gulf of Bothnia'	T. G. W. Ligertwood, Mast	39 35 ,,	106 23 ,,	34 20 ,,	115 20 ,,	May 27-99	South. Ocean	127	587	4·6	408
409	Oct. 27-97	,, 'Gulf of Lions'	A. Warden, Master	9 34 N	24 47 W	28 39 N	96 0 W	Mar. 24-99	Atlantic ,,	513	4,714	9·2	409
410	Aug. 9-97	,, 'Hawkes Bay'	J. C. Felgate, Commander	47 24 S.	88 20 E	35 30 S.	173 18 E.	Jan. 24-99	South. Ocean	533	4,550	8 5	410
411	May 20-97	R.M.S. 'Himalaya'	E. H. Gordon, ,,	35 35 ,,	131 40 ,,	37 30 ,,	140 0 ,,	Jan. 18-99	South Coast	608	485	0 8	411
412	Aug. 6-98	R.M.S. 'India'	W. D. G. Worcester, R.N.R.,	35 22 ,,	124 25 ,,	38 45 ,,	145 50 ,,	Dec. 11-98	,,	127	1,205	9 5	412
413	Oct. 9-98	,,	,,	40 51 N	9 30 W	40 50 N	8 30 W	Oct. 17-98	N. Atlantic...	8	56	7 0	413
414	Oct. 15-98	,,	,,	37 48 ,,	15 52 E.	37 8 ,,	15 14 E.	Oct. 25-98	Mediterranean	10	55	5 5	414
415	Oct. 24-98	,,	,,	12 17 ,,	49 26 ,,	10 33 ,,	44 7 ,,	Dec. 9-98	Gulf of Aden	46	385	8·4	415
416	Dec. 7-98	,,	,,	37 50 S.	140 10 ,,	37 55 S	140 25 ,,	Mar. 17-99	South Coast	100	15	0·2	416
417	Jan. 13-99	,,	,,	44 31 N	8 41 W	47 34 N	4 2 ,,	May 3-99	Bay of Biscay	110	261	2·4	417
418	Feb. 10-99	,,	,,	50 8 ,,	3 29 ,,	50 33 ,,	2 27 W	Feb. 13-99	Eng. Channel	3	53	17·8	418
419	Feb. 18-99	,,	,,	37 58 ,,	15 38 E.	37 42 ,,	15 13 E.	Feb. 22-99	Mediterranean	4	30	7·5	419
420	April 6-99	,,	,,	39 35 S.	149 21 ,,	31 52 S	151 55 ,,	June 28-99	East Coast ...	83	467	5·6	420
421	Mar. 5-99	,,	,,	35 46 ,,	135 34 ,,	34 0 ,,	137 30 ,,	July 16-99	South Coast	133	257	1·9	421
422	April 14-99	,,	,,	7 17 N	78 5 ,,	6 50 N	79 50 ,,	May 7-99	Indian Ocean	23	138	6·0	422
423	Aug. 25-96	,,	,,	29 7 ,,	17 55 W	34 40 ,,	76 35 W	Oct. 10-98	N. Atlantic	776	3,460	4·5	423
424	Mar. 21-99	,,	,,	38 16 S.	149 0 E	37 46 S	148 37 E.	Oct. 4-99	East Coast ..	197	38	0 2	424
425	July 30-96	,,	,,	11 42 ,,	1 2 W	24 30 N	97 0 W	Dec. 1-98	Atlantic Oc'n	850	6,300	7·4	425
426	Dec. 9-98	,,	,,	35 29 ,,	132 9 E	38 10 S.	140 43 E.	Oct. 16-99	South Coast	311	485	1·6	426
427	Aug 4-98	Barque 'Loongana'	W. T. Wawn, Master	14 40 ,,	176 42 ,,	10 30 ,,	142 20 ,,	June 8-99	South Pacific	308	2,335	7·6	427
428	April 11-99	,,	,,	24 50 ,,	156 32 ,,	25 54 ,,	153 12 ,,	May 9-99	East Coast...	29	221	7·6	428
429	Oct. 14-98	,,	,,	27 13 ,,	153 51 ,,	27 15 ,,	153 13 ,,	...	,,	...	36	...	429
430	June 18-96	Ship 'Lord Ripon'	J. Richards, Master	51 50 ,,	54 23 W	35 22 ,,	136 55 ,,	Mar. 18-99	South. Ocean	1003	9,567	9·5	430
431	June 30-99	S.S. 'Manapouri'	G. Crawshaw, Commander	31 1 ,,	157 26 E.	25 54 ,,	153 12 ,,	Aug. 6-99	East Coast ...	37	427	11·5	431
432	April 27-99	,, 'Menmuir'	St. John George, ,,	39 10 ,,	146 0 ,,	34 55 ,,	150 38 ,,	July 13-99	,,	77	462	6·0	432
433	Aug. 21-98	R.M.S. 'Miowera'	F. A. Hemming, ,,	28 48 ,,	178 25 ,,	18 36 ,,	177 40 ,,	Oct. 10-98	South Pacific	50	710	14·2	433
434	Aug. 22-98	,,	,,	23 0 ,,	178 32 W	19 0 ,,	178 25 ,,	Dec. 14-98	,,	114	280	2·5	434
435	Aug. 27-98	,,	,,	3 27 ,,	168 54 ,,	11 24 N	166 55 ,,	Jan. 21-99	North Pacific	147	943	6·4	435
436	Oct. 20-95	S.S. 'Nemesis'	J. F. Morrison, Master	35 20 ,,	133 40 E.	31 50 S.	128 40 ,,	April 20-99	South Coast	1277	380	0·3	436
437	Sept. 30-98	Ship 'Noetsfield'	J. B. Rugg, Master...	41 30 ,,	104 8 ,,	33 15 ,,	134 10 ,,	May 17-99	South. Ocean	229	2,000	8·7	437
438	Dec. 6-98	R.M.S. 'Ophir'	H. E. Inskip, Commander	38 24 ,,	141 14 ,,	38 23 ,,	142 10 ,,	Jan. 6-99	South Coast	31	55	1·8	438
439	May 5-99	,,	,,	35 25 ,,	132 32 ,,	38 4 ,,	141 5 ,,	Aug. 20-99	,,	107	510	4·8	439

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over.		Where Found.		Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day,	Ref. No.
				Lat. ° ′	Long. ° ′	Lat. ° ′	Long. ° ′						
440	Jan. 4-99	R.M.S. 'Orizaba'	A. W. Clarke, Commander	38 10 S.	140 35 E.	38 5 S.	141 0 E.	Jan. 10-99	South Coast	6	25	4·2	440
441	Jan. 30-99	,, ...	,, ...	33 45 ,,	114 16 ,,	32 0 ,,	115 30 ,,	April 5-99	West Coast...	65	145	2·2	441
442	Mar. 16-99	R.M.S. 'Ormuz'	E. A. Veale, R.N.R., Com...	38 38 ,,	149 40 ,,	30 12 ,,	153 12 ,,	July 13-99	East Coast...	119	705	5·9	442
443	Mar. 22-99	,, ...	,, ...	37 25 ,,	139 4 ,,	37 25 ,,	139 55 ,,	June 11-99	South Coast	81	48	0·6	443
444	Sept. 30-96	R.M.S. 'Orotava'	J. Linklater, Commander	38 24 ,,	141 16 ,,	38 15 ,,	141 20 ,	Dec. 4-98	,,	795	10	...	444
445	Sept. 9-98	R.M.S. 'Oroya'	A. McWatt, ,, ..	35 11 ,,	121 49 ,,	30 45 ,,	131 25 ,,	Aug. 25-99	West Coast...	350	610	1·7	445
446	Jan. 14-99	,, ...	,, ,, ..	35 32 ,,	126 17 ,,	32 55 ,,	124 40 ,,	May 8-99	South Coast	114	203	1·8	446
447	Jan. 6-98	Ship 'Patriarch'	M. Breach, Master... ...	11 39 ,	157 44 ,,	11 40 ,,	153 40 ,,	Mar. 20-99	South Pacific	438	272	0·6	447
448	May 21-98	S.S. 'Port Denison' ...	W. Newman, Master ...	0 43 N	84 12 ,,	5 0 N	73 0 ,,	Nov. 8-98	Indian Ocean	171	830	4·9	448
449	May 17-98	,, ...	,, ...	10 8 S	92 34 ,,	4 21 S	55 44 ,,	Nov. 10-98	,,	177	2,575	14·5	449
450	Oct. 15-98	,, ...	,, ...	40 33 ,,	75 16 ,,	32 40 ,,	125 15 ,,	May 29-99	South. Ocean	226	2,912	12·9	450
451	No date ...	Barque 'Rockhurst' ...	L. S. Quartermaine, Master	52 45 ,	55 10 W	29 13 ,,	114 40 ,,	Mar. 31-99	,,	..	8,850	...	451
452	Mar. 14-97	,, ...	,, ...	56 10 ,,	67 0 ,,	34 43 ,,	117 40 ,,	Mar. 26-99	,,	742	9,025	12·2	452
453	June 19-98	Ship 'Samuel Plimsoll' ..	J. Henderson, Master ..	39 35 ,,	127 55 E	40 0 ,	148 0 ,,	Dec. 29-98	South Coast	193	1,090	5·5	453
454	Feb. 2-99	Ship 'Silvercara'	J. Inkster, ,, ...	8 1 ,,	25 40 W	5 8 ,,	35 40 W	Mar. 28-99	S. Atlantic ...	54	656	12·1	454
455	Decr. 5-98	S S. 'Star of Victoria' ...	J. M. Hart, ,, ...	40 12 ,,	136 8 E.	38 15 ,,	141 0 E.	June 10-99	South Coast	187	288	1·5	455
456	Aug 31-98	N.D.L. 'Stuttgart'' ...	Captain Werner, Commd .	9 50 ,,	92 40 ,,	17 0 ,,	49 53 ,,	April 14-99	Indian Ocean	226	2,881	12·7	456
457	May 26-99	S.S. 'Talune'	G Hooper, ,, ..	43 47 ,,	149 26 ,,	43 35 ,,	147 5 ,,	Aug. 16-99	Tasman Sea	82	120	1·5	457
458	Mar. 9-95	S.S. 'Thermopylæ'... ..	A. Simpson, ,, ..	35 16 ,,	115 18 ,,	34 20 ,,	115 20 ,,	July 30-99	South Coast	1604	76	...	458
459	Jan. 8-98	,, ...	... ...	45 34 ,,	117 13 ,,	40 15 ,,	175 15 ,,	Nov 17-98	South. Ocean	314	2,925	9·3	459
460	Nov. 5-98	M.M. 'Ville de la Ciotat' ..	— Fiaschi, Commander ...	35 46 ,,	130 59 ,,	35 0 ,	136 53 ,,	June 28-99	South Coast	235	361	1·5	460
461	Feb. 2-99	,, ..	,, ...	33 16 ,,	152 11 ,,	33 37 ,,	151 20 ,	Feb 15-99	East Coast ..	10	55	5·5	461
462	June 21-99	,, ...	,, ..	33 14 ,,	113 13 ,,	33 38 ,,	115 30 ,,	July 21-99	West Coast	30	90	3·0	462
463	July 3-97	S.S. 'Waihora'	R. Neville, Commander ..	34 22 ,,	166 42 ,,	21 5 ,,	149 10 ,,	Dec. 28-98	Tasman Sea	543	1,410	2·6	463
464	Octr. 26-98	,, ...	,, ...	34 16 ,,	170 2 ,,	34 45 ,,	173 15 ,,	Dec. 6-98	New Zealand	41	190	4·6	464
465	Aug. 29-97	S S. 'Warrigal'	A. W. Bond, Commander	37 30 ,,	126 30 ,,	35 50 ,,	138 0 ,	Jan. 1-99	South Coast	490	655	1·3	465
466	Jan. 18-98	,, ...	,, ...	43 12 ,,	42 24 ,,	45 35 ,,	170 50 ,,	May 26-99	South. Ocean	493	6,550	13·3	466
467	Jan. 22-98	,, ...	,, ...	44 8 ,,	71 0 ,,	37 20 ,,	139 52 ,,	May 29-99	,,	492	3,494	7·1	467
		The following Papers have been received since the preceding List was arranged.											
468	Sept. 23-98	R M.S. 'Warrimoo' ..	C. W. Hay, Commander ..	5 8 S.	173 0 W	15 57 S.	173 59 W	Feb. 3-99	South Pacific	133	748	5·6	468
469	Dec. 16-98	,, ...	,, ...	1 15 ,,	171 8 ,,	5 35 ,,	176 20 E	Jan. 23-99	,,	99	932	9·4	469
470	Octr. 14-98	R.M.S. 'Aorangi'	C. Hepworth, R.N R., Com .	37 13 ,,	173 0 E.	36 25 ,,	174 15 ,,	June 24-99	Tasman Sea	253	91	0·4	470
471	...	S.S. 'Burrumbeet'... ...	C. B. Daly, Commander ...	36 15 ,	150 17 ,,	33 45 ,	151 19 ,,	July 10-99	East Coast...	...	185	...	471
472	...	S.S. 'Elingamite'	W. Waller, Commander ...	34 17 ,,	166 50 ,,	35 10 ,,	172 50 ,,	July 17-99	Tasman Sea	...	327	...	472
473	June 27-98	S.S. 'Moana'	P. T. Hull, Commander ...	4 15 ,,	167 45 W	10 54 ,,	162 28 ,,	June 1-99	South Pacific	339	2,089	6·1	473

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day,	Ref. No.
474	Sept. 17-99	R.M.S. 'Miowera'	F. A. Hemming, Com'der...	28 23 S.	153 26 E.	28 50 S.	153 31 E.	Sept. 21-99	East Coast ...	4	29	7·3	474
475	Sept. 26-98	S.S. 'Damascus'	A. H. H. G. Douglas, R.N.R.,	36 19 ,,	126 59 ,,	31 57 ,,	132 33 ,,	Sept. 1-99	South Coast	340	450	1·3	475
476	Octr. 21-97	Ship 'Patriarch'	M. Breach, Master... ...	41 24 ,,	150 33 ,,	164 0 ,,	21 0 ,,	Sept. 14-99	Tasman Sea	694	1,311	1·9	476
477	Sept. 13-99	R.M.S. 'Australia'	E. C. Downes, Fifth Officer	37 36 ,,	139 54 ,,	37 52 ,,	140 24 ,,	Sept. 25-99	South Coast	12	35	2·9	477
478	Sept. 12-99	R.M.S. 'Kasuga Maru' ...	E. W. Haswell, Commander	29 20 ,,	153 38 ,,	30 11 ,,	153 12 ,,	Sept. 30-99	East Coast ...	18	54	3·0	478
479	Sept. 28-99	,, ...	,, ...	30 1 ,,	153 23 ,,	30 5 ,,	153 12 ,,	Octr. 3 99	,,	5	12	2 4	479
480	Sept. 9-99	,, ...	,, ...	21 34 ,,	150 17 ,,	21 10 ,,	149 16 ,,	Octr. 5-99	,,	26	63	2·4	480
481	July 23-98	Barque 'Loongana' ...	W. T. Wawn, Master ...	31 5 ,,	159 30 ,	28 25 ,,	153 31 ,,	Sept. 20-99	Tasman Sea	423	400	0·9	481
482	July 26-99	S.S. 'Clitus'	M. McDonald, Master ...	37 39 ,,	149 55 ,,	40 15 ,,	147 55 ,,	Octr. 18-99	East Coast ..	84	216	2 6	482
483	Aug. 6-99	S.S. 'Ocampo'	Alfred J. Rainey, Master...	39 4 N	9 43 W	39 23 N	9 22 W	Aug. 17-99	Atlantic Oc'n	11	50	4 5	483
484	Aug. 30-99	S.S. 'Australasian'... ...	L. F. Taylor, Second Officer	39 35 S.	137 40 E.	38 17 S.	141 32 E.	Octr. 30-99	South Coast	61	236	3·9	484
485	July 31-98	Barque 'Loongana' ...	W. T Wawm, Master ...	21 2 ,,	176 1 ,,	18 0 ,,	178 40 ,,	Octr. 1-99	Fiji, Kaba Pt	427	162	0·4	485
486	Sept. 22-98	S S. 'Nineveh'	N. Allen, Master	44 36 ,,	112 48 ,	38 44 ,,	143 5 ,,	Nov. 15-99	Cape Patten	409	1,736	4·2	486
487	July 15-99	S.S. 'Wakatipu'	R. Neville, Master	40 0 ,,	169 57 ,,	37 16 ,,	174 55 ,,	Nov. 5-99	N. Z. Coast...	113	302	2 6	487
488	Octr. 15-99	M.M.S.S. 'Polynesien' ...	Chevalier, Commander ...	30 45 ,,	153 28 ,,	33 10 ,	151 40 ,,	Nov. 6-99	East Coast ...	22	277	12·6	488
489	April 9-99	R.M S. 'Ophir'	H. E. Inskip, Commander	35 39 ,,	134 18 ,,	35 58 ,	137 38 ,,	Nov. 12-99	South. Ocean	217	168	0·8	489
490	Nov. 13-98	R.M.S. 'Miowera'	F A Hemming, Com'der	28 10 ,,	178 28 ,,	20 17 ,,	169 59 ,,	Nov. 2-99	New Hebrides	354	838	2 4	490
491	Febr. 25-99	R.M.S. 'Victoria'	E. Crewe, Commander ...	14 58 ,,	97 39 ,,	4 0 ,,	40 0 ,,	Sept. 27-99	West Africa .	214	3,919	18 3	491

DRIFT OF THE "PERTHSHIRE."

Date. 1899.	Lat. ° ′	Long. ° ′	Direction of Wind	Date. 1899.	Lat. ° ′	Long. ° ′	Direction of Wind	Date. 1899.	Lat. ° ′	Long. ° ′	Direction of Wind.	Date. 1899.	Lat. ° ′	Long. ° ′	Direction of Wind.
April 28	38 37	156 48	light	May 10	36 56	159 39	S, fresh	May 22	34 23	162 00	NNW, 7*	June 3	29 37	165 48	S to SSE, strg
,, 29	38 28	157 00	SSW to N	,, 11	36 25	159 57	,,	,, 23	34 39	162 53	W, strg. gale	,, 4	29 17	165 16	SE light
,, 30	38 29	157 57	W to SE, 3 to 4	,, 12	35 54	160 23	SE, light	,, 24	34 29	163 40	SSW, strong	,, 5	29 6	165 0	N, light
May 1	38 10	157 57	SE, mod. gale	,, 13	35 29	160 30	,,	,, 25	34 09	164 15	,,	,, 6	29 25	164 54	NW, fresh
,, 2	37 21	157 28	E, 3 to 6	,, 14	35 14	160 34	variable	,, 26	33 57	164 57	,,	,, 7	29 40	165 6	NW to W †
,, 3	37 42	156 42	light NW to SW	,, 15	35 03	160 33	WSW, light	,, 27	33 30	165 36	SW, fresh	,, 8	29 24	165 38	SE, fresh
,, 4	37 49	156 50	E, light	,, 16	34 48	160 24	SSE, light	,, 28	32 54	165 59	E to SE, mod,	,, 9	29 34	166 9	WNW, fresh
,, 5	38 4	156 50	WSW gale	,, 17	35 18	160 24	NNE, 2 to 6	,, 29	32 33	165 19	E, mod. gale	,, 10	29 44	166 40	W to SW, md.
,, 6	38 11	157 36	,,	,, 18	35 48	161 6	N fresh	,, 30	32 12	164 40	E hard gale	,, 11	29 11	166 44	SE, fresh
,, 7	37 56	158 20	,,	,, 19	35 40	161 52	SSW, 6	,, 31	31 51	164 00	ESE md gale	,, 12	29 06	165 8	SE, light
,, 8	37 48	158 54	WSW, mod.	,, 20	34 55	162 04	SSW to S, 4	June 1	31 17	164 20	WSW, fr. gale	,, 13	'Talune' took the 'Perthshire' in tow at 8·25 a.m.		
,, 9	37 25	159 21	SSW, 4 to 6	,, 21	34 21	161 55	SSW to SE, 2	,, 2	30 25	165 20	SE, strg. gale				

* Strong gale, developed into a fierce gale. † Fresh to moderate gale.

DISCOVERY OF GLACIATED BOULDERS AT BASE OF PERMO-CARBONIFEROUS SYSTEM, LOCHINVAR, NEW SOUTH WALES.

By Professor T. W. E. David, B.A., F.G.S.

[With Plate IV.]

[*Read before the Royal Society of N.S. Wales, October 4, 1899. Date of final receipt October 25.*]

The late Government Geologist of New South Wales, Mr. C. S. Wilkinson was the first, as far as I am aware, to recognise evidence of ice action in the above district. The evidence observed by him was of the nature of large erratics of quartzite, slate, granite, etc., imbedded in a mass of fine sandy shales containing a rich marine fauna of Permo-Carboniferous affinities.

The locality where Mr. Wilkinson observed these evidences was on the main Northern Road between Branxton and Black Creek, and about eight miles distant from the spot near Lochinvar where glaciated boulders have been recently discovered. Although, as far as I am aware, Mr. Wilkinson did not publish any reference to glacial action in New South Wales further than his paper on supposed glacial action in the Triassic Hawkesbury Series,[1] he is yet entitled to a considerable share in the discovery, as it was his observations and verbal information which led Mr. R. D. Oldham and myself to this district where striated pebbles were subsequently found.

In 1885 Mr. R. D. Oldham, Assoc. R.S.M., Senior Superintendent of the Geological Survey of India, visited the erratic horizon near Branxton, and was fortunate enough to discover a pebble faintly

---

[1] Journ. Roy. Soc. N. S. Wales, Vol. XIII., 1879, pp. 105 - 107.—"Notes on the Occurrence of Remarkable Boulders in the Hawkesbury Rocks.

scratched and somewhat polished, which he considered to be of undoubted glacial origin.[1] There can be no question now in view of a later discovery this year that the markings on this pebble were really of glacial origin, though taken by themselves at the time they appeared to me, when the pebble was shown to me by Mr. Oldham, to be probable rather than positive evidence of contemporaneous ice action.

In 1887, in a paper read before the Geological Society of London,[2] I recorded the occurrence of numerous erractics in the Permo-Carboniferous Upper Marine Beds between Grasstree and Liddell, N. S. Wales. Many of these boulders were faintly scratched on the top, bottom and sides, but no grooves were visible. The markings on these boulders recalled the appearance of the surfaces of boulders in the redistributed boulder-clays of Glamorganshire in South Wales. I considered them to be of probable glacial origin, but the evidence was considered inconclusive by several members of the Geological Society of London who examined the boulders, and it must be admitted that the striæ were very faint.

In 1895[3] I exhibited at the Australasian Association Meeting in Brisbane a photograph taken by me of a block of granite measuring two feet three inches high by one foot three inches by at least three feet three inches long, bedded in the Upper Marine Permo-Carboniferous Rocks near the end of the Railway Cutting nearest Black Creek, west of Branxton Railway Station. The block is bedded on its edge, and the stratum on which it rests is indented, while the stratum above does not partake at all of the indentation, showing that the disturbance of the bed on which the boulder rests was due to the impact of the boulder as it fell

---

[1] Records Geol. Survey of India, Vol. XIX., p.t i., p. 44.

[2] Q.J.G.S., Vol. XLIII., pp. 190 - 196.—"Evidence of glacial action in the Carboniferous and Hawkesbury Series, N. S. Wales."

[3] Proc. Austr. Ass. Adv. Sci., Vol. VI., Brisbane—President's Address, Section C., p. 70.

probably from an ice raft, and not to any folding subsequent to the imbedding of the boulder. The peculiar position in which the boulder has come to rest with one of its narrow edges downwards is also in favour of its having been dropped from some height on to what at the time was a muddy sea-floor. Mr. R. D. Oldham has already pointed out *(op. cit.)* that the close association of large unbroken fronds of such delicate fossils as the *Fenestellidæ* with the boulders at Branxton precludes the possibility of the boulders having been carried to their present resting place by ocean currents; for some of these boulders weigh many tons, and an ocean current strong enough to move such huge blocks would obviously twist and tear the fronds of the *Fenestellidæ.* The latter, however, show every evidence of having been deposited in tranquil water, as they are in an exquisite state of preservation and so numerous as to constitute what might be termed a polyzoal shale horizon.

Last January Mr. W. G. Woolnough, B.Sc., Demonstrator in Geology at the University of Sydney, made the important discovery of a beautifully facetted and glacially striated pebble in a railway cutting west of Branxton Railway Station, at thirty-four miles seventy-two chains from Newcastle. This pebble is figured on *Plate* 4, fig. 1.

The opinions therefore of Mr. C. S. Wilkinson and Mr. R. D. Oldham as to there being undoubted evidence of glacial action in these beds has now therefore received important confirmation.

Recent discovery at Lochinvar.—A few days after the discovery by Mr. Woolnough, I was engaged in making a geological section near Lochinvar, in company with Mr. Oliver Trickett and Mr. E. C. Andrews, B.A. of the Geological Survey, and Mr. W. G. Woolnough, and we discovered at one and the same time what appears to be the base of the Permo-Carboniferous system, and an important glacial horizon. The best outcrop of these beds is about seventy chains north-east of the bridge at the township of Lochinvar. The strata containing the glacial boulders are about three hundred feet thick. The matrix in which the boulders are imbedded consists of fine shale, gritty in places, of a reddish-purple to purplish-brown colour, and bearing a remarkable general resemblance to some of the glacial shales in the Bacchus Marsh District of Victoria. The last mentioned, as is well known, contain such plant fossils as *Gangamopteris spathulata*, McCoy, which admits of their being provisionally correlated with the Permo-Carboniferous Glacial beds of N. S. Wales. The association, however, of the Triassic plant *Schizoneura* with the uppermost of the Glacial beds at Bacchus Marsh suggests that the latest of those beds may be referred perhaps to Triassic time. It was chiefly the close resemblance of the Lochinvar beds to those of Bacchus Marsh that led me to search the former for glacial pebbles. Upwards, the glacial beds at Lochinvar pass into ripple-marked, soft, flaggy sandstones, containing marine fossils of Lower Marine Age. Traced downwards the glacial beds are found to rest on hard tuffs which at a still lower level are seen to be interstratified with tuffaceous felsitic shales containing *Rhacopteris*. I propose, provisionally, to draw the line for the base of the Permo-Carboniferous System at the base of these glacial beds and at the top of the hard tuffs. The latter I propose for the present to consider as the top beds of the Carboniferous System. The change in the lithological character of the rocks on either side of this line is certainly very strongly marked: and there also appears to be a marked change of dip which lessens from 18° in the Carboniferous tuffs to 10° in the Glacial beds.

As regards the included boulders in the Glacial beds they vary in size from a few inches up to about two feet. The boulders consist of quartzite, sandstone, argillite, granite, diorite, greenish felsitic (?) rocks, serpentine etc. Perhaps from five to ten per cent., more or less, were originally glaciated, but owing to redistribution and attrition in probably shallow sea water it is exceptional to find boulders which have retained well defined grooves or striæ. The boulders vary from angular to rounded, and unlike those at Branxton and Grasstree, these exhibit distinct grooves as well as striæ, in this respect resembling those of Bacchus Marsh. The superficial markings, however, have I think a somewhat older appearance than those of the Bacchus Marsh boulders. The boulder reproduced in fig. 2, *Plate* 4, may be considered fairly typical of those in the Lochinvar Glacial beds. The ripple-marks in the flaggy sandstones near the top of the glacial beds show that shallow water conditions obtained at all events towards the deposition of the last of this group of beds.

No fossils, macroscopic or microscopic, have as yet been found in these three hundred feet of glacial beds. It is only at the very top of the beds that marine fossils, *Spirifer* and *Eurydesma*, have been found.

The height of the outcrop of these glacial beds above the sea is about two hundred feet. Their geological horizon is no less than approximately between 5,000 and 6,000 feet below that of the Branxton erratic horizon.

Mr. E. C. Andrews, B.A., is of opinion that some of the four hundred and forty feet of "Shales with erratics," as described on the section below, might also be considered as glacial beds. He states that he found striated pebbles in the paddocks where these upper beds had been denuded. These striated pebbles were not, however, *in situ* as were most of those found by us on the horizon of the beds three hundred feet thick. No favourable section was available for ascertaining whether or not a striated rock pavement lay at the base of the glacial beds.

Appended is a section showing the position of the glacial horizons respectively at Branxton and Lochinvar with reference to the Sydney Coal-field where it underlies the building of the Royal Society. It must not be assumed, however, that these beds all exist under Sydney, though there is a strong probability that at all events the Upper Glacial horizon, (that of Branxton), and even that of the Greta Coal Measures, would be met with under Sydney :—

				Feet.	Total Depth.
Section under Sydney.	I. TRIASSIC—Hawkesbury Series. Total thickness, 2,900 feet.		Hawkesbury Sandstone ...	1,000	1,000
			Narrabeen Beds	1,900	2,900
Continuation of Section in descending order, between Lake Macquarie and Lochinvar, New South Wales.	II. PERMO-CARBONIFEROUS SYSTEM. Total thickness about 13,800 feet.	Newcastle Coal-measures		1,200	4,100
		Dempsey Beds		2,000	6,100
		Tomago Coal-measures		700	6,800
		Upper Marine Series. Total thickness 5000 feet.	Upper Marine Beds above Branxton Glacial Horizon	3,500	10,300
			*Branxton Glacial Horizon		
			Upper Marine Beds below Branxton Glacial Horizon	1,500	11,800
		Greta Coal-measures Total thickness 130 feet.	Greta Coal-measures ...	130	11,930
		Lower Marine Series. Total thickness about 4,800 feet.	Marine Sandstones of Ravensfield Series ...	1,000	12,930
			Shales with occasionally Foraminifera	800	13,730
			Harpur's Hill Conglomerates and tuffs—Sandstones	270	14,000
			Marine Shales	1,000	15,000
			Marine (?) Shales with erratics and thin flows of Andesite and basic lava	900	15,900
			Shales with occasional erratics, perhaps striated	440	16,340
			Sandstones with bands of conglomerates passing down into marine ripple-marked flaggy beds	60	16.400
			*Lochinvar Glacial Beds ...	300	16,700
	III. CARBONIFEROUS		Tuffs, Sandstones and Shales with *Rhacopteris* and *Calamites*...	1,700	

On N. S. WALES COPPER ORES CONTAINING IODINE.

By Arthur Dieseldorff, M.E., Freiberg, Baden, Germany.

(Communicated by A. J. Bensusan, Assoc. R.S.M., F.C.S.)

[Received Oct. 30. Read before the Royal Society of N. S. Wales, Dec. 6, 1899.]

Last year Dr. W. Autenrieth of the Chemical Laboratory of the local University, found in a sample of cuprite from Cobar 0·14 per cent. of iodine; this specimen had been collected previously by the writer, and a fresh collection of N. S. Wales copper ores was sought. Samples were sent by Mr. W. B. Yates of Sydney, from thirteen different localities, each one was tested, and seven contained iodine.

The analysis was made as follows:—Five or six grammes were fused in a platinum or nickel crucible with twenty to twenty-five grammes of chemically pure caustic soda, the mass extracted with water and filtered, five to ten grammos of chloroform added, the vessel cooled, and a few drops of nitrite of sodium added ($NaNO_2$) solution acidified with sulphuric acid cooling it all the time. The iodine becoming free is absorbed by the chloroform, colouring it a reddish-pink.

In colorimetric analysis by comparison with standard solutions gauged from 0·1 per cent. down to 0·001 per cent., the percentage of iodine taken up by the chloroform can be found. The standard solutions are prepared from iodide of sodium. In the above manner the following percentages of iodine were found, and the samples also assayed for silver:—

		Iodine per cent.	Silver per cent.
No. 0.	Cuprite with malachite in the cavities of the former, being the original specimen collected by the author in N. S. Wales	0·13	0·002
No. 1.	Ore from British Broken Hill Mine, mixture of chrysocolla, cerusite cuprite, quartz	0·022	0·028

		Iodine per cent.	Silver per cent.
No. 2.	Earthy mixture of sulphide of copper, malachite, kaolin and gangue, from Balaclava, Broken Hill	0·01	0·005
No. 3.	Cuprite with little malachite, Cobar ...	0·017	0·002
No. 6.	Cuprite, mostly decomposed to malachite and azurite, Overflow Mine	0·01	0·006
No. 8.	Malachite with little sulphide of copper from Blayney	0·07	0·32
No. 9.	Malachite inside cuprite, and native copper, Wiseman's Creek	0·015	0·032
No. 10.	Sulphide of copper with a little malachite and kaolinised felspar	0·032	0·028

The following six samples showed no iodine, and were not tested for silver :—

No. 4. From Young Australia Mine, Cobar.
No. 5. From Nymagee.
No. 7. From New Mount Hope.
No. 11. From Tuglow, Oberon.
No. 12. From Bald Hill, Emmaville.
No. 13. From Brunswick River.

Samples of pure malachite from the Burra Burra Mine gave also negative results.

Iodine in such small quantities will not be payable, and therefore is not of commercial interest, but most decidedly will offer room for further research by the geologist and mineralogist.

Since Baumann (Professor of Chemistry, Freiberg) in 1886 found that the thyroid or scutiform gland (glandula thyrioidea) of human beings and most mammals contain iodine, if in a healthy and normal state, it is of physiological interest to find in nature new sources of it. It being somewhat inexplicable where this iodine comes from. As to the state in which the iodine exists in the ore, the writer is inclined to believe it to be cuprous iodide. The synthetic formula for silver iodide requires 46% of silver and 54% iodine, and will by comparison with above results not allow the construction of silver iodide ; on the other hand the iodine in the malachite (Nos. 8 and 9) must be present as hydrated oxy-iodide of copper being the natural product of marshite, just as atacamite is of nantokite. There is no doubt whatever, but that small quantities of marshite[1] are present in the copper ores.

The proof that it is distributed over much larger areas in New South Wales will be of interest, and leads the writer to hope that further material will be sent him from the colonies, especially for examination for the presence of bromine. The sample No. 8 from Blayney, contains in all probability bromine, but there was not enough of it to verify the tests. Should the percentage of iodine go higher, say up to 0·1% for large quantities of copper ores, it will doubtless be payable to extract it by sublimation in the flux. Iodine amounting to 0·1% means 1 kilo per ton, the present price is 30/- per kilo, while the cost of production would be 2/- to 3/-. Iodine is recovered as a by-product in the nitrate factories of Chili. The world's consumption in 1896 was 300 tons, value £350,000, while Chili had in stock at the end of 1896, 900 tons. To keep the price up enormous quantities of iodine are allowed to go to waste annually. There is very little iodine now made from seaweed.

---

[1] See Journal of the Royal Society of N. S. Wales, XXVI., 1892, p. 328.

ON THE *DARWINIAS* OF PORT JACKSON AND THEIR ESSENTIAL OILS.

By R. T. BAKER, F.L.S., Curator, and H. G. SMITH, F.C.S., Assist. Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

SUMMARY OF CONTENTS.

(*a*) Botany of Species.
(*b*) Chemistry of the Oils.
(*c*) Possibilities of Cultivation.

(*a*) BOTANY OF SPECIES.

The genus *Darwinia* was established by A. Rudge in 1817 in the Transactions of the Linnean Society, Vol. XI., 299, on specimens collected in the neighbourhood of Port Jackson by Robert Brown. It was named in honour of Erasmus Darwin, M.D., of Lichfield, author of several botanical works. The first species described was *D. fascicularis.*

Although the genus was founded originally from eastern species it might almost be said to be purely West Australian, as over thirty species are recorded from that colony, whilst only one occurs in Queensland, two in South Australia, two from Victoria, and three from New South Wales.

Darwinia fascicularis, Rudge (B. Fl. III. 13.) is a virgate shrub, varying in size in different localities, about five feet being the maximum height in the coast form. The mountain variety rarely exceeds two feet. The leaves are slender, numerous and crowded, and vary in length from four to eight lines. The flowers although small are attractive, being sometimes all white, or pink and white.

It occurs on sandy soil mostly, and covers many hundred acres of ground between Botany, La Perouse, and the coast. It has been found north of Manly and also on the Blue Mountains at King's Tableland, Wentworth, and Lawson.

D. taxifolia, A. Cunn., (B. Fl. III., 12) is a shrub of about the same dimensions as *D. fascicularis*, Rudge, but is easily distinguished in the field from that species by the shape of the leaves, their glaucous appearance, and its reddish branchlets. The flowers are not so attractive as those of *D. fascicularis*. Its habitat is almost identical with that of the previous species, although it has, however, been found as far south as Ghunnyenara Mountain (W.B.) It differs botanically from *D. fascicularis* in its laterally flattened, triquetrous leaves.

D. taxifolia, A. Cunn., var. *grandiflora*, Benth. As this variety is very constant throughout its range and it possesses distinctive characters from *D. taxifolia*, it is intended to raise it to specific rank when its chemical constituents have been investigated. It occurs in a very luxuriant form at Berowra. The leaves are much longer and broader than those of the other species, and the flowers are also more showy and larger than those of the other species.

Histological Notes.

A transverse section shows an absence of a midrib, but stomata are very numerous on the whole surface. The contour of a section much resembles a horse-shoe in shape, the flat edge corresponding to the upper surface of the leaf. Some difficulty was experienced in working upon a leaf-section measuring less than half a line in diameter. The very highest power objective was required to determine the form and structure of the various cells, etc. The palisade layers were found to be arranged with their long axes at right angles to the cuticle or surface, and of course containing chloroplastids. The layers were connected to a central body by spongy tissue, without chloroplastids. Vascular bundles were present, being distributed throughout the leaf structure. The oil glands appear to be numerously distributed throughout the leaf, being partly immersed in the cuticle and palisade layers. The oil globule is very minute and not easily detected in the cells. The cell is circular in shape with elongated cells forming the usual guard cells.

(*b*) CHEMISTRY OF THE OILS.

The Essential Oil of Darwinia fascicularis.

This oil was obtained by steam distillation on fresh material. When first distilled it is reddish-brown in colour, very mobile, with a somewhat strong odour, which when diffused is pleasant. The principal constituent of this oil is the important ester geranyl-acetate. When placed in a freezing mixture a small quantity of a stearoptene separates, but it is difficult to remove, and was not obtained in a separate condition. The specific gravity of the crude oil was ·9154 at 19° C. The colour was too dark to enable the rotation to be taken, but this colour being due to a constituent of an acid character is readily removed by agitating the oil with a very dilute solution of aqueous potash. The oil is then of a very light lemon tint and the rotation in 100 mm. tube was 1·2° to the right.

The yield of crude oil obtained by us from material collected under conditions that would obtain commercially, was ·318 per cent., the mean of several distillations on a total of 1,280 pounds of leaves or terminal branchlets. The collections were made in the months of March, September, October, and November. The yield of oil obtainable during these portions of the year is about the same for each month, and the percentage of ester present in the oil is also about the same, with the exception that the November oil was the richest in geranyl-acetate.

The material was obtained from shrubs growing naturally at La Perouse in the neighbourhood of Port Jackson. It was somewhat difficult to obtain the material without a predominance of woody stem; the shrubs, however, lend themselves very readily to clipping, and then grow more compact and bushy. It is to be expected, therefore, that in a state of cultivation (and of course no permanent success can be obtained without cultivation) the yield of oil would be much greater, as a larger quantity of the leafy portion of the plant would be obtainable. That this is so is shown by the fact, that after our September collection we obtained leaves from the same bushes that had previously been clipped for distillation six months before. The oil obtained was the same in colour and constituents, but the yield was slightly greater, and with careful growing and clipping not less than ·5 per cent. of oil would certainly be obtainable, as in one distillation we obtained ·456 per cent. of oil and ·436 per cent. in another. Of course the yield of oil depends upon the amount of leaves taken in proportion to the stem; the oil is obtained from the leaves of the plant, and as the leaves are very small, this is the more important. Six distillations on material when flowers were present gave a yield of oil equal to ·31 per cent. as a mean, while five distillations in March, when the plant is not in flower, gave ·314 per cent. as a mean yield of oil, so that the yield was actually greater when the plant is not in flower. We thus conclude that the yield of oil is practically the same throughout the whole year, and that it differs little in composition at any time, the average content of geranyl-acetate being about 60 per cent. The oil from the November distillation contained 65 per cent. of geranyl-acetate; this is the time of year when in the neighbourhood of Sydney the vegetation is most vigorous.

These results in regard to the yield and composition of the oil of *Darwinia fascicularis* are the more important when taken in conjunction with the oil from *D. taxifolia*, as this oil contains but just over five per cent. of an ethereal salt calculated as geranyl-acetate, and its value is poor when compared with the oil from *D. fascicularis.*

When the crude oil of *D. fascicularis* was treated with boiling alcoholic potash to saponify the ester, and the regenerated oil distilled under atmospheric pressure, very erratic results were obtained, and it is evident that decomposition or rather alteration takes place under this treatment. Three distillations each of 100 cc. of the saponified oil under different treatment with boiling alcoholic potash gave results as follows:—In the first 54 per cent. distilled between 190° and 195° under ordinary pressure, and 28 per cent. between 225° and 260°. In the second only 3 per cent. came over below 195° and only 9 per cent. below 205°. In the third only 2 per cent. distilled between 183° and 215°, and only three per cent. more below 220°; between 220° and 235° no less than 58 per cent. was obtained; this fraction was largely geraniol, its specific gravity was ·8874 at 20°; it gave a solid compound with calcium chloride, it formed citral on oxidation, it had an odour of roses. It is thus evident that change had taken place during the process of saponification by the methods used, as these three determinations were made from different portions of the same sample of oil. On ascertaining these facts, attempts were made to remedy this, and it was subsequently found that saponification of the ester takes place readily in the cold, using a semi-normal alcoholic solution of potash, and that the saponification is practically complete under three hours as will be seen from the following determinations :

1·9563 gram oil was added to 20 cc. semi-normal alcoholic potash and allowed to stand ten minutes at ordinary temperatures, it was then found that 4 cc. of potash solution had been absorbed; saponification figure therefore was 57·1, equal to 20 per cent. of ester, calculated as $C_{10}H_{17}OOCCH_3$.

1·274 gram. oil in 20 cc. alcoholic potash and allowed to stand one hour at ordinary temperatures absorbed 7·3 cc. of potash solution, saponification figure 160·4 equal to 56·1 per cent. of ester. The regenerated oil had still a faint odour of the ester showing that saponification had not been complete.

1·35 gram oil in 20 cc. alcoholic potash and allowed to stand three hours at ordinary temperatures absorbed 8·1 cc. potash solution, saponification figure 168 equal to 58·8 per cent of ester.

On allowing a sample to stand sixteen hours no different results were obtained. From the results of saponification obtained by boiling with the alcoholic potash solution for half an hour, it appears that there is a small quantity of an ester present not decomposed in the cold. When distilling off the volatile acids an odour was detected indicating an acid other than acetic acid, but it can only be present in minute quantity as will be seen from the result of the analysis of the silver salt obtained from the mixed volatile acids.

A larger quantity of oil was then taken for saponification by semi-normal alcoholic potash at ordinary temperature and allowed to stand four hours; it was found at the end of that time that saponification was practically complete. The regenerated oil is yellowish in tint, specific gravity ·898 at 20°, rotation 100 mm. tube + 0·75. It has a pleasant rose odour when diffused, and its freshness and fragrance are excellent. The objectionable odour detected when the ester is saponified by heat is missing, and it is thus seen to be unnecessary to apply heat to obtain separation of the alcohol.

When this regenerated oil from the cold saponification was distilled under ordinary pressure (760 mm.) less than three per cent. distilled below 225°, between 225° and 235° 43 per cent. was obtained, and between 235° and 240° 26 per cent. distilled. The fraction (225 – 235°) had no rotation, its specific gravity was ·890 at 15° C., and it was principally geraniol. The fraction 235 – 240° had a specific gravity ·892 at 21° C. Some decomposition had taken place under atmospheric pressure, but when distilled under reduced pressure about 60 per cent. of a fraction could be obtained, largely geraniol, as there are no terpenes or low boiling constituents to interfere. It is thus apparent that when the ester is decomposed in the cold but little alteration, if any, of the alcohol takes place, but it cannot be boiled with alcoholic potash without undergoing alteration. It is also apparent that the alteration is in the direction of the formation of lower boiling constituents.

We have obtained in four different directions during this research, a product boiling at 183 – 185° (uncor.) and having a very low specific gravity ·836 at 15°. It has no rotation when obtained under the most favourable conditions. It is worthy of remark that this product obtained by four different routes has the same boiling point in all; three gave practically the same specific gravity, while the fourth was a little higher. It is certain that it is a product of alteration formed when the crude oil is saponified by boiling with alcoholic potash under ordinary atmospheric pressure, as it does not exist in the oil obtained by cold saponification. When gently oxidised citral was obtained, and on further oxidation a viscid brown substance having an aromatic odour. On boiling with acetic anhydride and sodium acetate a determination showed 24·1 per cent. of ester to have been formed. It should not now be difficult to obtain it in a pure condition, and further investigation will be made concerning it.

In a paper by Bertram and Gildmeister[1] it is stated that the essential oils of the pelargoniums (the French, African, and Reunion geranium oils) contain a considerable proportion of geraniol which boils at 225 – 230°, but there is also present a second alcohol which has not yet been obtained in a pure condition, and whose properties and composition have in consequence not been determined. This second alcohol, they say, appears to be differentiated from geraniol by its lower boiling point, its lower specific gravity and its behaviour towards hydrogen chloride and towards calcium chloride with which it forms no solid compound. Possibly this may be also a product of alteration.

Barbier[2] obtained an alcohol by heating geraniol with alcoholic potash, this he stated to be dimethylheptenol $C_9H_{18}O$. This being questioned, he supports his statement in a paper[3] by publishing results of a synthetical dimethylheptenol.

Tiemann[4] shows that when geraniol is heated with alcoholic potash the product is methylheptenol $C_8H_{16}O$. This boils about 173° under atmospheric pressure.

It thus appears that different bodies are obtainable from geraniol or geraniol bearing compounds when these are heated with alcoholic potash under different conditions.

---

[1] J. Pr. Chem. 1896 [2] 53, 225 – 237—Abstract Journ. Chem. Soc., June 1896, 381.

[2] Compt. rend. 126, 1423. [3] Compt. rend. 128, 110. [4] Ber. 31, 2989.

The crude oil of *D. fascicularis* contains free alcohol, probably geraniol, as practically no constituent was present boiling below 222°.

By referring to Schimmel & Co's list of known constituents of essential oils, Report, April, 1897, we find that geraniol occurs in the oil from the following:—

Fresh flowers N.O. Rosaceæ (Roses).
Herb N.O. Geraniaceæ (Pelargonium sp.)
Grass N.O. Gramineæ (Andropogon sp.)
Flowers N.O. Rutaceæ (Citrus sp.)
Flowers N.O. Anonaceæ (Cananga sp.)
Wood N.O. Burseraceæ (Bursera sp.)
To this list may now be added; Shrub N.O. Myrtaceæ (Darwinia sp.)

With the doubtful exception of the oil from *Eucalyptus citriodora* this appears to be the first time that geraniol has been found occurring in plants belonging to the Myrtaceæ, although this genus consists so largely of oil-yielding plants.

Distillation of the original oil.

100 cc. of the crude oil of *D. fascicularis* was distilled under atmospheric pressure, only a few drops came over below 170°, principally water; the thermometer then rises rapidly with an occasional drop to 215°, between 215° and 222° 5 per cent. distilled, three fractions were then obtained :

1. 222° to 230° obtained 32 per cent.
2. 230 ,, 240 ,, 32 ,,
3. 240 ,, 270 ,, 22 ,,

Specific gravity first fraction ·897 at 20°
,, second ,, ·906 ,, 20°
,, third ,, ·913 ,, 20°

Another distillation gave—

222° to 230° = 34 per cent.
230 ,, 235 = 47 ,,
235 ,, 240 = 67 ,,

This was taken as one fraction, it had no rotation, its specific gravity at 18° = ·9036.

Some decomposition had taken place, the odour of acetic acid being most marked, so that the oil cannot be distilled under atmospheric pressure without alteration. The distillation results show an entire absence of terpenes and other constituents boiling at a low temperature, and the same results were also secured from the oil obtained by cold saponification.

When the fraction (222 – 240°) was saponified by alcoholic potash in the cold and the oil treated with dry calcium chloride, a solid mass was obtained; this was ground up with ether and dried at pump as much as possible, then pressed between drying paper until dry. On decomposing this with water 30 cc. of a slightly coloured oil was obtained; this had a fine rose odour, specific gravity at 16° = ·886, on distillation the greater portion distilled between 228 – 230° was practically colourless, had no rotation, and formed citral on oxidation. These characters indicate geraniol. It is also readily soluble to a clear solution in 55 per cent. alcohol. The crude oil of *D. fascicularis* does not form a clear solution with two volumes of 70 per cent. alcohol, but does so with 90 per cent. alcohol.

Saponification of the Ester.

Several determinations of the percentage of ester in the crude oil of *D. fascicularis* from several distillations obtained at different times, gave 57·05 per cent. as the least, and 65·1 per cent. as the greatest; this was from oil distilled in November. When the dark colour was removed by shaking with a very dilute solution of aqueous potash, the determination on the same sample of oil showed a diminution of 1·4 per cent. or 60·9 reduced to 58·5 per cent. A determination on the fraction 222 – 240° obtained on distilling the crude oil gave 73·1 per cent. of ester. The method adopted in these determinations was to weigh the oil into a flask, add 20 cc. of correctly standardised alcoholic potash (semi-normal) and heat to boiling on the water bath for half an hour with air condenser. It was then cooled, water added, also a few drops of phenolphthalein and the solution titrated with semi-normal sulphuric acid. The weight of potash used in the saponification was then calculated, the saponification figure determined, then

$$\frac{\text{saponification figure} \times 19{\cdot}6}{56} = \text{per centage of ester.}$$

1. 2·6468 gram required ·4312 gram potash
   S.F. 163 = 57·05 per cent. ester.
2. 1·6502 gram required ·2688 gram potash
   S.F. 163 = 57·05 per cent. ester.
3. 1·8938 gram required ·3248 gram potash
   S.F. 171·5 = 60 per cent. ester.
4. 1·8769 gram required ·3248 gram potash
   S.F. = 170·5 = 59·7 per cent. ester.
5. 1·777 gram required ·3108 gram potash
   S.F. = 174 = 60·9 per cent. ester.
6. 1·7649 gram required ·3276 gram potash
   S.F. = 185·6 = 64·9 per cent. ester.
7. 1·8509 gram required ·3444 gram potash
   S.F. = 186 = 65·1 per cent. ester.

(Nos. 6 and 7 represent the November oil.)

Determination of the free Alcohol.

10 cc. of the November oil containing 65 per cent. of geranyl acetate was mixed with an equal volume of acetic anhydride and a little anhydrous sodium acetate; this was boiled for three hours, water was then added and the whole again heated, the oil was separated, washed and dried.

1·3558 gram of this oil required ·3164 gram potash S.F. = 233·4 = 81·68 per cent. ester. We thus obtain 16·68 per cent. increase of ester, which calculated from $C_{10}H_{17}OOCCH_3$ represents 13·11 per cent. of free alcohol. From the distillation figures this alcohol is probably geraniol.

Oxidation of the alcohol to aldehyde.

The fraction 222 – 240° was saponified and the oil distilled; the fraction 227 – 230° was oxidised by bichromate of potassium, using Beckmann's method. Oxidation takes place readily, giving an oil with a strong lemon odour. The separated oil was agitated with a solution of acid sodium sulphite, the crystalline mass separated, purified, and decomposed by sodium carbonate. The aldehyde thus obtained had a strong odour of lemons. It was treated with pyrotartaric acid in absolute alcohol with β-naphthylamine, also dissolved in absolute alcohol (Doebner's reaction).[1] A lemon-yellow crystalline substance was obtained on cooling, melting at 197 – 198° and is the alcyl-β-naphtocinchoninic acid characteristic of citral. The same aldehyde was also obtained when the alcohol from the calcium chloride compound was oxidised. Citral is therefore, the aldehyde obtained on oxidising the alcohol of the ester in the oil of *D. fascicularis.*

Determination of the acid.

The liquid obtained after saponification and separation of the oil was made alkaline and evaporated nearly to dryness, this was then acidified with sulphuric acid, the sulphate of potassium separated and the liquid distilled. The volatile acid obtained in the distillate was almost entirely acetic acid, although the odour indicated the presence of a small quantity of another volatile acid. The silver salt was obtained, purified, and the molecular value of the acid determined. 0·2796 gram of the silver salt gave on ignition 0·1789 gram silver = 63·98 per cent.; CH_3COOAg requires 64·6 per cent. silver. The molecular value also shows 61·6 for the acid instead of 60 acetic acid. The probable presence of a small quantity of an acid with a higher molecular value is thus indicated. The reactions were those of acetic acid, no formic acid could be detected. The distillate was neutralised, evaporated down and allowed to crystallise; a good quantity of crystallised acetate of sodium was obtained showing some well developed monoclinic crystals. The principal acid of this ester is, therefore, acetic acid.

---

[1] Ber. 27, 352.

Essential oil of Darwinia taxifolia.

This oil was distilled from fresh material. It differs largely from the oil of *D. fascicularis* in all its characters. The specific gravity of the crude oil was ·8734 at 21° C. and its rotation in 100 mm. tube was 6·5° to the left.

When distilled 4 per cent. came over below 165°, and by 175° 54 per cent. had been obtained, by 185° 65 per cent. had distilled. From 165 – 185° was considered as first fraction. Second fraction 185 – 230° = 6 per cent. Third fraction 230 – 255° = 16 per cent.

Specific gravity, first fraction = ·8545 at 21° C.
„ third fraction = ·9062 „
Rotation 100 mm. tube, first fraction – 10·6
„ „ „ third fraction + 4·7

The lower boiling portion of the first fraction consisted largely of lævopinene shown by its boiling point and the formation of its nitrosochloride melting point 103°. Neither phellandrene nor cineol could be detected. The ester determination gave results as follows:—1·3381 gram crude oil required ·0196 gram potash

S.F. = 14·5 = 5 per cent ester.
1·2176 gram required ·0196 gram potash
S.F. = 16 = 5·6 per cent. ester.

An ester determination on the third faction gave the following result:—

1·5175 gram required ·0532 gram potash
S.F. 35 = 12·3 per cent. ester.

Determination of free alcohol.

10 cc. of the crude oil was boiled three hours with an equal volume of acetic anhydride and a little anhydrous sodium acetate. The separated oil was washed and dried:

1·7198 gram required ·0756 gram potash
S.F. = 44 = 15·4 per cent. ester.

The oil thus contains some free alcohol, but it is doubtful if it be geraniol, as the regenerated oil, after saponification of the ester had a marked odour of linalool. If the alcohol be considered as having a formula $C_{10}H_{18}O$ there was 7·9 per cent. of alcohol present in the free condition in this oil. The bromide obtained from the first fraction was liquid.

The commercial prospects of this oil, in comparison with that from *D. fascicularis*, being poor, no further investigation of its remaining constituents was undertaken.

The yield of oil from *D. taxifolia* is almost identical with that from *D. fascicularis*, being ·313 per cent. The crude oil is much lighter in colour than that from *D. fascicularis*. The crude oil did not form a clear solution with two volumes of 90 per cent. alcohol.

(c) Possibilities of Cultivation.

As these species do not present any very marked horticultural attractions they have received little or no attention from gardeners and are therefore only known in the wild state, and so very little data can be given under this heading. However, as *D. fascicularis* has such good commercial possibilities it is hoped that experiments will be taken up at once in regard to it.

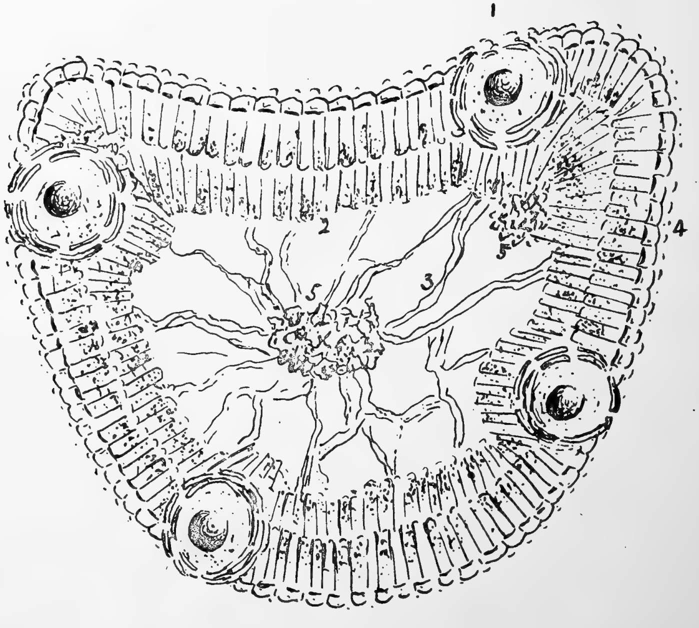
The seeds are exceedingly small and apparently difficult to obtain, but they must be numerous, and with ordinary care and application they could be easily collected. From a few experiments made with plants of *D. fascicularis*, this species survives transplanting very well. This species is peculiar to the Hawkesbury Sandstone country, so that it will grow in very poor soil, and is evidently able to survive the severest drought, as during the last four years the rainfall has been almost the lowest on record, and yet the shrubs at La Perouse have been in no way affected by it.

Like most of our indigenous plants it is an evergreen, so that its leaves could be distilled irrespective of the season. Plants at La Perouse from which all our material was obtained are all in vigorous health, and have sent forth new growth soon after clipping. In no instance were the trees cut down or uprooted, but only the terminal branchlets cut off.

In its natural state it has a tendency to run very much to wood, but this is probably owing to the plants growing so very close together—in many cases almost forming an impenetrable bush. Under cultivation and with the trees planted some distance apart this defect should be removed, and bushy foliaceous plants produced. The results of the experiments in transplanting now being carried out at this Museum will be available to the general public at any time.

We wish to express our acknowledgements to Miss S. Hynes, B.A. for the locality of *Darwinia taxifolia* at Randwick, to Mr. Connelly for photographs of the plants, and to Mr. H. Oakes (one of the Technical College Students in organic chemistry) who gave up much time to assist.

Transverse Section of Leaf of *Darwinia fascicularis*, A. Rudge
(Highly magnified.)



1—Lysigenous oil gland with oil globules. 2—Palisade-layers. 3—Spongy tissue. 4—Epidermis of Leaf. 5—Vascular bundles.

ORBIT ELEMENTS COMET I., 1899 (SWIFT).

By C. J. MERFIELD, F.R.A.S.

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

Introduction.—This comet was discovered by Prof. Lewis Swift of the Lowe Observatory, on the date 1899 March 3, in the constellation Eridanus. The comet was described as bright and visible to the naked eye, and having a short tail. During the second week of March this apparition appeared to the writer as a nebulous object of about the 6th magnitude.

During March the comet was well placed in the western sky for southern observers, and Mr. John Tebbutt, F.R.A.S., was successful in obtaining twenty-six differential measures, between the dates 1899 March 7, 1899 March 31, at his private observatory Windsor, New South Wales. Many northern observers obtained measures also, but the comet was not so well placed for them during this period of visibility. Throughout the month of April the comet was in proximity to the sun so that observations could not be obtained.

The comet arrived at perihelion during mid-day on April 13, and about May 5 it was plainly visible to the naked eye as a morning object in the eastern sky, its brightness having considerably increased, and was well placed for observatories of both latitudes. From this date forward until the end of July it has been well observed by most of the leading observatories. For the latitudes of the southern half of Australia the comet was just below the horizon from May 27 to June 2, but Mr. Tebbutt again commenced observing on June 28, and concluded a fine series of observations on the evening of July 13.

Towards the end of June the comet still remained well defined as seen in large telescopes, and permitted accurate observations to be made, but its distance from the earth was increasing rapidly and was out of reach of ordinary telescopes during August.

Signor Cerulli succeeded in making several comparisons on the date 1899 July 31, which is one of the latest observations published. The comet was, on this date, described by the observer as a faint nebula having a nucleus of about the 14th magnitude.

Physical Aspects.[1]—During 1899 March, the comet appeared as a nebulous mass some four or five minutes of arc in diameter, with a central condensation. After perihelion passage however, some interesting changes were noticeable. Mr. Perrine of the Lick Observatory, saw the nucleus double and obtained measures of their distance apart, during the period 1899 May 11 to May 14 the distance between the components increased from 12″ to 18″. This increasing distance would appear to be partly due to an actual separation of the two portions, but the writer has not examined the question critically. Prof. Barnard of the Yerkes Observatory also observed this aspect of the comet on May 20, and obtained several measures until May 23, the distance between the components increasing during this interval from 29 to 38 seconds of arc. A photograph taken by this observer shews a slender tail some eight degrees in length.

On June 5th a considerable increase in brightness took place, which was observed by many. Prof. Hartwig says, that there was no doubt that the comet had increased in brightness about this date, the magnitude of the nucleus being about 9·5, while the comet as a whole being of the 5th magnitude, the diameter of the coma being some 12 minutes of arc. Dr. Schorr also says that on the same date the nucleus appeared to be excentrically placed, the magnitude being 6·5, whole comet 5th magnitude, the diameter being 9 minutes of arc. Part of this increased brightness may have been due to some physical change in the mass, but it may be mentioned that the comet was nearest to the earth on the date 1899 May 29, and the distance was not increas-

---

[1] Astronomische Nachrichten, 3572-74-86. Astronomical Journal, 464. Publications of the Astronomical Society of the Pacific, 1899 August. Bulletin de la Société Astronomique de France 1899. Comptes Rendus, 1899.

ing rapidly, also that the earth was approaching the line of sight between the sun and comet; these facts combined would possibly have some effect on the brightness.

The publications of the Astronomical Society of the Pacific contain some beautiful photographs of this comet, taken at the Lick Observatory by Messrs. Coddington and Palmer. These photographs seem to indicate that on May 6th the tail consisted of one main branch some seven degrees in length with side streamers, on the following day the streamers, also the tail, had a a twisted appearance. A sharp bend in the main tail was noticed on May 9th and a day later it would appear to have been longest, being some nine degrees in extent. On May 19th the tail had a curious unsymmetrical aspect, as if one side had been destroyed. On all the dates, the axis of the main tail pointed nearly away from the sun, the greatest observed deviation being about three degrees.

In the same publications Mr. Perrine gives further details of the curious separation of the two portions and their subsequent recession from one another. He also gives some observations made to examine whether the refraction produced by the comet appreciably altered the positions of the stars over which it passed; the result of his inquiry is negative.

Orbit Elements.—Preparatory to the calculation here given, approximate orbit elements were deduced from a combination of Mr. Tebbutt's observations of March, these were kindly sent in manuscript, but now published, A.N. 3579. The usual formulæ for the determination of the orbit elements of a celestial body from three positions being employed; the result of this calculation will be found in the *Astronomische Nachrichten*, Band 149, No. 3575. The following remark was made by the computer, that " the observations were not represented by a parabola, and that the ratio of the residuals indicated some alteration to the eccentricity." Prof. Kreutz in a footnote says, "*Die aus einer grösseren Zwischenzeit abgeleiteten Elemente von Dr. Stichtenoth in Nr 3567 ergeben keine Abweichung von der Parabel*

It will be seen from the table of "Residuals for the Equations of Condition" that Dr. Stichtenoth's elements represent the observations during the period of the extreme places used in his calculation March 4 to May 5 fairly well, but on the date 1899 May 26, the residuals amount to $+13^{s}.2$ in right ascension and $-118''$ in declination and increased to $+21^{s}.7$ in right ascension on June 12. The elements II. by Dr. Stichtenoth are however somewhat better than elements I., so that they have been adopted as the assumed elements for correction.

Having computed an ephemeris from elements I., for observer's purposes, it was not thought necessary to form a new ephemeris, this was therefore adopted for comparing the observations.

Previous to this calculation, orbit elements[1] were deduced from five normals and with satisfactory results, these were forwarded to Prof. Kreutz. With the information gained it was thought advisable to increase the number of equations of condition, and also introduce other observations into the calculation of the normals, these observations becoming available to the writer just prior to this calculation. This final investigation the author has much pleasure in presenting to this Society. The results obtained are on the assumption of undisturbed motion; the perturbations produced by the earth as well as those by the inner planets will be small, and will not affect the results materially.

CALCULATION OF THE ORBIT ELEMENTS.

Elements I. (Merfield.)[2]

$$T = 1899 \text{ April } 12{\cdot}98324 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 8^{\circ}\ 43'\ 48''{\cdot}8 \\ \Omega &= 24\ \ 59\ \ 41{\cdot}4 \\ \iota &= 146\ \ 15\ \ 35{\cdot}5 \end{aligned}\right\} 1899$$

$$\text{Log } q = 9{\cdot}5138016$$

Equation for Co-ordinates.

$$\begin{aligned} x &= [9{\cdot}9876979]\ r \sin (v + 77^{\circ}\ 32'\ 24''{\cdot}76). \\ y &= [9{\cdot}9962487]\ r \sin (v + 165\ \ 42\ \ 49{\cdot}87). \\ z &= [9{\cdot}4292867]\ r \sin (v + 47\ \ 28\ \ 20{\cdot}21). \end{aligned}$$

---

[1] Astronomische Nachrichten, No. 3602. [2] *Ibid.*, No. 3575.

Elements II. (Dr. Stichtenoth.)[1]

$$T = 1899 \text{ April } 12{\cdot}97774 \text{ G.M.T.}$$

$$\left.\begin{array}{lr} \omega = & 8^\circ\ 41'\ 29''{\cdot}70 \\ \text{☊} = & 24\ \ 58\ \ 15{\cdot}10 \\ \iota = & 146\ \ 16\ \ \ 8{\cdot}50 \end{array}\right\} 1899$$

$$\text{Log } q = 9{\cdot}5137940$$

$$q = 0{\cdot}326432930$$

Equations for Co-ordinates.

$$x = [9{\cdot}9877266]\, r \sin (v + 77^\circ\ 31'\ 14''{\cdot}16).$$

$$y = [9{\cdot}9962519]\, r \sin (v + 165\ \ 41\ \ 50{\cdot}06).$$

$$z = [9{\cdot}4288656]\, r \sin (v + 47\ \ 26\ \ 12{\cdot}86).$$

Observations.—The observations used in forming the definitive positions of the comet ; have been obtained from the pages of the *Astronomische Nachrichten*, *Comptes Rendus*, and the Astronomical Journal, but in several cases they have been communicated in manuscript previous to publication.

As most of the observations used are comparisons with stars, the true positions of the comet depend in a great measure upon the accuracy of the adopted co-ordinates of these comparison stars. Before deciding the co-ordinates of the comet, the star places have been investigated, and to several, proper motion has been applied; they were also reduced to the A.G. system, the quantities for this purpose being interpolated from the tables of Professor Auwers, A.N. 3195 – 96, 3413 – 14.

The reduction of the mean places of the stars to apparent has been made by the usual formulæ, adopting the quantities of the Nautical Almanac. In finding the parallax of the comet in right ascension and declination the value 8·″80 has been used for the equatorial horizontal parallax of the sun.

The following table contains the results of the comparison of the observations with the ephemeris ; also the weights adopted in forming the normals, these depend on the number of comparisons made and combined to form a completed observation ; in a few instances the number of comparisons has not been given by the observer, in these cases the computer has used his discretion.

---

[1] Astronomische Nachrichten, No. 3567.

TABLE OF RESIDUALS.

Normals.	Observatory.	Date 1899.		Residual α o − c	Weight p	Residual δ o − c	Weight p
Normal I.			d.	s.		″	
	Lick	March	4·63	+ 0·54	0·8	+ 0·6	0·8
	Algiers	,,	5·30	+ 0·54	0·8	+ 0·2	0·6
	Algiers	,,	5·31	+ 0·72	0·8	− 0·3	0·6
	Algiers	,,	5·32	+ 0·12	0·6	− 3·0	0·8
	Lick	,,	5·64	+ 0·27	0·9	+ 0·7	0·8
	Rome College ...	,,	6·25	+ 0·84	0·9	− 5·4	0·3
	Heidelberg ...	,,	6·28	[+ 1·88]	0·0	− 2·8	0·5
	Heidelberg ...	,,	6·28	[+ 1·90]	0·0	− 3·7	0·5
	Arcetri	,,	6·28	+ 0·46	0·8	+ 3·1	0·4
	Arcetri	,,	6·28	+ 0·32	0·8	− 2·0	0·4
	Strasburg ...	,,	6·28	+ 0·33	2·0	+ 7·8	0·7
	Munich	,,	6·28	+ 0·49	1·0	+ 11·0	0·5
	Bamberg ...	,,	6·28	+ 0·37	0·4	− 1·1	0·4
	Besançon ...	,,	6·29	+ 0·25	1·2	+ 0·2	0·9
	Cape	,,	6·32	+ 0·53	0·5	+ 8·3	0·5
	Lick	,,	6·64	+ 0·41	0·8	+ 3·4	0·8
	Windsor... ...	,,	6·90	+ 0·16	0·7	+ 1·2	0·7
	Windsor... ..	,,	6·93	+ 0·12	0·6	− 0·9	0·6
	Windsor... ...	,,	6·93	− 0·06	0·6	− 0·1	0·6
	Padova	,,	7·29	+ 0·40	0·5	+ 6·6	0·5
	Windsor... ...	,,	7·91	− 0·10	1·2	+ 2·2	1·2
Normal II.			d.	s.		″	
	Windsor	March	14·90	− 0·49	1·0	+ 6·9	1·0
	Rome College ...	,,	15·26	− 0·22	0·9	+ 2·5	0·3
	Padova	,,	15·27	− 0·31	1·0	− 0·1	1·0
	Besançon ...	,,	15·28	− 0·55	0·9	− 2·5	0·6
	Munich	,,	15·28	− 0·65	1·5	− 0·4	0·5
	Padova	,,	15·29	− 0·37	0·6	+ 0·9	0·6
	Nice	,,	15·29	− 0·50	1·5	+ 1·3	1·5
	Arcetri	,,	15·29	− 0·33	1·6	− 2·3	0·8
	Windsor... ...	,,	15·90	− 0·86	1·0	+ 4·0	1·0
	Munich	,,	16·27	− 0·54	1·8	− 0·2	0·6
	Padova	,,	16·28	− 0·35	1·0	+ 4·4	1·0
	Besançon ...	,,	16·28	+ 0·07	0·9	+ 1·0	0·6
	Nice	,,	16·29	− 0·92	1·5	− 5·3	1·5
	Arcetri	,,	16·29	+ 0·49	1·6	− 4·1	0·8
	Toulouse ...	,,	16·31	+ 0·77	0·6	− 5·3	0·8
	Bethlehem ...	,,	16·50	− 0·14	1·0	− 2·7	1·0
	Rome College ...	,,	17·26	− 0·70	0·9	− 2·5	0·3
	Padova	,,	17·27	− 0·60	1·0	+ 4·8	1·0
	Besançon ...	,,	17·28	− 0·73	0·9	[+16·0]	0·0
	Arcetri	,,	17·28	+ 0·34	1·6	+ 1·2	0·8
	Geneve	,,	17·28	− 0·46	0·4	+12·3	0·3
	Nice	,,	17·29	− 0·72	1·5	+ 3·0	1·5
	Toulouse ...	,,	17·30	+ 0·61	0·8	− 0·6	1·2
	Algiers	,,	17·31	− 0·41	0·8	+ 7·7	0·8
	Algiers	,,	17·32	+ 0·11	1·0	+ 8·5	1·0
	Bethlehem ...	,,	17·51	− 0·73	1·0	− 0·5	1·0

TABLE OF RESIDUALS—*continued.*

Normals.	Observatory.	Date 1899.	Residual α $o-c$	Weight p	Residual δ $o-c$	Weight p
		d.	s.		″	
NORMAL III.	Bamberg ...	March 25·28	0·00	1·0	+ 2·8	1·0
	Geneve	„ 25·29	− 0·40	0.1	− 7·0	0·1
	Windsor... ...	„ 25·88	− 1·18	0·3	+ 0·7	0·3
	Geneve	„ 27·29	− 1·73	0·1	− 8·2	0·1
	Windsor... ...	„ 27·87	− 1·46	0·6	+ 3·1	0·6
	Geneve	„ 28 28	− 0·92	0·6	+ 11·3	0·6
	Windsor... ...	„ 28·87	− 1·32	0·7	+ 1·9	0·7
	Windsor... ...	„ 28·87	− 1·15	0·7	+ 0·3	0·7
	Windsor... ...	„ 29·86	− 0·83	0·6	+ 1·2	0·6
	Windsor... ...	„ 30 86	− 1·07	0·4	− 2·5	0·4
		d.	s.		″	
NORMAL IV.	Hamburg ...	May 5·57	− 1·61	2·0	− 19·7	2·0
	Hamburg ...	„ 5·57	− 1·76	2·0	− 19·6	2·0
	Utrecht	„ 5·57	− 1·78	0·8	− 17·6	0·5
	Hamburg ...	„ 5·58	− 1·85	2·0	− 22·7	2·0
	Hamburg ...	„ 5·58	− 1·94	2·0	− 20·1	2·0
		d.	s.		″	
NORMAL V.	Greenwich ...	May 25·46	+ 13·88	1·0	− 184·4	1·0
	Geneve	„ 26·38	+ 17·30	2·4	− 187·5	0·8
	Geneve	„ 26·41	+ 17·45	2·4	− 186·8	0·8
	Greenwich ...	„ 26·44	+ 17 87	1·0	− 186·4	1·0
	Geneve	„ 27·37	+ 21·28	1·5	− 189·5	0·8
		d.	s.		″	
NORMAL VI.	Lyons	June 8·47	+ 35·76	0·5	+ 78·1	0·5
	Lyons	„ 8·49	+ 35 66	0·5	+ 68·9	0·5
	Geneve	„ 9·37	+ 34·54	1·8	+ 85·2	0·6
	Greenwich ...	„ 9 42	+ 34·68	1·0	+ 86·0	0·5
	Lyons	„ 9·52	+ 34·72	0·5	[+ 65·0]	0·0
	Lyons	„ 10·40	+ 32 88	0·5	+ 88·4	0·5
	Lyons	„ 10·42	+ 33·36	0·5	+ 81·6	0·5
	Greenwich ...	„ 10·45	+ 33·06	1·0	+ 97·8	0·6
	Greenwich ...	„ 10·48	+ 33·10	1·0	+ 96·8	0 6
	Greenwich ...	„ 11·42	+ 31·67	1·0	+ 105·3	0·6
	Lyons	„ 12·38	+ 31·47	0·5	+ 105·6	0·5
	Lyons	„ 12·40	+ 31·24	0·5	+ 111·0	0·5
	Greenwich ...	„ 12·44	+ 30·59	1·0	+ 111·7	0·6
	Geneve	„ 13·40	+ 30·03	2·4	+ 125 0	0·8
	Bordeaux ..	„ 13·44	+ 29·82	1·0	+ 118·8	1·0
	Lyons	„ 13·50	+ 29 70	0·5	+ 114·7	0·5
	Lyons	„ 13·52	+ 29·80	0·5	+ 115·4	0·5
	Bordeaux ...	„ 14·42	+ 28·08	0·5	+ 115·6	0·5
	Lyons	„ 14·46	+ 28·45	0·5	+ 113·7	0·5
	Lyons	„ 15·43	+ 27·45	0·5	+ 130·5	0·5
	Lyons	„ 15·45	+ 27·54	0·5	+ 131·3	0·5

TABLE OF RESIDUALS—*continued.*

Normals	Observatory.	Date 1899.	Residual α $o-c$	Weight p	Residual δ $o-c$	Weight p
		d.	s.		″	
NORMAL VII.	Lyons	June 30·39	+ 18·40	1·0	+ 96·8	1·0
	Lyons	„ 30·40	+ 18·21	1·0	+ 98·1	1·0
	Lyons	„ 30·42	+ 18·35	1·0	+ 99·3	1·0
	Windsor... ...	July 2·95	+ 18·47	0·5	+ 103·7	0·5
	Windsor... ...	„ 3·91	+ 18·08	1·0	+ 96·5	1·0
	Bordeaux ...	„ 4·44	+ 17·78	1·0	+ 103·4	1·0
	Bordeaux ...	„ 5·40	+ 17·03	1·0	+ 100·8	1·0
	Windsor... ...	„ 5·89	+ 17·66	1·0	+ 96·5	1·0
	Bordeaux ...	„ 7·40	+ 16·53	1·0	+ 92·3	1·0
	Bordeaux ...	„ 8·42	+ 16·06	1·0	+ 87·7	1·0
	Bordeaux ...	„ 9·42	+ 15·95	1·0	+ 90·3	1·0
		d.	s.		″	
NORMAL VIII.	Windsor... ..	July 12·89	+ 16·02	1·0	+ 95·4	1·0
	Bordeaux ...	„ 13·42	+ 15·76	1·0	+ 97·0	1·0
	Bordeaux ...	„ 14·43	+ 15·38	1·0	+ 96·2	1·0
	Bordeaux ...	„ 15·44	+ 14·79	1·0	+ 86·3	1·0

CONSTRUCTION OF NORMALS.

Normal I.—This normal has been found by the following method :—If we put n, n' etc. to represent the residuals, in the case of either spherical co-ordinate, corresponding to the dates t, t' etc., and as the interval of time between the extreme observations to be combined is small, then

$$n_0 = \frac{[pn]}{[p]} \text{ and } t_0 = \frac{[pt]}{[p]}$$

The value of n_0 being applied to the ephemeris position for the date t_0 we have the normal place for this date. The weight of the normal will then be $[p]$.

The *Normals* II., III., IV., VIII., have been found in a similar manner. The several values of the definitive co-ordinates will be found in the table, "Residuals for the Equations of Condition."

Normal V.—The difference between the observed and computed places cannot be considered as varying proportionally to the time in the case of α, so that the error of the ephemeris has been computed from an equation of the form

$$n_\alpha = a + b\tau + c\tau^2 \dots\dots\dots\dots\dots\dots 1$$

$$\tau = T - t$$

T being some date which is about a mean of the dates corresponding to n n' etc. The values of a and the coëfficients b, c, have been found from equations of condition formed with the values of n n' etc. between the dates 1899 May 17, 1899 May 29.

The computed values of these quantities being placed in equation 1 we have the following

$$n_{\alpha} = +\ 8^{\mathrm{s}}{\cdot}747 + [0{\cdot}46350]\tau + [9{\cdot}35631]\tau^2$$

The quantities within brackets are logarithms, and the initial date *T* equals 1899 May 24.

The values of n_{α} n'_{α} etc. being subtracted from the residuals n n' etc. corresponding to the dates t t' etc., then small differences will result, which are weighted and applied to the value of n_{α} corresponding to the date desired.

The value of the definitive co-ordinate in declination has been found as in the case of Normal I.

The method just described will be made explicit by the example given in the case of Normal VI.

Normal VI.—From a number of values of n, between the dates 1899 June 8, 1899 June 15, see next page, the following equations have been obtained,

$$n_{\alpha} = +\ 31{\cdot}610 - [0{\cdot}07584]\tau - [7{\cdot}86053]\tau^2$$
$$n_{\delta} = +\ 108''{\cdot}583 + [0{\cdot}95095]\tau - [8{\cdot}37020]\tau^2$$

the initial date being 1899 June 12.

$$\frac{[p(n - n_{\alpha})]}{[p]} = -\,0^{\mathrm{s}}{\cdot}14$$

This normal has been constructed for the date 1899 June 12, therefore τ equals o, so that we have

$$n_{\alpha} = +\ 31^{\mathrm{s}}{\cdot}61$$

The value of n_0 to be applied to the ephemeris position for the date 1899 June 12 is therefore

$$n_0 = +\ 31^{\mathrm{s}}{\cdot}47. \quad p = 16$$

The value of n_0 to be applied to the declination, has been found in the same manner.

NORMAL VI.—Right Ascension.

Date 1899.		n	n_α	$n - n_\alpha$	p	$p(n - n_\alpha)$
		s. +	s. +			
June	8·47	35·76	35·72	+ 0·04	0·5	+ 0·020
,,	8·49	35·66	35·70	− 0·04	0·5	− 0·020
,,	9·37	34·54	34·69	− 0·15	1·8	− 0·270
,,	9·42	34·68	34·63	+ 0·05	1·0	+ 0·050
,,	9·52	34·72	34·52	+ 0·20	0·5	+ 0·100
,,	10·40	32·88	33·50	− 0·62	0·5	− 0·310
,,	10·42	33·36	33·47	− 0·11	0·5	− 0·055
,,	10·45	33·06	33·44	− 0·38	1·0	− 0·380
,,	10·48	33·10	33·40	− 0·30	1·0	− 0·300
,,	11·42	31·67	32·30	− 0·63	1·0	− 0·630
,,	12·38	31·47	31·16	+ 0·31	0·5	+ 0·155
,,	12·40	31·24	31·13	+ 0·11	0·5	+ 0·055
,,	12·44	30·59	31·09	− 0·50	1·0	− 0·500
,,	13·40	30·03	29·93	+ 0·10	2·4	+ 0·240
,,	13·44	29·82	29·88	− 0·06	1·0	− 0·060
,,	13·50	29·70	29·81	− 0·11	0·5	− 0·055
,,	13·52	29·80	29·78	+ 0·02	0·5	+ 0·010
,,	14·42	28·08	28·69	− 0·61	0·5	− 0·305
,,	14·46	28·45	28·64	− 0·19	0·5	− 0·095
,,	15·43	27·45	27·44	+ 0·01	0·5	+ 0·005
,,	15·45	27·54	27·42	+ 0·12	0·5	+ 0·060
				Sums	16·7	− 2·285

Normal VII.—The equations in this case are as follows:

$$n_\alpha = 17^{s}{\cdot}50 - 0{\cdot}3\,\tau$$

$$n_\delta = 100''{\cdot}00 - 1{\cdot}1239\,\tau - 0{\cdot}1524\tau^2$$

The initial date being 1899 July 4.

RESIDUALS FOR THE EQUATIONS OF CONDITION.

Right Ascension.

Normals	Date 1899.		α_o			α_c			$d\alpha$	Weight p
			h.	m.	s.	h.	m.	s.	s.	
I.	March	6	3	40	12·88	3	40	13·47	− 0·59	16
II.	,,	16	2	57	9·86	2	57	10·03	− 0·17	25
III.	,,	28	2	19	37·76	2	19	37·97	− 0·21	4
IV.	May	5·5	23	53	51·23	23	53	51·30	− 0·07	9
V.	,,	26·5	20	27	27·53	20	27	14·36	+ 13·17	9
VI.	June	12	15	27	57·99	15	27	36·28	+ 21·71	16
VII.	July	4	14	19	12·10	14	18	59·61	+ 12·49	9
VIII.	,,	14	14	13	0·99	14	12	49·91	+ 11·08	4

Declination.

Normals	Date 1899.	δ_o	δ_c	$d\delta$	Weight p
		° ′ ″	° ′ ″	″	
I.	March 6	− 25 5 14·2	− 25 5 2·5	− 11·7	13
II.	„ 16	− 12 19 49·3	− 12 19 34·3	− 15·0	25
III.	„ 28	− 1 23 47·1	− 1 23 41·6	− 5·5	4
IV.	May 5·5	+ 26 17 29·7	+ 26 17 28·4	+ 1·3	9
V.	„ 26·5	+ 55 40 41·9	+ 55 42 39·8	− 117·9	5
VI.	June 12	+ 40 46 47·9	+ 40 45 43·1	+ 64 8	12
VII.	July 4	+ 18 42 53·6	+ 18 42 1·6	+ 52·0	9
VIII.	„ 14	+ 13 37 47·1	+ 13 36 54·2	+ 52·9	4

In the foregoing tables the right ascension α_o, and the declination δ_o have been deduced from the combination of the observations as already explained. The values of α_c δ_c being computed from the elements II.

Before introducing the values of $d\alpha$ into the equations of condition, they have been changed into seconds of arc, also multiplied by $\cos\delta$.

Equations of Condition.—If θ represent any co-ordinate of the place of the comet computed from assumed elements of the orbit, then in this discussion

$$\theta = f(\omega, \Omega, \iota, T, q, e.)$$

The equations of condition will therefore take the form

$$\cos\delta d\alpha = \cos\delta\frac{d\alpha}{d\omega}d\omega + \cos\delta\frac{d\alpha}{d\Omega}d\Omega \ldots\ldots\ldots \cos\delta\frac{d\alpha}{de}de$$

$$d\delta = \frac{d\delta}{d\omega}d\omega + \frac{d\delta}{d\Omega}d\Omega \ldots\ldots\ldots\ldots\ldots\ldots \frac{d\delta}{de}de$$

The formulæ for computing the differential coefficients in these equations may be easily deduced by differentiating the various equations that determine the position of the comet.

In the equations of condition the quantities $d\omega$, $d\Omega$, $d\iota$, are to be determined in seconds of arc; so that the equations may be homogeneous, the coefficients of the terms containing dT, dq, de, have been divided by $\sin 1''$; they have also been multiplied by 10^{-4}, 10^{-6}, 10^{-6} respectively; this has been done as a matter of convenience for the numerical reduction.

Equations of Condition.

$$
\begin{array}{llllllllr}
\sqrt{16} & [-0{\cdot}4255\,d\omega & +0{\cdot}3142\,d\Omega & +0{\cdot}3292\,d\iota & +0{\cdot}5778\,dT & -0{\cdot}2889\,dq & +0{\cdot}0973\,de & = & -8{\cdot}20] \\
\sqrt{25} & [-0{\cdot}2649 & +0{\cdot}2148 & +0{\cdot}2166 & +0{\cdot}5233 & -0{\cdot}1864 & +0{\cdot}0629 & = & -2{\cdot}49] \\
\sqrt{4} & [-0{\cdot}2332 & +0{\cdot}2141 & +0{\cdot}1087 & +0{\cdot}5225 & -0{\cdot}1327 & +0{\cdot}0272 & = & -3{\cdot}15] \\
\sqrt{9} & [-0{\cdot}1604 & +0{\cdot}1221 & -0{\cdot}0932 & +0{\cdot}5621 & +0{\cdot}1119 & -0{\cdot}0603 & = & -0{\cdot}94] \\
\sqrt{9} & [-1{\cdot}3202 & +1{\cdot}1657 & +0{\cdot}1845 & +0{\cdot}8374 & +0{\cdot}7152 & -0{\cdot}0703 & = & +111{\cdot}40] \\
\sqrt{16} & [-1{\cdot}8380 & +1{\cdot}7257 & +0{\cdot}3994 & +0{\cdot}0953 & +0{\cdot}6604 & +0{\cdot}2971 & = & +246{\cdot}60] \\
\sqrt{9} & [-1{\cdot}1623 & +1{\cdot}1048 & +0{\cdot}2210 & -0{\cdot}0225 & +0{\cdot}3361 & +0{\cdot}2748 & = & +177{\cdot}45] \\
\sqrt{4} & [-1{\cdot}0302 & +0{\cdot}9807 & +0{\cdot}1832 & -0{\cdot}0192 & +0{\cdot}2822 & +0{\cdot}2581 & = & +161{\cdot}53] \\
\sqrt{13} & [+0{\cdot}6360 & -0{\cdot}6570 & +1{\cdot}0611 & -0{\cdot}2104 & +0{\cdot}3143 & +0{\cdot}0367 & = & -11{\cdot}70] \\
\sqrt{25} & [+0{\cdot}2986 & -0{\cdot}2681 & +0{\cdot}7783 & -0{\cdot}1916 & +0{\cdot}1727 & +0{\cdot}0023 & = & -15{\cdot}00] \\
\sqrt{4} & [+0{\cdot}1168 & -0{\cdot}0170 & +0{\cdot}4323 & -0{\cdot}1561 & +0{\cdot}0750 & -0{\cdot}0040 & = & -5{\cdot}50] \\
\sqrt{9} & [+0{\cdot}1809 & -0{\cdot}2385 & -0{\cdot}7258 & -0{\cdot}1421 & -0{\cdot}1115 & -0{\cdot}0002 & = & +1{\cdot}30] \\
\sqrt{5} & [+0{\cdot}9022 & -1{\cdot}2127 & -1{\cdot}2582 & +0{\cdot}1514 & -0{\cdot}3317 & -0{\cdot}1967 & = & -117{\cdot}90] \\
\sqrt{12} & [-0{\cdot}8152 & +0{\cdot}1558 & -1{\cdot}0577 & +0{\cdot}4179 & +0{\cdot}4072 & -0{\cdot}0715 & = & +64{\cdot}80] \\
\sqrt{9} & [-0{\cdot}5577 & -0{\cdot}0374 & -0{\cdot}8017 & +0{\cdot}1180 & +0{\cdot}2115 & +0{\cdot}0198 & = & +52{\cdot}00] \\
\sqrt{4} & [-0{\cdot}4473 & -0{\cdot}1003 & -0{\cdot}6987 & +0{\cdot}0743 & +0{\cdot}1574 & +0{\cdot}0262 & = & +52{\cdot}90]
\end{array}
$$

Normal Equations.

$$\begin{array}{lllllll}
+\,2{\cdot}05965\,x & +\,1{\cdot}99384_{n}\,y & +\,0{\cdot}46265\,z & +\,1{\cdot}45849_{n}\,t & +\,1{\cdot}51209_{n}\,u & +\,1{\cdot}10968_{n}\,w & =4{\cdot}10560_{n}\\
+\,1{\cdot}99384_{n} & +\,1{\cdot}97025 & +\,1{\cdot}08419 & +\,1{\cdot}32404 & +\,1{\cdot}42770 & +\,1{\cdot}10409 & =4{\cdot}05360\\
+\,0{\cdot}46265 & +\,1{\cdot}08419 & +\,1{\cdot}85010 & +\,0{\cdot}75696_{n} & +\,0{\cdot}85166 & +\,0{\cdot}77139 & =3{\cdot}04171\\
+\,1{\cdot}45849_{n} & +\,1{\cdot}32404 & +\,0{\cdot}75696_{n} & +\,1{\cdot}42677 & +\,0{\cdot}29181 & +\,9{\cdot}86611 & =3{\cdot}16489\\
+\,1{\cdot}51209_{n} & +\,1{\cdot}42770 & +\,0{\cdot}85166 & +\,0{\cdot}29181 & +\,1{\cdot}31196 & +\,0{\cdot}50258 & =3{\cdot}66466\\
+\,1{\cdot}10968_{n} & +\,1{\cdot}10409 & +\,0{\cdot}77139 & +\,9{\cdot}86611 & +\,0{\cdot}50258 & +\,0{\cdot}47245 & =3{\cdot}24550
\end{array}$$

The reduction from the preliminary to the normal equations has been made by the method of least squares, using an arithmometer to obtain the several sums. In the reduction to the final equations Zech's *Additions und Substractions Logarithmen* have been employed. The notation of the equations will now be

$$x = d\omega \qquad y = d\text{☊} \qquad z = d\iota \qquad t = 10^{4}\,dT \qquad u = 10^{6}\,dq \qquad w = 10^{6}\,de$$

Elimination Equations.

$$\begin{array}{rrrrrrl}
x & +\,9{\cdot}93420_{n}\,y & +\,8{\cdot}40300\,z & +\,9{\cdot}39884_{n}\,t & +\,9{\cdot}45244_{n}\,u & +\,9{\cdot}05003_{n}\,w & =2{\cdot}04595_{n}\\
 & y & +\,0{\cdot}22833\,z & +\,9{\cdot}62065_{n}\,t & +\,9{\cdot}13155_{n}\,u & +\,9{\cdot}27924\,w & =1{\cdot}61200\\
 & & z & +\,8{\cdot}38736\,t & +\,9{\cdot}33347\,u & +\,8{\cdot}87517\,w & =1{\cdot}25358\\
 & & & t & +\,9{\cdot}58520_{n}\,u & +\,9{\cdot}02108_{n}\,w & =1{\cdot}95076_{n}\\
 & & & & u & +\,9{\cdot}43223_{n}\,w & =1{\cdot}61011\\
 & & & & & w & =2{\cdot}54293
\end{array}$$

The numerical quantities in the normal equations are logarithms; the same remark applies to the elimination equations. From these final equations the values of x, y, z, etc. have been deduced.

Parabola.

$\log x = 2{\cdot}08183_{\mathrm{n}}$
„ $y = 0{\cdot}44714_{\mathrm{n}}$
„ $z = 1{\cdot}03918$
„ $t = 1{\cdot}86689_{\mathrm{n}}$
„ $u = 1{\cdot}61011$

$d\omega = -2'\ 0{\cdot}73''$
$d\Omega = -0'\ 2{\cdot}80''$
$d\iota = +0'\ 10{\cdot}94''$
$dT = -0{\cdot}007360$
$dq = +0{\cdot}00004075$

Hyperbola.

$\log x = 1{\cdot}17811$
„ $y = 1{\cdot}74664$
„ $z = 1{\cdot}57260_{\mathrm{n}}$
„ $t = 9{\cdot}79224_{\mathrm{n}}$
„ $u = 2{\cdot}13093$
„ $w = 2{\cdot}54293$

$d\omega = +15{\cdot}07''$
$d\Omega = +55{\cdot}80$
$d\iota = -37{\cdot}38$
$dT = -0{\cdot}000062$
$dq = +0{\cdot}000135186$
$de = +0{\cdot}00034908$

$$\text{Weights } p' \left\{\begin{array}{r} 1{\cdot}1980 \\ 2{\cdot}7853 \\ 10{\cdot}4287 \\ 4{\cdot}3510 \\ 2{\cdot}4367 \\ 0{\cdot}2898 \end{array}\right.$$

Elements III.

$$T = 1899 \text{ April } 12{\cdot}97038 \text{ G.M.T.}$$

$$\left.\begin{array}{lrrr} & {}^{\circ} & ' & '' \\ \omega = & 8 & 39 & 28{\cdot}97 \\ \Omega = & 24 & 58 & 12{\cdot}30 \\ \iota = & 146 & 16 & 19{\cdot}44 \end{array}\right\} 1899$$

$$q = 0{\cdot}32647368$$
$$\log q = 9{\cdot}5138482$$

Equations for Co-ordinates.

$$x = [9{\cdot}9877294]\, r \sin (v + 77^{\circ}\ 29'\ 13{\cdot}44'')$$
$$y = [9{\cdot}9962545]\, r \sin (v + 165^{\circ}\ 39'\ 52{\cdot}39'')$$
$$z = [9{\cdot}4287933]\, r \sin (v + 47^{\circ}\ 24'\ 34{\cdot}81'')$$

Elements IV.

$$T = 1899 \text{ April } 12{\cdot}977678 \text{ G.M.T.} \pm 10^{-4} \times 1{\cdot}06$$

$$\left.\begin{array}{lrrrl} & {}^{\circ} & ' & '' & '' \\ \omega = & 8 & 41 & 44{\cdot}77 & \pm 2{\cdot}03 \\ \Omega = & 24 & 59 & 10{\cdot}90 & \pm 1{\cdot}33 \\ \iota = & 146 & 15 & 31{\cdot}12 & \pm 0{\cdot}69 \end{array}\right\} 1899$$

$$q = 0{\cdot}326568116 \pm 10^{-6} \times 1{\cdot}42$$
$$\log q = 9{\cdot}5139738$$
$$e = 1{\cdot}00034908 \pm 10^{-6} \times 4{\cdot}12$$
$$\log e = 0{\cdot}0001516$$
„ $p = 9{\cdot}8150796$

Equations for Co-ordinates

$$x = [9{\cdot}9877050]\, r \sin (v + 77 \quad 30 \quad 48{\cdot}56)$$
$$y = [9{\cdot}9962456]\, r \sin (v + 165 \quad 41 \quad 13{\cdot}03)$$
$$z = [9{\cdot}4292320]\, r \sin (v + 47 \quad 25 \quad 44{\cdot}35)$$

RESIDUALS—*Elements III.*

Equations.		Elements.
	″	″
1	− 7·9	− 7·8
2	+ 9·9	+ 9·8
8	+ 12·0	+ 12·0
4	+ 17·9	+ 17·8
5	− 14·0	− 14·2
6	+ 5·2	+ 5·2
7	+ 22·4	+ 22·5
8	+ 25·0	+ 25·1
9	+ 23·3	+ 23·3
10	− 9·4	− 9·5
11	− 10·7	− 10·7
12	+ 24·6	+ 24·5
13	+ 26·1	+ 26·0
14	− 7·4	− 7·3
15	− 6·6	− 6·5
16	+ 5·3	+ 5·4

$[vv] = 10^4 \times 0{\cdot}41332$
$= 4133{\cdot}2$

RESIDUALS—*Elements IV.*

Equations.		Elements.
	″	″
1	− 1·4	− 1·4
2	+ 1·2	+ 1·3
3	+ 1·3	+ 1·3
4	− 2·5	− 2·7
5	+ 1·5	+ 1·4
6	+ 0·1	+ 0·2
7	+ 0·2	+ 0·4
8	+ 0·9	+ 1·0
9	− 0·4	− 0·4
10	+ 0·3	+ 0·2
11	+ 1·0	+ 1·0
12	− 0·2	− 0·3
13	+ 2·7	+ 2·8
14	− 0·9	− 0·8
15	− 2·9	− 2·8
16	+ 8·7	+ 8·9

$[vv] = 108{\cdot}12$

The agreement between the residuals, computed from the equations of condition and those found from the corrected elements, is satisfactory in each case. The residual of the final equation, Elements IV., is somewhat large in comparison with the others but unaccountable, the number of observations employed in finding this normal is small, but the measures are consistent, and to reject this normal would be unjustifiable.

The agreement of the residuals would seem to indicate, that the higher order of differentials, neglected in the calculation of the coefficients, will have little or no effect on the result. If the residuals found from the Elements IV. are again introduced into the equations of condition, the corrections obtained are small and will not alter the residuals to the extent desired.

Before concluding the calculation the residuals from the Elements IV. were assumed to be in the form

$$\theta' = v + f\,(de)_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

the complete corrections to the elements would then take the form

$$(d\omega)_2 = d\omega + A'(de)_2$$

$$(d\Omega)_2 = d\Omega + B'(de)_2 \text{ etc., etc.}$$

upon introducing the values of v into equation (2) then it would be found that $(de)_2 = 10^{-6} \times 0{\cdot}58$

This correction having been made, and the values of $(d\omega)_2$ $(d\Omega)_2$ etc. computed, it was found that the residuals were practically the same, the resulting value of $[vv]$ being 109·70.

Probable Errors etc.—The probable errors of the quantities $d\omega$, $d\Omega$, etc., have been obtained from the following formulæ

$$r = 0{\cdot}6745 \sqrt{\frac{[vv]}{m - \mu}}$$

$$r_x = \frac{r}{\sqrt{p_x}}. \qquad r_y = \frac{r}{\sqrt{p_y}} \text{ etc.}$$

in which m equals the number of equations of condition and μ the number of unknowns.

For Elements IV. it will be found that

$$\text{Log. } r = 0{\cdot}34593.$$

In obtaining the values of p_x p_y etc., the order of elimination has been reversed, so that these quantities were deduced by the usual formulæ.

Concluding Remarks.—The reversal of the order of elimination of the unknowns from the normal equations acted as a check upon this part of the calculation, a further check being obtained by placing the deduced values of the unknowns in the normal equations, the checks in both cases being completely satisfied. In reducing the preliminary equations, the usual controls were maintained, the several sums being fully verified. The residuals of the several elements being compared, it will be observed, that assuming no correction is required to the eccentricity, then the sum of the squares of the residuals has been reduced from $10^4 \times 15{\cdot}5$ approximately, to $10^4 \times 0{\cdot}4$; taking de into account reduces this sum to $10^4 \times 0{\cdot}010812$.

The observations appear to be well represented by the Elements IV., and there appears to be every indication that the orbit of this comet is an hyperbola. As previously mentioned, the purturbations produced by the earth will be small, and should the definitive discussion of the orbit elements be undertaken, it will be found that the Elements IV. will require no material correction.

ON THE COMPOSITION OF N. S. WALES LABRADORITE AND TOPAZES WITH A COMPARISON OF METHODS FOR THE ESTIMATION OF FLUORINE.

By G. HARKER, B Sc.

(Communicated by Professor LIVERSIDGE, M.A., LL.D., F.R.S.)

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

ANALYSIS OF MINERAL LABRADORITE FROM N. S. WALES.

The specimen described in the following note was collected by Mr. D. A. Porter of Tamworth on Sandilands Mountain, some fifty-seven miles from Tenterfield, who forwarded it to Professor Liversidge for examination. Mr. Porter states that it occurs there in a basalt and also between Hillgrove and Grafton.

The specimens were in broken fragments about half an inch in diameter. Some were colourless, others brown to greyish. One perfect cleavage was exhibited, probably basal, and a second not quite so good. The fracture was uneven inclining to conchoidal; the lustre vitreous. The hardness was 6 and the specific gravity 2·70. Before the blowpipe it fused to a colourless glass, its fusibility being about three. All these properties agree in every detail with those given in Dana for typical labradorite, as do all the optical properties which were determined. The refractive index was low and the double refraction weak. In convergent polarised light a cleavage flake gave a figure with one brush nearly straight and was therefore the section of a bi-axial mineral cut at right angles to the optic axis, the optic axes being nearly at right angles. The dispersion could not be obtained. The mineral was optically positive and shewed multiple twinning.

Analysis.

	1	2	3	4	5
	New South Wales.		Veltlin.	Thannbergthal.	Rameni-Brod.
Silica	55·05	54·81	55·15	53·61	54·55
Alumina ...	30·15	29·70	29·15	29·68	28·68
Ferric oxide ...		·42	...	...	1·03

(Analysis continued)	1 New South Wales.	2	3 Veltlin.	4 Thannbergthal.	5 Rameni-Brod.
Lime	10·32	9·61	9·90	10·96	11·23
Soda	5·11	undeter.	5·23	4·36	4·62
K_2O	none	·29	·80	1·15	·42
MgO	none	·28	...	...	...
H_2O on ignit.	undeter.	·13	·67	·65	...
	100·63	incompl.	100·90	100·41	100·53

Nos. 1 and 2 are analyses of two different samples of the mineral. In the first analysis the ferric oxide was not determined separately 30·15 is the percentage of mixed oxides of iron and alumina; the analysis was done on the dried ignited sample. Nos. 3, 4, and 5 are three analyses of labradorite given in Dana, and are put in for sake of comparison. The silica in the labradorite analyses given in Dana varies from 52·45 to 56·18, the alumina from 27·33 to 29·85, the lime from 9·90 to 12·01, and the soda from 3·90 to 5·23. From these it will be seen that the chemical composition of the mineral agrees well with that of labradorite, and taken in conjunction with its physical properties shews that it is that mineral.

TOPAZ.

The following investigation was also made in the Chemical Laboratory of the University of Sydney at the suggestion and under the direction of Professor Liversidge, with the object of determining the composition of some N. S. Wales specimens and of comparing certain of the published methods for the analysis of fluorides. The most difficult constituent to analyse in topaz is fluorine, for the estimation of which a number of methods have been proposed. To find the most satisfactory was the first object in view.

Before proceeding farther a resumé of previous methods for the determination of fluorine might be of use :—

(*a*) *Fluorides not decomposable by sulphuric acid.*—Berzelius was the first to accomplish the analysis of fluorides undecomposable by sulphuric acid. He fused the fluorides with alkaline carbonates. To separate the silica from silicates combined with fluorine he employed a solution of zinc carbonate in ammonia; zinc silicate is formed and the solution is freed from the rest of the zinc oxide by evaporation.

H. Rose in 1849 separated the fluorine as calcium fluoride, a more convenient form than the sodium fluoride employed by Berzelius. He precipitated the calcium fluoride together with calcium carbonate to help in its filtration. He pointed out that some fluorides which were not associated with silica were not completely decomposed by fusion with alkaline carbonates. A combination of the methods of Berzelius and Rose is still the best method known for the estimation of fluorine. Wöhler in analysing topaz fused with sodium carbonate alone.

(*b*) *Fluorides decomposable by sulphuric acid.*—For the analysis of these a large number of methods have been proposed; Wöhler added silica and sulphuric acid weighed and determined the fluorine by loss due to escape of silicon tetra-fluoride.

Liversidge (Chem. News, 1871) decomposed with silica and sulphuric acid, and collected the silicon tetra-fluoride in ammonia solution. By partial evaporation the gelatinous silica was dissolved. He then added potassium chloride and weighed the fluorine direct as potassium silicon fluoride.

1872, Fresenius collected the silicon tetra-fluoride in tubes containing moistened pumice.

Penfield (Journ. Chem. Soc. 1879) passed the silicon tetra-fluoride into a solution of potassium chloride and alcohol, and titrated the hydrochloric acid set free by the reaction.

Carnot (Comptes Rendus, 1893) collected the silicon tetra-fluoride in a ten per cent. solution of potassium fluoride and weighed as potassium silicon fluoride.

Three of the above methods were tried for the estimation of fluorine in topaz:—

First method, fusion with alkaline carbonates.—The topaz first analysed was from Mudgee, N.S.W. It was in the form of transparent rolled pebbles of from one quarter to one eighth of an inch in diameter. The method of analysis first used was that of Wöhler, as given in his Mineral Analysis, English edition of 1871.

"The substance when fused with four times its weight of anhydrous carbonate of soda is decomposed with formation of fluoride of sodium, which is extracted with water. Before filtering off the residual silicate of alumina, the solution should be digested with carbonate of ammonia to precipitate any small quantities of alumina and silica which may have been dissolved." The residue is evaporated down with hydrochloric acid, and the silica and alumina extracted. The fluorine in solution is removed as calcium fluoride by adding calcium chloride.

This method when tried on the topaz crystals from Mudgee gave results for fluorine which were low and irregular, viz., from five to eleven per cent. On treating some Brazilian topaz later in the same way, similar unsatisfactory results were obtained, viz. 4·7 to 12·9 per cent.

Second or tetra-fluoride method.—That of Liversidge as given in Crookes' Select Methods, p. 580, 1884 edition.

In this method the substance is decomposed with sulphuric acid and silica and the silicon tetra-fluoride passed into solution of ammonia. The mixture is heated in a platinum retort first over the water bath and finally at 160° C., the last traces of gas being removed by a current of air. The ammonia solution is evaporated until the gelatinous silica passes into solution and is then precipitated as protassium silicon fluoride by potassium chloride and alcohol.

So far this method had only been used for the determination of fluorine in coprolites and apatite. In order to make the method applicable to topaz, which is not decomposable by sulphuric acid, the topaz was first fused with sodium potassium carbonate, silica was then added and the mixture decomposed with sulphuric acid.

Preliminary trials were made with calcium fluoride, apatite, and cryolite, the substance in each case being fused with two or three grams of sodium potassium carbonate and then decomposed. The silicon tetra-fluoride was collected in water after the first few experiments, as it was found that on evaporation with ammonia some of the hydrogen silicon fluoride was converted into silica. The method gave uniform results, which however, were rather low in all cases.

The cause of the lowness in the results is not apparent. It is probably due to the equation $3\ SiF_4 + 4\ H_2O = 2\ H_2SiF_6 + H_4SiO_4$ not being a quantitative one. Potassium silicon fluoride was found to be slightly soluble in a fifty per cent. solution of alcohol. After filtering off the gelatinous silica, the solution in which the potassium silicon fluoride was precipitated was always made of the same volume and hence the error due to solubility could be allowed for. Potassium chloride was used prepared from different sources but caused no difference in the results.

The discrepancy was not due to incomplete absorption of silicon tetra-fluoride in the water. A second absorption tube gave no trace of a precipitate. To completely remove the gas from the decomposition flask dry air was passed through for four to five hours.

The amounts of calcium fluoride used were varied to see if the error was constant or proportional. The percentage of fluorine obtained was increased as more calcium fluoride was taken, but not proportionally, and tended to reach a maximum. For amounts approximately equal the results were constant and hence the error can be corrected from the weight of potassium silicon fluoride obtained.

Results obtained by the tetra-fluoride method on calcium fluoride, cryolite and apatite.—First series.—The substance was fused with sodium potassium carbonate and then decomposed. The calcium fluoride used in these experiments was from ground crystals, and on testing, by conversion into calcium sulphate, gave 99·6 per cent. of calcium fluoride. Four experiments gave 44·60, 45·97, 46·12, and 46·20 per cent., the theoretical percentage of fluorine being 48·53 and the average difference 2·82 per cent.

Second series.—The substance was decomposed without previous fusion with alkaline carbonates. The calcium fluoride in the first four of these experiments was from crystals of fluor-spar ground, and evaporated to dryness with hydrofluoric acid to get rid of silica and then ignited. On testing by conversion into calcium sulphate they gave 99·8 per cent. of calcium fluoride.

Amount taken	(1)	·1565	grams.	Percentage of fluorine found	45·90
,,	(2)	·2722	,,	,,	47·08
,,	(3)	·5212	,,	,,	47·21
,,	(4)	·2900	,,	,,	46·64
,,	(5)	·1736	,,	,,	46·31
,,	(6)	·1787	,,	,,	45·95

The theoretical percentage was 48·62 and the average difference 2·25 per cent. These results were corrected for the solubility of potassium silicon fluoride which was found to be ·0016 gram. in 50 ccms. of a 50 per cent. alcohol solution. Nos. 5 and 6 were precipitates of calcium fluoride obtained by Berzelius' method from the Mudgee topaz.

Cryolite similarly gave 52·17 per cent. when previously fused with alkaline carbonates, and 52·62 without previous fusion, and when treated by Berzelius' method 55·34. Apatite gave 2·80 by the first method and 2·81 by the second.

Application of the tetra-fluoride method to topaz.—The Mudgee topaz by this method gave only 13 per cent. of fluorine which was much too low. When repeated on the Brazilian topaz a similar low result was obtained, viz. 10·9 per cent. It seems therefore that this method works well for minerals not containing silica. That it is the presence of silica in the topaz which causes the error was shewn by adding silica to calcium fluoride or topaz before fusing, when in all cases a much lower result was obtained, the error being larger as more silica was added. Thus calcium fluoride gave 36·54 and 35·06 per cent. of fluorine and topaz 7·05 and 4·26 per cent., results much lower than those obtained when silica was not added.

Third method, fusion with alkaline carbonates and silica.—A third method for the determination of fluorine was then tried, viz. that of Berzelius as modified by Rose. The ground topaz is fused with one half its weight of pure silica; the fused mass extracted with water; five to ten grams of ammonium carbonate added to precipitate silica, and the solution allowed to stand twelve hours. The solution is filtered and evaporated to get rid of excess of ammonia, and a solution of zinc carbonate in ammonia added to precipitate any silica in solution. The liquid is then further evaporated to get rid of ammonia, filtered from zinc oxide and silicate and the fluorine precipitated by calcium chloride in the usual manner.

The results from the Mudgee topaz were much higher than those obtained by the two previous methods and were constant; the same constant results were obtained in the case of the Brazilian topaz and the green topaz from New England.

The calcium fluoride obtained by precipitation in this method from the Mudgee topaz was tested and found to be free from calcium silicate. Berzelius' method therefore gave the best results for fluorine in topaz, but as there seemed to be no reason why the fluorine should be lost in Wöhler's method which did not apply equally to that of Berzelius', an attempt was made to find where the fluorine was lost in the former case.

It was found that no fluorine is left in the residue after extracting the fused mass with water. The decomposition in Wöhler's method is therefore complete. It was noticed that the precipitate of aluminium hydroxide obtained on addition of ammonium carbonate to the solution was more granular than the usual gelatinous precipitate, and on trial this precipitate was found to contain no silica but always more or less fluorine. (Hydrofluoric acid was liberated from the precipitate by sulphuric acid and etched glass. Mixed with silica and sulphuric acid, silicon tetrafluoride was given off which was passed into water and the potassium silicon fluoride precipitated.) On one occasion 6·6 per cent. of fluorine was obtained in this precipitate by Berzelius' method, but this was exceptionally large, the usual amount not being more than one to three per cent. When the ammonium carbonate was added hot to the solution and then allowed to stand until quite cold, a larger proportion of fluorine was found in the precipitate than when it was filtered hot, the precipitate containing the fluorine coming down on cooling. This precipitate contained a larger amount of fluorine when sodium potassium carbonate was used than when sodium carbonate alone was employed. In obtaining the results given by Wöhler's method for fluorine, sodium potassium carbonate was frequently employed, which accounts for some of them being so low, but even when sodium carbonate alone was employed, the highest percentage obtained was 12·69.

On adding the amount of fluorine recovered from the precipitate to the amount obtained from the solution after the addition of ammonium carbonate, the total is nearly the same as that obtained by Berzelius' method. Thus 14·2 per cent. was obtained from Brazilian topaz by Berzelius' method. In one experiment 6·92 per cent. was obtained from the solution and 6·50 from the precipitate, total 13·42 per cent. In a second experiment 12·69 from the solution and 1·21 from the precipitate, total 13·90 per cent. This seems to shew that Berzelius' method gives the total fluorine present. The precipitates of calcium fluoride were tested by conversion into calcium sulphate. The residue obtained on treating the fused mass with water in Wöhler's method, contained all the silica and about two-thirds of the alumina and some soda, and had approximately the constitution $3\ SiO_2$, $2\ Na_2O$, $2\ Al_2O_3$. On boiling with water the soda and alumina were slowly removed, but to what extent this could be carried out was not determined. In the case of Berzelius' method, the residue contained all the aluminium. The silica prevents the aluminium from passing into solution and thus stops the loss of fluorine which occurs in Wöhler's method. The amount of silica necessary to do this was found to be 31·6 per cent. in the case of the Brazilian topaz.

Examination of the ammonium carbonate precipitate.—The topaz was fused with sodium carbonate alone and the fused mass dissolved in water and filtered. Ammonium carbonate was added to the hot solution and a gelatinous precipitate, consisting chiefly of aluminium hydroxide, formed. After filtering and cooling a more granular but still gelatinous precipitate separated out and collected at the bottom of the beaker. This was filtered off and examined. Only a small amount was obtained which on drying became powdery and fused at a red heat. The sodium and aluminium were determined by conversion into sulphates, the fluorine by fusion with silica and alkaline carbonates. ·0210 gram heated to redness gave 23 8 per cent. sodium, 26·2 per cent. aluminium, and 0·200 gram gave 3·33 per cent. of fluorine, leaving oxygen by difference 16·7 per cent. Assuming some of the aluminium to be combined with the oxygen as alumina due to imperfect separation of the fluorine precipitate from aluminium hydroxide, we have for the composition of the former fluorine precipitate sodium 36·8, aluminium 11·7 and fluorine 51·5 per cent. Cryolite requires 32·9, 12·8, and 54·3 per cent.

In another experiment on a different precipitate ·0130 gram. gave sodium 20·8, aluminium 29·2 per cent., and 0·201 gram gave 30·8 per cent. of fluorine, hence oxygen by difference 19·2 per cent. Allowing for alumina this gives sodium 35·1, aluminium 13·0, fluorine 51·9 per cent.

It seems probable therefore that the fluorine is precipitated as a double fluoride of sodium and aluminium. Like cryolite this precipitate also fuses readily. But as the amounts analysed were so small it is proposed to confirm the results by working with larger quantities.

Comparison of the various methods for fluorine on the topazes.—

	1 Fusion with alkaline carbonates.	2 Tetra-fluoride.	3 Fusion with alkaline carbonates and silica.
N. S. W. topaz from Mudgee	5, 11·01	12·93	17·04, 17·60, 17·10
Brazil... ...	4·73, 11·2, 11·71, 11·21, 6 92, 12·69	10·90	14·23, 14·61
New England topaz	... ...	...	16·30, 15·92

A table is given above shewing the results obtained by the various methods for fluorine, on the topazes. While obtaining the percentages for fluorine by methods (1) and (3), the silica and alumina were also estimated, so that with the exception of water, the whole of the constituents were now obtained.

It has been found by Penfield and Minor (Am. J. Sc. 94) and Jannasch and Locke (J. Chem. Soc. 94) that all topazes contain more or less water of constitution. The former found 2·45 and the latter 2·69 per cent. in Brazilian topaz. The water takes the place of the fluorine. Penfield and Minor decomposed the topaz with sodium carbonate and the water free from acid was weighed in sulphuric acid or calcium chloride tubes. Jannasch and Locke decomposed with litharge in a bulb tube and collected the water in a calcium chloride tube, a stream of dry air being passed through the apparatus. This last method was found more convenient as a much lower temperature could be used to decompose the topaz; both methods however gave the same results. In the experiments the topaz was first heated to bright redness over a strong bunsen to drive out any contained water; it was then decomposed by litharge and its so-called water of constitution determined. Blank tests on the litharge shewed that the calcium chloride tube gained two to three deci-milligrams and in calculating the percentages this was deducted. In the experiments about ·5 gram. of topaz was mixed with 2 – 2·5 grams. of previously heated litharge, the same amount of litharge being used in the blank tests.

Water of Constitution.

Locality.	Amount taken.	Water found.	Percentage.	
Brazil ...	·6324 grams.	·0134	2·12	2·12
	·5080	·0107	2·11	
New England	·5038	·0050	·99	1·07
	·5780	·0066	1·14	
Mudgee ...	·4900	·0038	·78	·75
	·4958	·0038	·73	

Results of analyses.—Appended is a table giving the complete analyses of these three varieties of topaz. In the latter it will be seen that the silica and alumina obtained by Wöhler's method are always higher than by Berzelius', and this is apparently due to the aluminium hydroxide taking down with it some of the fluorine and sodium.

The alumina was always tested by potassium bi-sulphate and the silica by hydrofluoric acid purified from the commercial acid by redistilling in a platinum retort. The calcium fluoride precipitates were tested by conversion into calcium sulphate or in some other way.

Analysis of Topazes.

		Fusion with alkaline carbonates and silica.		Fusion with alkaline carbonates alone.		
		1	2	1	2	
Mudgee, N.S.W.	SiO_2	31·90	31·84	32·30	32·46	
	Al_2O_3	56·62	56·80	59·70	59·21	
	F	17·90	17·00			
	H_2O on ignit.	·23	·26			
	H_2O by PbO	·75	·75			
		107·10	106·65			
Brazil	SiO_2	31·95	32·16	32·31	31·90	32·18
	Al_2O_3	54·52	54·61	55·90	56·45	55·88
	F	14·62	14·23			
	H_2O on ignit.	·23	·30	·26	·24	·26
	H_2O by PbO.	2·12	2·12			
	Fe_2O_3	...	...	...	·10	·09
		103·44	103·42			
New England, N.S.W.	SiO_2	31·73	31·92			
	Al_2O_3	55·62	55·43			
	F	16·30	15·92			
	H_2O on ignit.	·37	·39			
	H_2O by PbO	1·07	1·07			
	Fe_2O_3	·12	...			
		105·21	104·73			

Analyses of topazes from other sources.

	Curran.	Penfield and Minor, Am. J. S. 94.			Liversidge.
	N. S. Wales.	Utah.	Stoneham.	Brazil.	*Shoalhaven, N.S.W
SiO_2	30·29	31·93	32·28	32·53	28·19
Al_2O_3	60·90	56·25	56·33	55·67	62·66
F	15·05	20·33	18·56	15·48	14·01
H_2O	·40	·19	1·04	2·45	...
	106·64	108·71	108·17	106·13	104·86

---

* Dull and impure.

ON A REMARKABLE INCREASE OF TEMPERATURE AFTER DARK AT SEVEN OAKS, MACLEAY RIVER.

By HUGH CHARLES KIDDLE, F.R Met. Soc., Public School, Seven Oaks, Macleay River.

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

I AM led to pen the following lines because, so far as my general acquaintance with meteorological literature goes, I cannot call to mind any such phenomenon, as I desire to bring under your notice this evening, being hitherto noted or published. Bearing in mind the fact that our next and last monthly meeting is so close at hand, I have not time to discuss the subject exhaustively by quoting records from other stations, as the phenomenon occurred only last evening. In order to be as methodical as space will permit, however, I will divide the matter under two headings, viz., (*a*) the phenomenon, (*b*) the details in connection therewith.

(*a*) *The phenomenon.*—During a dry thunderstorm (much lightning with no rain) which passed over this locality from the westward after sunset on the 27th November last, the temperature of the air suddenly rose from 75° to 95·5°, an increase of over twenty degrees; and, as the disturbance worked off in the course of half an hour or so, the temperature gradually resumed its normal condition.

(*b*) *Details.*—During the previous two or three days a moderate heat wave had passed over the district. On both the 25th and 26th, the maximum temperature in the shade was over 90°, and this was reached as a rule about 10 a.m. About that hour a north-north-east breeze, moderate to fresh in strength, used to set in from the seaboard, and under its cooling influence the temperature gradually decreased throughout. The three days in particular were remarkable for the fact that it was as hot at 7·30 a.m. as at midday, and in the subjoined table the temperatures at various times of the day are recorded. On the 27th, the day's shade maximum temperature reading had reached 91·8° about 10 a.m., and with the N.N.E. breeze the temperature as usual decreased, till at 7 p.m. the reading in the louvred screen stood at 75°. Shortly after, a thunderstorm, which had been working up from the westward for about half an hour previously, now involved us within its influence, and instead of experiencing the usual expected cooling breeze accompanying such a phenomenon we were prostrated by a blast as from a furnace. In a few minutes the temperature rose to 86°, and at 8·15 p.m., after the disturbance had passed, my maximum shade thermometer reading stood at 95·5° instead of 91·8°. Thus the hot air of this thunderstorm was three and a half degrees warmer than the air in the screen during the hottest part of the forenoon.

The phenomenon is the more remarkable when it is remembered that it occurred quite after dark, in fact I was outside taking photographs of the lightning accompanying the disturbance when the first blast struck us. The force of the wind was fresh to strong and came from the W.N.W., that being the point of the compass that the disturbance itself bore down upon us. Bearing in mind these conditions, it will be noted that heat-wave was directly connected with the electric disturbance, and as the phenomenon passed to the eastward, the prevailing northerly breeze re-asserted itself, and the temperature decreased to its usual condition. The total duration of the phenomenon with its abnormal conditions was thirty minutes.

In the attached table will be seen the shade temperature readings at 8 a.m., the dry and wet bulb at 9 a.m., the daily shade maximum readings, and also the maximum reading in the sun's rays :—

Date. November	Shade Temperature in Louvred Screen.				Maximum reading in Sun's rays.
	8 a.m.	9 a.m., Dry.	9 a.m., Wet.	9 a.m., Max.	
27	81°	83°	69°·4	92°	159°·8
28	84°	86°·8	72°·1	91°·8	153°
29	87°	87°·4	76°·4	95°·5	150°

The temperature readings are obtained from the following thermometers, all by Messrs. Negretti and Zambra of London, and certificated at Kew for index error —Dry bulb, No. 81792, index error 0·0°, Max. shade, No. 77421, index error 0·0°, Black bulb in vacuô, No. 80520, index error +0.2°. The index error has been applied to the readings in the foregoing tables.

With a hope that this note will help to trace the remarkable phenomenon herein recorded, I will now conclude my contribution to the year's work. I may add that this observing station is situated on the Macleay River, approximately in Lat. 31° 2′ S., Long. 151° 3′ E., and is about seven miles in a direct line from the coast.

RECORDS OF ROCK TEMPERATURES AT SYDNEY HARBOUR COLLIERY, BIRTHDAY SHAFT, BALMAIN, SYDNEY, N. S. WALES.

By J. L. C. Rae, E. F. Pittman, Assoc. R.S.M., and Professor T. W. E. David, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

I. *Introduction.*—About seventeen years ago Professor J. D. Everett, F.R.S., Secretary to the Underground Temperature Committee of the British Association for the Advancement of Science, furnished one of us (Professor David) with two slow-action thermometers and one maximum thermometer for observing rock temperatures underground. The thermometers were made by Negretti and Zambra, and were tested at Kew Observatory. The Kew certificates were forwarded with them and the corrections applied in the table given later on in this paper are in accordance with these certificates.

The first opportunity for observing underground temperatures near Sydney was afforded by the diamond drill bores for coal, put down at Cremorne, Robertson's Point, Sydney Harbour. The second of these bores was completed in November 1893. The maximum thermometer, sent by Professor Everett, became mislaid in the interval between the completion of the first and second Cremorne bores, and when it became necessary to observe underground temperatures at the No. 2 Bore, Mr. H. C. Russell, B.A., C.M.G., F.R.S., Director of the Sydney Observatory, kindly lent maximum thermometers for the purpose, similar to the one sent by Professor Everett, but not protected by a thick, hermetically sealed outer glass casing. It was, accordingly, necessary to protect these thermometers against the water pressure at the bottom of the bore, and this was done efficiently, though the method is cumbrous, by enclosing the thermometers in a strong wrought iron pipe, hermetically sealed at both ends by means of screw cap pieces which were screwed on hot, with molten lead in the threads of the screws. The results of these observations have been recorded by two of us elsewhere.[1]

The results of these observations show that the rate of increase of rock temperature downwards at Cremorne is about 1° Fahr. for every eighty feet. Shortly after these observations were made at Cremorne, Professor Everett kindly sent another protected Negretti and Zambra maximum thermometer, as well as a protected Phillips maximum thermometer, for further observing of underground rock temperatures. The thermometers used on the present occasion were the two slow-action and the two maximum Negretti and Zambra thermometers sent by Professor Everett. Their numbers are 50452 and 50454 (slow-action) and 15888 and 65294 (maximum).

II. *Methods of Observing.*—The observations of underground temperatures at the Sydney Harbour Colliery, Balmain, Sydney, were obtained by the methods recommended by the Underground Temperature Committee of the British Association for the Advancement of Science. The sinking of the Birthday Shaft had reached a depth of 600 feet before the first observations were made, but since then, readings of the rock temperatures have been taken at intervals of practically 50 feet, and an opportunity will be afforded of making observations at less depth than 600 feet during the sinking of the Jubilee Shaft, which is situated at a distance of 168 feet from the Birthday Shaft (the distance given being from centre to centre of shafts) and has reached, at the present time, a depth of 225 feet.

From 600 feet down to 1,100 feet only the two slow-action thermometers were used, and the horizontal holes, which were drilled into the walls of the shaft for their reception, were put in a distance of 3 feet down to the 950 feet level, while from that

---

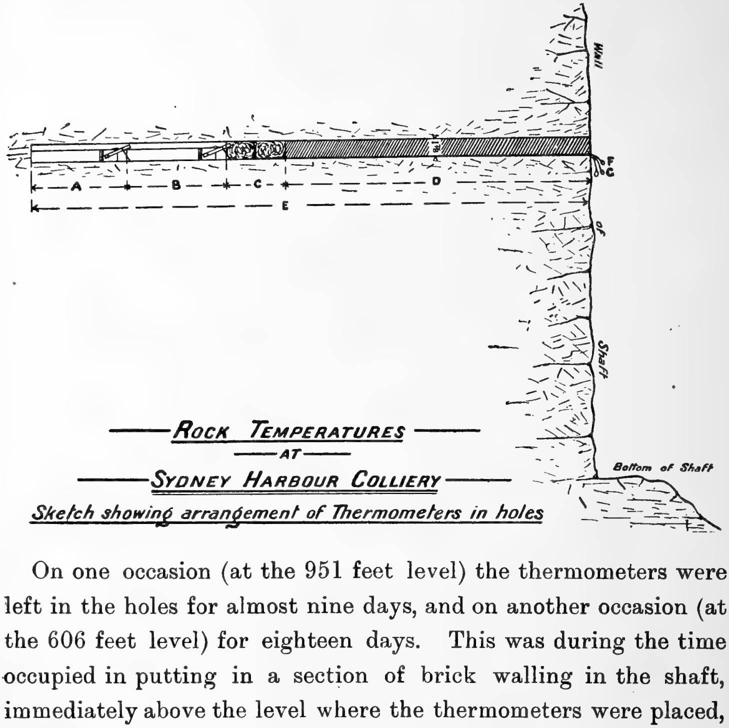
[1] T. W. E. David and E. F. Pittman—Records Geol. Survey N. S. W., 1894, IV., pt. 1, p. 7; Proc. Roy. Soc. N. S. Wales, 1893, XXVII., pp. 460 - 465.

to the 1,150 feet level they were put in a distance of 4 feet in each case. Beginning at the 1,150 feet level the two maximum thermometers were used, in addition to the two slow-action instruments, and the practice has been to place one instrument of each type in each of the holes, which have been put in to a distance of 5 feet.

After the completion of the drilling, the holes were allowed to remain open for a period of from 34 to 84 hours (as specified in the table appended) in order that the heat generated by drilling might escape before the thermometers were inserted. The thermometers were then taken down the shaft and read immediately before being placed in position in the holes. This was done in the case of the maximum thermometers, to ascertain that they then registered a lower temperature than that likely to be observed on their withdrawal from the holes, and in order to ensure this, the instruments were, excepting during the winter, steeped for some time in cold water before being placed in the holes. To the copper cases enclosing the thermometers, strong pieces of string were attached to facilitate their subsequent withdrawal from the holes, and when the instruments were in position 'end on' to one another at the back of the holes, the strings extended from the cases to a little beyond the mouths of the holes. The plugging of the holes consisted, in each case, of about six inches of greasy cotton waste, placed next to the thermometers and gently rammed against the outer instrument case with a wooden rammer, the remainder of the hole being filled up with plastic clay, rammed into the hole. Attached to the cotton waste, in each hole, was a piece of pliable wire, by means of which the plugging could be quickly withdrawn after the clay tamping was removed by a scraper.

After being left in the holes for a period of from 37 hours upwards (as specified in the table appended) the clay tamping and cotton waste plugging were removed from the holes, and the thermometers pulled out by means of the strings and read immediately. In the case of the slow-action thermometers the thick layer of paraffin wax around their bulbs prevented any appreciable alteration in the height of the mercury column taking place before the records were taken.

The following diagram shows, to scale, the arrangement of thermometers in the holes :—



——*Rock Temperatures*——
——*at*——
——*Sydney Harbour Colliery*——
Sketch showing arrangement of Thermometers in holes

On one occasion (at the 951 feet level) the thermometers were left in the holes for almost nine days, and on another occasion (at the 606 feet level) for eighteen days. This was during the time occupied in putting in a section of brick walling in the shaft, immediately above the level where the thermometers were placed, it being impracticable to remove the thermometers whilst this work was going on. The whole of this part of the work was done by one of us (Mr. Rae the manager of the Sydney Harbour Colliery) assisted by the contractor for the sinking of the shaft (Mr. T. Cater).

III. *Section of strata passed through in sinking the Birthday Shaft, Sydney Harbour Colliery, Balmain.*—The following section was taken by Mr. W. S. Dun, Palæontologist to the Geological Survey of N. S. Wales, and one of us (Mr. Rae):—

Birthday Shaft, Sydney Harbour Colliery.

Strata.	Thickness		Depth from Surface.	
	'	"	'	"
Brickwork	7	0	7	0
Yellowish-red, gritty, thick bedded ferruginous sandstone	32	2	39	2
Grey shaly sandstone	4	0	43	2
Shale parting	0	1	43	3
Rather hard thick-bedded grey sandstone	49	8	92	11
Dark bluish-grey sandy shale	5	5	98	4
Rather fine grained greyish sandstone	1	9	100	1
Bluish-grey sandy shale	8	4	108	5
Rather fine light grey sandstone with narrow bands of nodular carbonate of iron	15	0	123	5
Shale parting	0	0½	123	5½
Greyish-white sandstone with mica streaks	42	6	165	11½
Shale, horizontally bedded	4	6	170	5½
Greyish-white sandstone with mica streaks	24	3	194	8½
Shale parting	0	1	194	9½
Greyish-white sandstone, false-bedded with streaks of mica	15	8	210	5½
Fine grained greyish-white sandstone	10	9	221	2½
Grey sandstone, horizontally bedded with shale bands	18	8	239	10½
Greyish-white sandstone, false-bedded	5	6	245	4½
Sandstone with pebbles of shale	13	0	258	4½
Shale band	0	3	258	7½
Greyish-white sandstone with balls of shale	12	9	271	4½
Fine grey sandstone with mica	19	8	291	0½
Greyish-white sandstone with a little fine conglomerate	12	7	303	7½
Shale band	0	3	303	10½
Coarse sandstone, false-bedded	9	6	313	4½
Grey sandstone with pipes of shale	7	0	320	4½
Clay parting	0	0½	320	5
White sandstone	10	0	330	5
Hard grey sandstone with dark streaks false-bedded in places	23	10½	354	3½
Clay parting	0	2	354	5½
Hard grey sandstone with dark streaks, carbonate of iron nodules	1	3½	355	9
Hard grey streaky sandstone, shewing current bedding	35	11	391	8
Fine conglomerate passing into gritty sandstone with occasional nodules of carbonate of iron	9	2	400	10

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Dark sandy shale	0	11½	401	9½
Hard grey sandstone	1	7½	403	5
Dark blue shale	0	3	403	8
Shaly sandstone	2	5	406	1
Clay shale parting	0	1	406	2
Grey streaky sandstone with occasional pebbles of shale	10	4½	416	6½
Very porous sandstone, loose, with boulders of harder sandstone and bands of clay. In this bed the water increased from 75 to 275 gallons per hour	22	1½	438	8
Hard greyish- white sandstone	7	3½	445	11½
Very hard greyish-white sandstone with dark bands, false-bedded	17	11	463	10½
Hard greyish-white sandstone	10	4	474	2½
Very hard ferruginous sandstone	0	4	474	6½
Hard greyish-white sandstone, dark bands	26	8½	501	3
Hard ferruginous sandstone	2	0	503	3
Hard greyish-white banded sandstone ...	7	0	510	3
Rather softer greyish-white sandstone ...	3	0	513	3
Very hard greyish-white sandstone, banded and shewing false-bedding in places...	20	7½	533	10½
Very hard ferruginous sandstone	0	11	534	9½
Hard greyish-white banded sandstone ...	8	6	543	3½
Bluish-grey shale	1	1½	544	5
Rather softer greyish-white sandstone ...	12	6	556	11
Dark bluish-grey sandstone, upper 2″ loose	10	3	567	2
Hard greyish-white sandstone	4	0	571	2
Dark bluish-grey shale	3	0	574	2
Fine grained greyish-white sandstone, false-bedded and friable	15	7½	589	9½
Hard greyish-white sandstone, false-bedded and very friable	20	2½	610	0
Clay shale, bluish-grey	7	0	617	0
Greyish-white sandstone	11	0	628	0
Alternate bands of clay shale and sandstone with impressions of *Equisetum* and fern fragments	6	0	634	0
Fine grained greyish-white sandstone, false-bedded and very friable	38	0	672	0
Clay shale, soft and jointed	1	0	673	0
Grey sandstone with nodules and pebbles of shale and quartz	3	0	676	0
Greyish-white sandstone, false-bedded and friable	43	10	719	10

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Coarse grained white sandstone	13	6	733	4
Dark blue shale (6″ – 12″ thick)	1	0	734	4
Fine grained white sandstone with micaceous bands	4	2	738	6
Fine grained white sandstone with shaly partings, becoming more frequent ...	14	5	752	11
Hard white sandstone	13	10	766	9
Two bands of dark blue shale with sandstone parting	1	0	767	9
Hard white sandstone	0	6	768	3
Dark blue shale with sandstone partings...	5	4	773	7
Hard fine grained sandstone with shaly streaks...	1	0	774	7
Dark blue shale	4	9	779	4
Coarse white sandstone with thin bands of micaceous shale	14	5	793	9
Dark blue shale with thin sandstone bands very hard, varying from 3″ – 5″ thick (At 825′ 830′ and 835′ bands of hard white sandstone). Bottom of this bed dipping N.N.E. about 1 in 16 ...	47	10	841	7
Hard white sandstone with current bedding strongly developed, very friable...	38	9	880	4
Dark blue shale with thin bands of dark sandstone (At 888′ impression of *Equisetum* or *Zeugophyllites* in grey shales; 890′ fine grained sandstone	9	10	890	2
Sandy shale with dark shale bands (At 919′ thin parting with calcite crystals, 925′ hard fine grained sandstone bands, 930′ dark shale with abundant *Equisetum*, 932′ band of brownish-black shale) ...	63	8	953	10
Hard white sandstone with nodules of shale	10	0	963	4
Dark blue shale with thin sandstone bands (975′ dark shale with *Alethopteris?* 980′ dark shale with *Thinnfeldia?* 986′ calcite, 992′ concretionary markings)...	30	0	993	10
Light greyish shale...	4	6	998	4
Dark blue shale, plants *Thinnfeldia*, *Equisetum*, &c., (1,000′ coalpipes)... ...	6	3	1,004	7
Light grey shale (1,010′ 10″ band of very hard grey sandstone 1,022′ 7″ coalpipes	20	2	1,024	9
[In this bed were found *Thinnfeldia odontopteroides*, Morris; *T. narrabeenensis*, nov. sp.; *Alethopteris*, nov. sp.; *Tæniopteris*, nov. sp.; *Equisetum*, Fructification (*cf. Sphæreda* and *Beania*)—all of Triassic Age.]				

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Dark chocolate shale (at 1,038′ three inch band of dark grey sandstone with coal-pipes; 1,072′ hard band of purplish-brown micaceous sandstone, with darker purple streaks, 4″ thick; 1,075′ six inch band of mottled chocolate and greenish grey shale)	52	3	1,077	0
Grey shale	1	3	1,078	3
Mottled chocolate shale	1	10	1,080	1
Dark chocolate shale	2	8	1,082	9
Mottled chocolate and grey shale... ...	12	10	1,095	7
Dark chocolate shale	6	4½	1,101	11½
Greenish glauconitic sandstone	0	1½	1,102	1
Dark chocolate shale	0	1	1,103	1
Mottled chocolate and grey shale	19	2	1,122	3
Dark chocolate shale	5	3	1,127	6
Mottled chocolate shale and greenish sandstone	0	5½	1,127	11½
Greenish-grey glauconitic sandstone ...	6	11½	1,134	11
Dark grey shale with *Equisetum*	6	5	1,141	4
Dark chocolate shale	2	9	1,144	1
Greenish glauconitic sandstone	5	1	1,149	2
Dark chocolate shale	23	10	1,173	0
Greenish glauconitic sandstone (coalpipes at 1,175′)	3	0	1,176	0
Mottled chocolate shale	6	6	1,182	6
Dark chocolate shale	2	2	1,184	8
Dark blue shale with *Equisetum* (shale ball near slip at 1,187′)	2	6	1,187	2
Very dark grey shale	0	3	1,187	5
Dark grey shale	2	7	1,190	0
Dark blue shale	0	9	1,190	9
Chocolate and grey shale, slip in shaft wall and very hard shale balls	0	7	1,191	4
Grey sandstone	0	8	1,192	0
Grey shale with dark sandy micaceous shale	0	10	1,192	10
Grey shaly sandstone with dark pebbles ...	0	2	1,193	0
Hard grey micaceous sandstone	1	0	1,194	0
Hard mottled chocolate shale, lighter near a slip	1	0	1,195	0
Dark chocolate shales, slightly mottled in places	1	5	1,196	5
Purplish gritty micaceous shale	1	3	1,197	8
Purple and green sandy shale (glauconitic)	2	0	1,199	8

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Dark purplish-green mottled shale (glauconitic)	1	0	1,200	8
Mottled shale, chocolate and grey	2	7	1,203	3
Light grey sandy shale, glauconitic streaks	0	9	1,204	0
Dark blue shale	1	1	1,205	1
Hard light grey shale	4	9	1,209	10
Alternate streaks of light and dark shale	0	3	1,210	3
Hard light grey shale with *Equisetum*	0	9	1,210	10
Alternate streaks of light and dark shale	0	5	1,211	3
Hard light grey shale	1	1	1,212	4
Alternate streaks, hard light and dark shale	0	8	1,213	0
Very hard dark blue shale	4	9	1,217	9
Very hard grey sandstone with dark streaks	1	2	1,218	11
Very hard dark micaceous sandstone	0	10	1,219	9
Very hard grey sandstone with dark micaceous streaks	4	3	1,224	0
Light grey micaceous shaly sandstone with streaks of dark shale (1,230′ bright bitumen coal pipe)	9	11	1,233	11
Hard dark blue shale (1,234′ *Thinnfeldia* n. sp.)	4	0	1,237	11
Hard grey shaly sandstone with bands of darker sandstone and blue shale	20	10	1,258	9
Dark blue shale with bands of shaly sandstone	7	6	1,266	3
Alternate bands, 1½″ – 2½″ thick, of grey shaly sandstone and dark blue shale	1	4	1,267	7
Grey shaly sandstone	1	4	1,268	11
Dark blue shale	0	10	1,269	9
Shaly sandstone with streaks of darker micaceous sandstone	0	6	1,270	3
Grey shaly sandstone	1	0½	1,271	3½
Alternate bands of grey shaly sandstone and dark blue shale, averaging 2½″ thick	1	2	1,272	5½
Grey shaly sandstone	1	2	1,273	7½
Dark blue shale with streaks of shale, with *Thinnfeldia odontopteroides*, Morris	6	10½	1,280	6
Very hard grey shaly sandstone with streaks of darker sandstone	0	7½	1,281	1½
Alternate bands of dark shale and hard grey sandstone	2	0	1,283	1½
Blue sandy shale, fissile, micaceous with *Thinnfeldia odontopteroides*	8	2½	1,291	4
Mottled chocolate shale—dark chocolate and bluish-green	1	5	1,292	9

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Blue shale	1	0	1,293	9
Mottled chocolate shale	3	0	1,296	9
* Bluish shale with *Thinnfeldia odontopteroides*	8	2	1,304	11
Bluish shale with dark bands and small patches of glauconitic sandstone ...	0	6	1,305	5
Dark blue shale with coal pipe ($\frac{1}{2}$″) ...	2	$0\frac{1}{2}$	1,307	$5\frac{1}{2}$
Carbonaceous shale, with coal pipes and *Equisetum*	0	$1\frac{1}{2}$	1,307	7
Dark blue micaceous shale with $\frac{1}{2}$″ coal-pipe	1	1	1,308	8
* These beds contain *Thinnfeldia odontopteroides*, Morris, *T. narrabeenensis*, sp. nov., and a *Thinnfeldia* with small pinnules, probably a new variety—Triassic.				
Mottled chocolate and green shale, micaceous	3	11	1,312	7
Bluish-grey shale with dark streaks jointed, coarse, with carbonaceous bands, *Thinnfeldia sp.* abundant	3	4	1,315	11
Bluish-green sandy shale, *Thinnfeldia* ...	2	10	1,318	9
Grey sandy shale	1	7	1,320	4
Greenish-grey micaceous sandy shale with carbonaceous streaks, $\frac{3}{8}$″ coal pipe at bottom	1	5	1,321	9
Greenish-grey micaceous shale, glauconitic in parts, stained with chocolate, large *Thinnfeldia*	2	0	1,323	9
Greenish-grey micaceous sandy shale with tinges of chocolate in places	1	6	1,325	3
Greyish shale	0	2	1,325	5
Dark micaceous shale with patches of chocolate shale	3	7	1,329	0
Dark chocolate and green mottled shale, micaceous	2	0	1,331	0
Greenish-grey glauconitic sandstone ...	1	2	1,332	2
Mottled shale—grey and dark grey ...	0	3	1,332	5
Chocolate shale	1	4	1,333	9
Mottled chocolate shale	6	7	1,340	4
Bluish-grey shale	2	0	1,342	4
Very hard dark blue sandy shale, micaceous	4	6	1,346	10
Bluish-grey sandy shale	0	$5\frac{1}{2}$	1,347	$3\frac{1}{2}$
Dark blue shale	2	0	1,349	$3\frac{1}{2}$
Dark bluish-grey micaceous sandy shale, hard	3	$10\frac{1}{2}$	1,353	2
Bluish sandy shale	0	$9\frac{1}{2}$	1,353	$11\frac{1}{2}$
Hard fine grained bluish-green sandstone, coarse, dark streaks	0	6	1,354	$5\frac{1}{2}$

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Hard fine grained greenish sandstone, micaceous	0	4½	1,354	10
Greyish micaceous sandy shale	0	1	1,354	11
Fine grained sandstone with dark shaly streaks, micaceous	0	10	1,355	9
Bluish-grey micaceous sandy shale ...	0	1½	1,355	10½
Hard fine grained grey sandstone, micaceous fragments of shale and garnets (?)	3	11	1,359	9½
Alternate bands 2½″ – 4½″ thick of hard fine grained sandstone and bluish shale ...	1	2½	1,361	0
Hard fine grained grey sandstone with thin carbonaceous streaks	7	7	1,368	7
Dark grey sandy shale	0	2	1,368	9
Hard fine grained, light grey sandstone (garnets)	5	11	1,374	8
Dark grey sandy shale	0	2½	1,374	10½
Hard fine grained light grey micaceous sandstone	2	4	1,377	2½
Dark grey sandy shale	0	3½	1,377	6
Hard fine grained light grey sandstone ...	0	4	1,377	10
Dark grey sandy shale	0	0½	1,377	10½
Hard fine grained light grey sandstone ...	0	3½	1,378	2
Dark grey sandy shale	0	0½	1,378	2½
Hard fine grained light grey sandstone ...	0	6½	1,378	9
Dark grey sandy shale	0	3	1,379	0
Hard fine grained light grey sandstone ...	0	7	1,379	7
Dark grey sandy shale	0	5	1,380	0
Hard fine grained light grey sandstone ...	2	7	1,392	7
Dark greenish-grey shale, with chocolate ...	1	6	1,394	1
Greenish-grey micaceous sandstone ...	4	8	1,398	9
Micaceous sandy shale	0	6	1,399	3
Greenish sandstone, fine grained, micaceous	3	9	1,403	0
Bluish-grey micaceous shale	1	6	1,404	6
Irregular fragments of bluish shale in grey micaceous sandstone	0	10½	1,405	4½
Light grey micaceous sandstone with included fragments of shale and red grains (garnets ?)	1	0	1,406	4½
Dark bluish sandy shale	0	7½	1,407	0
Hard grey micaceous sandstone with pebbles of shale (included)	2	0	1,409	0
Bluish-grey micaceous sandy shale ...	0	8	1,409	8
Bluish-grey micaceous shale with *Equisetum*	0	1	1,409	9
Bluish-green sandstone, fine grained, hard	3	7	1,413	4
Bluish-grey micaceous sandy shale ...	0	1	1,413	5

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Hard fine grained light grey micaceous sandstone	4	1	1,417	6
Dark blue micaceous sandy shale	1	0	1,418	6
Hard fine grained bluish-grey micaceous sandstone	1	8	1,420	2
Hard fine grained light grey micaceous sandstone	3	11	1,424	1
Dark blue micaceous sandy shale	5	1	1,429	2
Hard fine grained bluish-grey micaceous sandstone	0	10½	1,430	0½
Bluish-grey micaceous sandy shale ...	3	1½	1,433	2
Hard fine grained light grey micaceous sandstone	0	9	1,433	11
Bluish-grey micaceous sandy shale ...	0	2½	1,434	1½
Hard fine grained bluish-grey micaceous sandstone	1	0½	1,435	2
Bluish-grey micaceous sandy shale ...	0	4	1,435	6
Hard fine grained bluish-grey micaceous sandstone	5	0	1,440	6
Dark blue micaceous sandy shale	2	1	1,442	7
Hard fine grained bluish-grey micaceous sandstone	0	1	1,442	8
Bluish-grey micaceous sandy shale ...	0	4½	1,443	0½
Hard fine grained bluish-grey micaceous sandstone	0	4	1,443	4½
Bluish-grey micaceous sandy shale ...	0	9½	1,444	2
Hard fine grained bluish-grey micaceous sandstone	1	2½	1,445	4½
Bluish-grey micaceous shaly sandstone ...	0	11½	1,446	4
Dark blue micaceous sandy shale	2	7	1,448	11
Hard fine grained bluish-grey micaceous sandstone	9	7	1,458	6
Bluish-grey micaceous sandy shale ...	4	3½	1,462	9½
Hard fine grained grey micaceous sandstone	6	6	1,469	3½
Hard fine grained bluish-grey micaceous sandstone	0	10	1,470	1½
Bluish-grey micaceous sandy shale ...	0	6	1,470	7½
Very hard fine grained bluish-grey micaceous sandstone	0	11½	1,471	7
Hard fine grained bluish-grey micaceous sandstone	0	8½	1,472	3½
Fine grained bluish-grey micaceous shaly sandstone	0	11	1,473	2½
Hard fine grained bluish-grey micaceous sandstone	7	8½	1,480	11

Strata.	Thickness		Depth from Surface.	
	′	″	′	″
Bluish-grey micaceous sandy shale	0	6	1,481	5
Very hard fine grained bluish-grey micaceous sandstone	1	2½	1,482	7½
Greenish-grey micaceous sandy shale	3	0	1,485	7½
Hard fine grained dark bluish-grey micaceous sandy shale	0	8½	1,486	4
Bluish-grey micaceous sandy shale	2	11	1,489	3
Hard fine grained light grey micaceous sandstone	1	4½	1,490	7½
Bluish-grey micaceous sandy shale with light streaks	1	4½	1,492	0
Hard fine grained light grey micaceous sandstone	2	8	1,494	8
Bluish-grey micaceous sandy shale	0	4½	1,495	0½
Hard fine grained light grey micaceous sandstone			[1,500]	

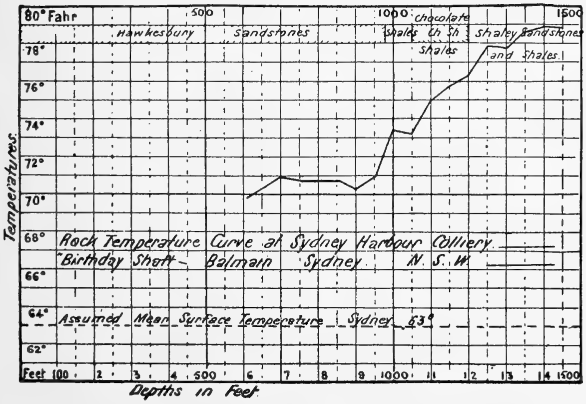
It may be mentioned that the Birthday Shaft bears S. 67° 15′ W. from the No. 2 Cremorne Bore, and is 260 chains distant. The original rock level at the Birthday Shaft was 73 feet above mean low tide level in Sydney Harbour, but the top of the brick walling in the shaft is now 80 feet above mean low tide, this being the finished level of the pit mouth. The distance from the shaft to the shore of the harbour at the nearest point is 70 yards.

With regard to features, connected with the geological section, which may have some modifying influence on rock temperature, it may be mentioned that very little gas has, as yet, been met with in the shaft, with the exception of a small blower at the 607 feet level. A bed of clay shale, having a thickness of 7 feet, was met with three feet below this level. For some distance above this, and for a considerably greater depth, the sandstone showed a tendency to burst off, in large flakes, from two sides of the shaft as though it were under considerable pressure. This necessitated the walls of the shaft being temporarily secured by close timbering, pending the putting in of the permanent brick walling.

As regards water circulating in the strata penetrated by the shaft, the following may be recorded :—The amount of water met with down to 416 feet 6½ inches was about 75 gallons per hour. Below this a bed of soft porous sandstone was passed through, having a thickness of 22 feet 1½ inches. The base of this bed was, therefore, at a depth of 438 feet 8 inches, and water made in the shaft at this level, at the rate of 200 gallons per hour, thus bringing the total inflow up to 275 gallons per hour. At a depth of 442 feet, where a "walling curb" was seated, a "water ring" or "garland" was also put in. In this all the water was collected and thence led down one side of the shaft in a 2″ diameter wrought iron pipe. The same amount of water, viz. 275 gallons per hour, continued to a depth of 607 feet, when in a bed of hard, greyish-white, false bedded, and very friable sandstone, a feeder of water accompanied by gas was met with, the inflow of water being at the rate of 170 gallons per hour, thus making the total inflow 445 gallons per hour. The gas, which evidently came from a bed of clay shale which was struck three feet below the feeder, took fire when a light was applied. At a depth of 672 feet, in a bed of clay shale, soft and jointed and one foot thick, another small feeder of water was struck which raised the total inflow to 463 gallons per hour. At a depth of 690 feet, the sinking being then in a thick bed of greyish-white sandstone, false bedded and friable, the water increased to 597 gallons per hour, and in the same bed of rock, at a depth of 700 feet, the total inflow still further increased to 654 gallons per hour. This bed of sandstone was 43 feet 10 inches thick, the top being 676 feet from the surface (top of brick walling) and the bottom 719 feet 10 inches. At a depth of 720 feet the water began to decrease, the total inflow being at the rate of 550 gallons per hour, and at the 750 feet level it had still further decreased to 511 gallons per hour. At the 768 feet level another "water ring" was put in, from which the whole of the water was led down the shaft in two inch diameter wrought iron pipes. When a depth of 774 feet was reached it was found that the inflow of water had still further decreased, the total amount being about 502 gallons per hour. Thence, down to the bottom of the shaft, the average inflow has ranged from 480 to 510 gallons per hour.

The water flowing into the shaft from between the "water rings" fixed at the 442 feet and 768 feet levels, is remarkably rich in lime, with distinct traces of barytes. So much lime is present that, in the space of a fortnight, the two inch pipe, leading the water down from the 768 feet level to the bottom of the shaft, became almost completely blocked with a solid fibrous, radial incrustation of barytic carbonate of lime. The iron pipes were consequently replaced with wooden boxes, three inches square, which can be taken to pieces when it is necessary to remove the incrustation. As the two inch wrought iron pipes from the "water ring" at the 442 feet level show no signs of lime incrustation, it is evident that it comes from somewhere between the 442 feet and 768 feet levels. Mr. H. G. Smith, F.C.S., and one of us (Professor David) have already noticed the occurrence of barytes in the Hawkesbury series, but this abundance of lime in the Hawkesbury Sandstone is quite exceptional.

IV. *Diagram showing Temperature Curve and Table of Records of Rock Temperatures.*—The following curve diagram and table give full particulars of the results of the observations made in the Birthday Shaft :—



RECORDS OF ROCK TEMPERATURES AT SYDNEY HARBOUR COLLIERY BIRTHDAY SHAFT, BALMAIN, SYDNEY, N.S.W.

Depth from surface, feet	Nature of Rock.	Date of first exposure of rock in sinking (1899)	Date of boring of holes for thermometers (1899).	No. of hours intervening between completion of holes and insertion of thermometers.	Depths of holes in which thermometers were placed in feet. (Diameter of holes 1 7/8 inches.)	Temperatures of thermometers at time of insertion in holes (° Fah.)				No. of hours thermometers were left in holes	Date of withdrawal and reading of thermometers (1899).	Temperatures of thermometers at time of withdrawal from holes (° Fah.)				Corrected temperatures of thermometers in accordance with Kew certificate (degrees Fah.)				Mean of corrected temperatures.
						Slow-action thermometers.		Maximum thermometers.				Slow-action thermometers.		Maximum thermometers.		Slow-action thermometers.		Maximum thermometers.		
						No. 50452	No. 50454	No. 15888	No. 65294			No. 50452	No. 50454	No. 15888	No. 65294	No. 50452	No. 50454	No. 15888	No. 65294	
606	Hard greyish-white sandstone, current bedding strongly developed, very friable	Jan. 9	Jan. 12	84	3	...	...	...	...	432	Feb. 3	70	69·75	...	...	70	69·75	...	...	69·875
700	Hard greyish-white sandstone, current bedding strongly developed, very friable	Feb. 27	Feb. 28	39	3	...	...	...	...	140½	Mar. 8	71	70·9	...	...	71	70·9	...	...	70·95
758	Hard white sandstone	Mar. 28	Mar. 30	40½	3	...	...	...	...	129½	April 6	70·8	70·5	...	...	70·8	70·5	...	...	70·65
854	Hard white sandstone, current bedding strongly developed, very friable	May 1	May 3	48	3	...	...	...	...	76½	May 8	71	70·5	...	...	71	70·5	...	...	70 75
902	Sandy shale with occasional bands of dark shale	May 27	May 31	60¼	3	...	...	...	...	150	June 9	70·5	70·25	...	...	70·5	70·25	...	...	70 375
951	Sandy shale with occasional bands of dark shale	June 9	June 12	40¾	3	...	...	...	...	213¼	June 23	70·75	71	...	...	70·75	71	...	...	70·875
1000	Dark blue shale with numerous plants (*Thinnfeldia*, *Equisetum*, *Tæniopteris*) and coal pipes...	June 23	June 24	61	4	...	...	...	...	43½	June 28	73·5	73·25	...	...	73 515	73·25	...	...	73·382
1050	Dark chocolate shale	July 15	July 17	48	4	64	68·5	...	...	85½	July 23	73·25	73·1	...	...	73·262	73·1	...	...	73 181
1100	Dark chocolate shale	July 25	July 26	45	4	61·5	61·25	...	...	41¾	July 30	75	74·75	...	...	75·03	74·75	...	...	74·89
1150	Dark chocolate shale	Aug. 2	Aug. 3	57½	5	69·5	67	71	69	65½	Aug. 8	75·75	75·8	76	75·5	75·787	75·8	75·95	75 5	75 762
1200	Dark purple and green mottled shale	Aug. 23	Aug. 25	37¾	5	65	64·5	67·5	68	161¼	Sept. 2	76·25	76·1	76·25	76·4	76·292	76·1	76·208	76·4	76·25
1250	Hard grey shaly sandstone with bands of darker sandstone and blue shale	Sept. 5	Sept. 7	43⅚	5	74·5	73·3	74·5	75·5	37	Sept. 9	77·8	77·75	77·8	78	77·858	77·75	77·742	78	77 837
1300	Blue shale with plant impressions (*Thinnfeldia odontopteroides*) ...	Sept 23	Sept. 25	35⅙	5	74·25	70·25	75·5	73	113½	Oct. 1	78	77·75	77·6	77·6	78·06	77·75	77·544	77·6	77 738
1350	Hard, dark bluish-grey micaceous sandy shale	Oct. 3	Oct. 4	51⅓	5	74·25	75·25	76	76	38¼	Oct. 8	78·9	78·75	78·6	78·3	78·962	78·75	78·534	78·3	78·638
1400	Fine grained greenish-grey micaceous sandstone	Oct. 13	Oct. 15	34	5	78	72·75	72·5	74·75	49	Oct. 18	79·5	79	79·1	78·25	79 575	79	78·98	78·25	78·951
1449	Hard, fine grained bluish-grey micaceous sandstone	Nov. 21	Nov. 23	37½	5	73	73·75	75	74·5	146	Dec. 1	79	79	79	78·25	79·07	79	78·93	78·25	78·812

NOTE.—From 1,150 feet downwards, the thermometers were placed in the holes in pairs, one slow-action and one maximum thermometer being inserted in each hole, as follows :—

	No. 1 Hole. Thermometers—		No. 2 Hole. Thermometers—
At the 1150 feet level	Nos. 50452 and 65294	...	Nos. 50454 and 15888
„ 1200 „	„ 50452 „ 65294	...	„ 50454 „ 15888
„ 1250 „	„ 50452 „ 66294	...	„ 50454 „ 15888
„ 1300 „	„ 50452 „ 15888	...	„ 50454 „ 65294
„ 1350 „	„ 50452 „ 65294	...	„ 50454 „ 15888
„ 1400 „	„ 50452 „ 15888	...	„ 50454 „ 65294
„ 1449 „	„ 50452 „ 65294	...	„ 50454 „ 15888

In the observations of rock temperatures at the No. 2 Cremorne Bore (referred to in the introduction to this paper) the mean annual surface temperature at Sydney was taken as 63° Fahr. (this having been determined by Mr. H. C. Russell, F.R.S., Director of the Sydney Observatory), whilst the stratum of invariable temperature was assumed to be 15 feet below the surface. On this basis the average rate of increase of temperature downwards, in the Birthday Shaft will be found to be 1° Fahr. for every 90·7 feet.

V. *Rock temperatures, observed elsewhere, for comparison with the observations made in the Birthday Shaft, Sydney Harbour Colliery :—*

Place where observations were made.	Depth in feet.	Feet for 1° Fahr.
Schladebach Bore, Prussia...	5,735	65
Astley Colliery, Dukinfield...	2,700	72
Ashton Moss Colliery, Manchester	2,790	77
Dukenfield Colliery	2,055	83
St. Gothard Tunnel...	5,578	82
Lansell's Gold Mine, Victoria	3,250	111
Prizbam Silver Mines, Bohemia	1,930	126
Calumet and Hecla Lode, Lake Superior, U.S.A.	4,712	223

VI. *Conclusion.*—It is proposed to continue these observations to the full depth to be reached by the Sydney Harbour Colliery Shafts (nearly 3,000 feet), and it would, therefore be premature as yet, to comment on the temperature curve obtained from the observations made so far.

Our thanks are specially due to Mr. T. Cater (contractor for the sinking of the shafts) for his valuable co-operation in the work. We also desire to express our obligations to Professor J. D. Everett, F.R.S., for the use of the thermometers, and to Mr. W. S. Dun for the detailed section of the shaft and determination of the fossils.

NOTE ON THE EDIBLE EARTH FROM FIJI.

By the Hon. B. G. CORNEY, M.D., Professor DAVID, B.A., F.G.S., and F. B. GUTHRIE, F.C.S.

[*Read before the Royal Society of N. S. Wales, December 6, 1899.*]

THE sample of edible earth, which forms the subject of this note was collected by one of us (Dr. Corney), by whom it was presented to Professor T. P. Anderson Stuart, who in turn presented it to the Geological Department of the University of Sydney.

The earth occurs in several localities in the Fiji Islands. The specimen examined was collected near the northern coast of the large island called Vanua Levu, where the rocks are igneous. The natives, that is the women, eat small portions of it at times, and assert that it has some salutary influence over the later stages of pregnancy. It seems not unlikely that it may relieve some of the disagreeable or painful sensations incidental to that condition; and the practice may have arisen in consequence. The natives have no specific name for this earth, calling it merely *Qele kana,* which means 'edible earth.'

At Tavuki, on the north side of the island of Kadavu, it is met with in the solid, and the people cut it into brick-shaped blocks with which they face up the raised foundation mounds upon which their dwellings are constructed. The women there also eat it in small quantities.

At Naitasiri, on the bank of the Rewa river, the Indian coolies who work on the sugar plantations recently quarried out some three quarters of a ton of the earth, which by degrees they ate. In their case it was noticed that those who were afflicted with the small intestinal nematode called *Anchylostomum duodenale* were almost always geophagists; but it is uncertain whether the discomforts arising out of the presence of this worm in the intestine give origin to a craving which the ingestion of the earth seems to partially satisfy, or whether the habit of earth-eating occurs first and is the means of introducing the ova of the parasite. Moist earth is understood to be the principal habitat of these ova during the extra-corporeal stage of their life-history, and therefore the latter supposition has received, perhaps, the most support.

The material consists of a very soft, pale pink, clayey material, with small white patches of similar substance and occasional lumps of grey to reddish chalcedony. Its hardness is less than 1 on Moh's scale. The matrix is extremely fine-grained for the most part, but here and there are lumps of angular chalcedony up to $1\frac{1}{2}''$ in diameter. Angular and rounded pyramidal quartz crystals are also fairly numerous, and attain a diameter of from $\frac{1}{8}''$ to $\frac{1}{6}''$. There are also present numerous small and very perfect octahedral crystals of magnetite. Mr. W. G. Woolnough, B.Sc., has estimated the amount of quartz and magnetite crystals present, and has found 5 per cent. quartz crystals and 0·5 per cent. magnetite.

The rock has suffered so much from decomposition that it is difficult to obtain definite evidence as to whether it represents a decomposed volcanic tuff or a decomposed lava. On the whole it is probable that it represents a decomposed tuff of the nature perhaps of a quartz andesite (dacite). It is even possible that the lava may have been sufficiently acid to justify its being classed as a rhyolite. Mr. E. C. Andrews, B.A., has already described both rhyolites and andesites from Fiji.

On the whole, in view of the abundance of magnetite crystals, it is more probable that the rock was originally a dacite. It was probably of tuffaceous origin, and though now, as the subjoined analysis shows, practically a kaolinite, was probably originally a dacite tuff.

Moisture at 120° C...	2·45
Combined water	12·78
Silica	41·53
Alumina	35·09
Oxide of Iron, (Fe_2O_3)	7·66
	99·51

The earth in question is very soft, of a pinkish colour, with redder patches of ferric oxide distributed irregularly throughout. The oxide of iron can be dissolved out with hydrochloric acid. The colour is unaltered on ignition. Moistened with water, the earth has the greasy feel and peculiar odour of moistened clay or kaolin. For analysis the sample was reduced to fine powder with very gentle pressure and separated from the harder quartz particles by means of a very fine sieve. Lime and magnesia are absent; alkalies were not determined. The silica, alumina and combined water are present in approximately the proportions required by the formula $Al_2O_3(SiO_2)_2(H_2O)_2$; the percentage composition of which would be—

Silica = 46·51
Alumina = 39·54
Water = 13·95
100·00

The amount of silica found in the edible earth, if combined in these proportions with the alumina and water, would require 35·30 per cent. alumina and 12·46 combined water, quantities which are very close to those obtained by analysis.

Assuming the material to be $Al_2O_3(SiO_2)_2(H_2O)_2$ containing 7·66 per cent. ferric oxide and 2·45 per cent. moisture its composition would be :—

	Calculated.	Found.
Moisture at 120° C... ...	= 2·45	... 2·45
Combined water	= 12·54	... 12·78
Silica...	= 41·81	... 41·53
Alumina	= 35·54	... 35·09
Oxide of iron (Fe_2O_3) ...	= 7·66	... 7·66
	100·00	99·51

The substance appears therefore, to be a silicate of the composition $Al_2O_3(SiO_2)_2(H_2O)_2$—kaolinite—with about 7·6 per cent. uncombined ferric oxide as mechanical impurity.

It may be of interest to note in connexion with Dr. Corney's remarks (in the earlier part of the paper) as to the prevalence of intestinal worms amongst clay-eaters, that the same thing is frequently observed amongst cattle, more especially in the dry part of New South Wales. Samples of clayey earth from what are called "lick-holes" are frequently sent to the N. S. Wales Department of Agriculture for examination. The earth in these places is used as a lick by cattle, and it is stated that the cattle suffer from worms. Nothing unusual has been found in these licks except that they are generally fairly rich in saline matter, and the conclusion arrived at is that the cattle relish them on this account alone, and that the presence of worms is due to their poor condition and want of nourishment. The cases are certainly not quite parallel.

228

130 **NITOPHYLLUM** *Grev. Frond*

167 **CŒLOCLONIUM**, *J. Ag. Frond filiform, dendroid, periphery of small polygon*

168 **CORYNECLADIA**, *J. Ag. Frond*

200 **BOSTRYCHIA**, *Mont. Frond dull red, inarticulate, or an articulate tube surroun*

201 **POLYSIPHONIA**, *Grev. Frond opaque or reticulate, joints longitudinally striate,*

ELONGATÆ, *Stem opaque, inarticulate, branches articulate. Harv. Ner. A*

DICHOTOMÆ, *Frond all pellucid, articulate, subdichotomous, decompou*

GLOMERULATÆ, *Frond all pellucid, articulate, pinnate, densely clothe*

BYSSOIDEÆ, *Frond alternately branched, 1-tubed branchlets. Hook. Hdbk.*

PENNATÆ, *Frond rose-colour or purple, often distichously pinnate, branchlets*

CANCELLATÆ, *Frond brown, black when dry, shrubby, furrowed, vaguely branc*

202 **DASYA**, *Ag. Frond articulate or not, cylindric or compressed, emitting fructife*

COMPSOTEIA, *Frond more or less articulate, polysiphonous, crimson, pinnato-dichotom*

RHODONEMA, *Frond inarticulate, cylindric, vaguely branched, branches and bran*

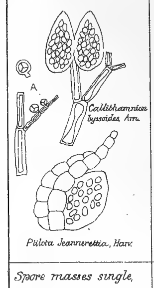
STICHOCARPUS, *Frond more or less articulate, polysiphonous, crimson, decompo*

LOPHOTHALIA, *Frond articulate or not, tetrasiphonous, virgate, alternately br*

Richd. a. Bastow.

KEY TO TRIBES AND GENERA OF FLORIDEÆ (RED OR PURPLE ALGÆ).

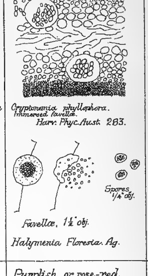
1. CERAMIACEÆ.



Ptilota Jeannerettia, Harv.

Spore masses single, naked or involucrate (by small branchlets), spores aggregated without order within a hyaline membranous cell, developed externally. Articulated one-tubed algæ, naked, or covered with decurrent fibres, at length cellulose. Nucleus (spore-mass) adnate, simple or lobed, lobes as if coalescing. Spores roundish-angular; Tetraspores variously divided. Ag. 1876. 2.

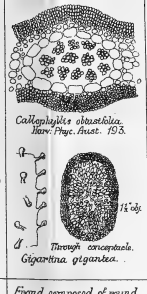
2. CRYPTONEMIACEÆ.



Halymenia Floresia. Ag.

Purplish or rose-red, with an inarticulate, horny, cartilaginous, gelatinous, or membranous frond, formed in great part of articulated confervoid filaments held in gelatine. The membranous ones with cells gradually smaller towards the surface. Spore masses immersed in the frond or slightly prominent, nucleus simple, of a roundish mass of spores. Tetraspores frequently cruciately divided. Ag. 1876. 112.

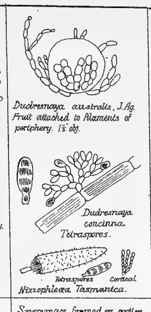
3. GIGARTINEÆ.



Gigartina gigantea.

Frond composed of round filaments surrounded by a continuous stratum of moniliform filaments or vertical cells. Nucleus compound, immersed in the frond or contained in a proper pericarp, sub-indefinitely surrounded, composed of many fertile cells more or less approximating. Tetraspores immersed or evolved from nemathecia, transformed from the cells of the cortical stratum. Ag. 1876. 173.

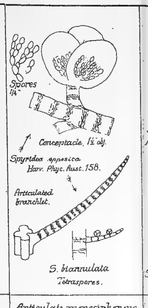
4. NEMATOSPERMEÆ.



Nizzophlœa Tasmanica.

Sporemass formed on articulated ramelli, the spore-bearing filaments divided, supported in gelatine. Frond articulate or continuous, tubular or filled with filaments in Dumontia. Tetraspores at the apices of ramelli in Dudresnaya, oblong, zonate. Tetraspores immersed in the peripheric stratum in Halosaccion. See Dasyphlœa Tasmanica, Harv. Phyc. Aust. 115, and Nizzophlœa in Ag. 1876. 253.

5. SPYRIDIEÆ.



S. biannulata Tetraspores.

Articulate, monosiphonous, more or less densely corticated. Spore masses in a proper external pericarp frequently lobed. Sub-compound nucleus. Nucleoli arranged around a central placental column, frequently radiating, the fertile filaments frequently subdichotomous, articulate below, sometimes crowded without order. Tetraspores on the ramelli, sub-external, triangularly divided. J. Ag. 1876. 266.

6. ARESCHOUGIEÆ.

Section of frond showing tetraspores. Erythroclonium.

Inarticulate, tubulose, medullary stratum of percurrent filaments, the outermost of radiating cellules or conjoined vertical filaments. Conceptacles immersed in the frond, suspended amongst the medullary filaments and enclosed in a network of filaments. Nucleoli radiately disposed around the central placenta, and consisting of bundles of fertile filaments in fastigiate fascicles, subdichotomous and articulate below. J. Ag. 273.

7. CHAMPIEÆ.

Champia compressa.

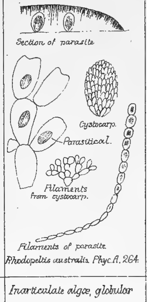
Inarticulate tubular algæ, the medullary stratum of large empty cells, or divided by diaphragms, the diaphragms joined by vertical filaments. The outer cells frequently in conjoined vertical filaments. Favellæ within a proper external pericarp and surrounded with slender cobwebby filaments, the fertile filaments aggregated from the base, reticulate and anastomosing, spores amongst the articulations. J. Ag. 1876. 290.

8. RHODYMENIACEÆ.

Rhodophyllis [illegible] Phyc. Aust. 254.

Inarticulate algæ, rarely inflated-tubulose, frequently solid cellular, the outer cells conjoined vertical filaments. Conceptacles immersed in the frond, or a round nearly naked nucleus in an external pericarp. Fertile filaments articulate sub-corymbose or sub-paniculately branched, the upper branches sub-confluently forming a nucleus. Tetraspores variously divided. J. Ag. 1876. 307.

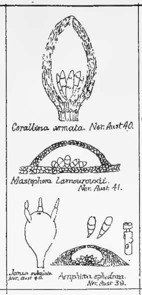
9. SQUAMARIACEÆ.



Rhodopeltis australis. Phyc. A. 264.

Inarticulate algæ, globular or horizontally expanded, crustaceous or membranous. cells in lose mucus or solidly concreted. Cystocarps evolved from nemathecia, transformed articulate filaments in a hyaline membrane, in the form of warts on the upper surface or immersed in the frond. Tetraspores transformed from the articulations of the filaments, generally cruciately divided. J. Ag. 1876. 373.

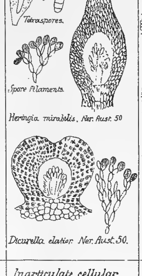
10. CORALLINACEÆ.



Jania rubens Ner. Aust. 40. Amphiroa ephedræa. Ner. Aust. 39.

Frond calcareous, its cells secreting carbonate of lime, horizontally or vertically expanded, or filiform or continuous, articulate. Ceramidia opening by a pore, immersed, or more or less wart-form, or sub-ovate, including 4-zoned spores. The central cells of frond long cylindrical, with joints coinciding. The surface cells shorter, very small. J. Ag. 1852.

11. SPHÆROCOCCOIDEÆ.



Dicurella elatior. Ner. Aust. 50.

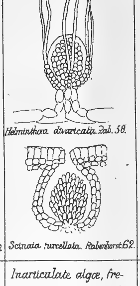
Inarticulate cellular algæ, innermost cells filiform, medullary cells large, longitudinal, outermost round-cells or conjoined vertical filaments. Cystocarps frequently within an external prominent hemispherical pericarp, sometimes pedicellate, nucleus simple. Fertile filaments radiating from base of placenta, branched, articulate, gemmæ on the highest articulations. Tetraspores minute, on changed frond or superficial sori.

12. DELESSERIEÆ.

Caloglossa Leprieurii. Ner. Bor. Am. 22.

Inarticulate expanded leaf-like fronds, often nerved, surface cells large, elongate. Cystocarp in an external rather wide pericarp. Fertile filaments from cells of placenta, depressed, large above base, radiating orbicularly. The gemmæ at apices become earliest mature, obovate-oblong, emitted round. Tetraspores in slightly prominent sori, large, round, triangularly divided. J. Ag. 1876 444.

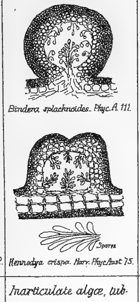
13. HELMINTHOCLADIEÆ.



Scinaia furcellata. Rabenhorst. 62.

Inarticulate algæ, frequently cylindric, gelatinous, sometimes with a calcareous deposit. The interior longitudinal filaments become vertical as they approach the exterior, outer cells round-angular. Cystocarps generally immersed in the frond, evolved amongst the cortical filaments, or suspended in the frond by interwoven filaments, generally on a proper placenta, radiate, articulate. J. Ag. 503.

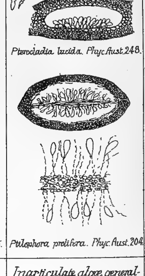
14. CHÆTANGIEÆ.



Hennedya crispa. Harv. Phyc. Aust. 75.

Inarticulate algæ, tubulose or dense, composed of anastomosing filaments of long or short cells. Cystocarps immersed in the frond, pericarp more or less prominent, apertured, in a hollow of woven placenta bearing filaments, short or long, prominent, free above, articulate, branched, single, clavate-obovate spores in the terminal articulations. J. Ag. 1876. 532.

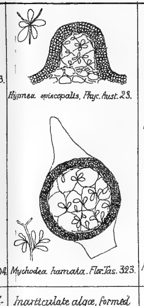
15. GELIDIEÆ.



Ptilophora prolifera. Phyc. Aust. 204.

Inarticulate algæ, generally formed of densely woven fibrous cells. Cystocarps hemispherical, single or double, and prominent, the dissepiment longitudinal and connected with the walls of cavity by slender filaments. Fertile filaments densely seriate, in many shortened fascicles, with at times columns of sterile filaments, spores clavate-obovate, terminal. Tetraspores amongst the cortical filaments. J. Ag. 543.

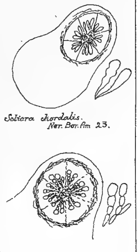
16. HYPNEACEÆ.



Mychodea hamata. Flor. Tas. 323.

Inarticulate algæ, formed of longitudinal filaments and vertically seriated cellules. Cystocarps immersed in the frond or in an external pericarp, enclosing a compound nucleus. The placenta formed of a number of articulated filaments constituting hollows, with fertile filaments aggregated in the hollows, sparingly branched, spores terminal, pyriform. J. Ag. 556.

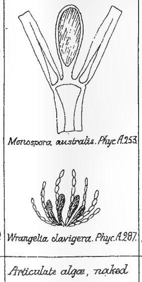
17. SOLIERIEÆ.



Rhabdonia dendroides. P. A. 149.

Inarticulate algæ, tubulose, and containing percurrent filaments, or partly filled, and with a tubular axis, or furnished with a medullary stratum. Cystocarps immersed in the frond or contained in pericarps, containing a sub-compound nucleus, placenta in centre, suspended by filaments, nucleoli disposed radially about central placenta, clavate-pyriform spores in the terminal articulations.

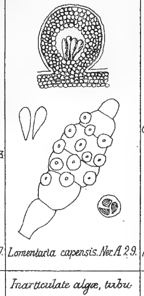
18. WRANGELIEÆ.



Wrangelia clavigera. Phyc. A. 287.

Articulate algæ, naked or corticate, sub-continuous, with a percurrent articulated axis. Fertile filaments rarely single, frequently many in a naked nucleus, or protected with filaments, radiating from the placenta, containing single pyriform clavate spores. Tetraspores triangularly divided, external, in scarcely changed branches. J. Ag. 1876. 607.

19. LOMENTARIEÆ.



Lomentaria capensis. Ner. A. 29.

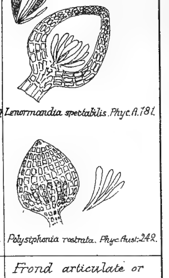
Inarticulate algæ, tubulose and articulated only in the upper part, with cellular diaphragms. Cystocarp embracing nucleus in a closed globose external pericarp. Fertile filaments radiating subramosely from the placenta, obconic, close, stipitate. Tetraspores immersed, triangularly divided. J. Ag. 1876. 630.

20. CHONDRIEÆ.

Ptilonia australasica. F. Tas. 190.

Inarticulate algæ, tubulose or solid, filaments or cells woven together, frequently a percurrent axis. Cystocarps inflated, most frequently in an external ovate pericarp with a terminal opening. Fertile filaments in bundles from the base of the placenta, single obovate-clavate large spores in the terminal articulations. Tetraspores in the cortical stratum, scattered. J. Ag. 1876. 636.

21. RHODOMELEÆ.



Polysiphonia rostrata. Phyc. Aust. 242.

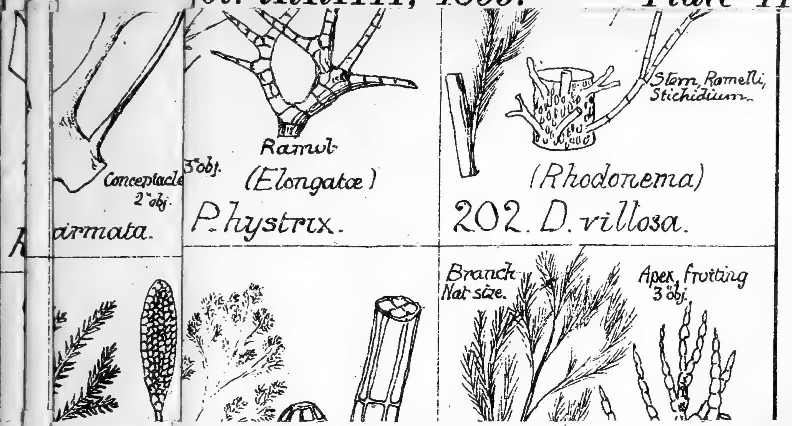
Frond articulate or cellulose-areolate, nucleus of cystocarp in an external pericarp. Fertile filaments free, radiating from the placenta, containing terminal clavate articulations transformed into single pyriform spores. Tetraspores generally in series in the branchlets or in pod-like bodies (Stichidia), sometimes in sori on the network of the frond.

54 **CALLITHAMNION**, *Lyngb.* Frond rose-red or purplish, filiform, articulate, branched, generally pellucid at the nodes, tetraspores on branchlets. J. Ag. 1876. 4.
55 **BALLIA**, *Harv.* Frond rose-red, fading to green or brown, filiform, rigid, dendroid, branchlets pellucid, pinnately decompound, tetraspores on branchlets. Hook. Hdbk. F.N.Z. 709.
56 **GRIFFITHSIA**, *Ag.* Frond naked, rose-red, filiform, pellucid, di or trichotomous, sometimes whorled, nodes transparent, tetraspores sometimes verticellate. J. Ag. 1876. 60.
57 **PTILOTA**, *Ag.* Frond dull red, corticated, decompound pinnate, axis of one tube, pellucid and articulate at the tips, favellæ involucrate, tetraspores conspicuous. J. Ag. 1876. 73.
58 **THAMNOCARPUS**, *Harv.* Frond subterete, vaguely branched, a stratum of longitudinal filaments around central axis, tetraspores on small branchlets. J. Ag. 1876. 81. Kuetz. 668.
59 **CROUANIA**, *J. Ag.* Frond filiform, whorled with ramelli, single tube, gelatinous, jointed, favellæ at the base of ramelli, obovate tetraspores triangularly divided. J. Ag. 1876. 83.
60 **GULSONIA**, *Harv.* The nodes swollen and deeply coloured with many branched filaments in dense gelatine, fruit unknown. Flor. Tas. 320. Tab. 193. A.
61 **DASYPHILA**, *Sond.* Filiform frond, distichous, decompound-pinnate, densely clothed with articulated hair-like ramelli, favellæ involucrate, tetraspores tripartite. Harv. P. A. 66.
62 **PTILOCLADIA**, *Sond.* Frond compressed, pinnately decompound, a central articulated filament surrounded with ramelli, favellæ binate, tetraspores tripartite. Harv. Phyc. A. 209.
63 **HALOPLEGMA**, *Mont.* Frond sponge-like, expanded, interwoven filaments, favellæ sessile on network of frond, tripartite tetraspores on filaments. Harv. Phyc. Aust. 79.
64 **BRACHYCLADIA**, *Sond.* Frond hollow, of branching articulated filaments, (favellæ on apices of filaments, binate?) Specimen in National Herbarium, V. J. Ag. 1876. 91n.
65 **CERAMIUM**, *Ag.* Frond red, filiform, dichotomous, jointed, joints opaque, of a single cell, nodes coated with small cells, spore masses globular, sessile, involucral. Harv. Phyc. Britt. 181.
66 **CENTROCERAS**, *Kuetz.* Frond filiform, dichotomous, articulate, cortical cells transversely and longitudinally seriate, favellæ sessile on branches. J. Ag. 1876. 107.
67 **SCHIZYMENIA**, *J. Ag.* Frond of two strata, medullary of branched interwoven threads, cortical of moniliform vertical threads set in gelatine. Harv. Phyc. Aust. 277.
68 **NEMASTOMA**, *J. Ag.* Frond dull-red-purple, compressed, two strata, medullary of longitudinal interwoven filaments, cortical of radiating moniliform filaments. Hook. Hdbk. F.N.Z. 704.
69 **HALYMENIA**, *Ag.* Frond terete or flat, gelatinous, membranaceous, dichotomous or pinnatifid, medullary of loose filaments, cortex of minute cellules, favellæ immersed. Harv. Phyc. Aust. 214.
70 **POLYOPES**, *J. Ag.* Frond cartilaginous, compressed, dichotomous, fastigiate, two strata, inner branched reticulated, outer vertical moniliform, tetraspores cruciate. J. Ag. 1876. 147.
71 **GRATELOUPIA**, *Ag.* Frond dull purple or greenish, membranous, flexible, pinnate, densely woven filaments in medullary layer, those of periphery moniliform, dense. Hook. Hdbk. F.N.Z. 704.
72 **PRIONITIS**, *J. Ag.* Frond flat, dichotomous, proliferous or glandulose, medullary of interwoven filaments, intermediate of roundish cells, cortical minute seriated cells. Harv. Ner. Bor. Am. 197.
73 **CRYPTONEMIA**, *J. Ag.* Frond flat, rigid, caulescent, proliferous, branched, medullary longitudinal filaments, intermediate roundish cells, cortical minute cells. Harv. Phyc. Aust. 289.
74 **THAMNOCLONIUM**, *Kuetz.* Frond dendroid or flabelliform, rigidly horny, tubercled, medullary of cylindrical seriated cellules, cortical cells coloured. Harv. Phyc. Aust. 293.
75 **IRIDÆA**, *Bory.* Nucleus in a pseudo-pericarp, frond flat, simple, or vaguely cleft, nuclei immersed in the frond. J. Ag. 1876. 179.
76 **RHODOGLOSSUM**, *J. Ag.* Frond usually lingulate, cystocarp large, prominent on both surfaces, structure of frond as Gigartina. Flor. Tas. II. 326.
77 **GIGARTINA**, *Lamx.* Nucleus in a pseudo-pericarp, frond terete or flat, mostly branched, conceptacles external, globose. J. Ag. 1876, 169.
78 **GYMNOGONGRUS**, *Martius.* Frond linear, filiform, subterete, compressed or flattish, sub-cartilaginous, conceptacles immersed, Harv. Ner. Bor. Am. 165.
79 **STENOGRAMMA**, *Harv.* Frond leaf-like, flat, dichotomous, membranaceous, rose-red, conceptacles external, linear, rib-like, medial on lobes. Harv. Ner. Bor. Am. 162.
80 **KALLYMENIA**, *J. Ag.* Frond subsessile, expanded, indefinite in form, flat, inner layer of longitudinal interlaced filaments, tetraspores scattered, cruciate. Ner. Bor. Am. 171.
81 **POLYCŒLIA**, *J. Ag.* Pale rose-red, very soft, dichotomously foliaceous, cystocarps immersed, tetraspores evolved from cortical strata, cruciate. J. Ag. 1876. 227.
82 **CALLOPHYLLIS**, *Kuetz.* Frond flat, its inner stratum composed of large round cells, surrounded by anastomosing filaments, bright red. Harv. Ner. Bor. Am. 171.
83 **DUDRESNAYA**, *Bonn.* Frond coated with dichotomous moniliform filaments, globose favellidæ attached to filaments, tetraspores zoned. Harv. Phyc. Britt. 244.
84 **NIZZOPHLÆA**, *J. Ag.* (Dasyphlœa, Harv.) Frond coated with microscopic hyaline hairs, central axis an articulated filament. J. Ag. 1876. 256.
85 **HALOSACCION**, *Kuetz.* (Halocœlia) Frond beset with proliferous ramuli, tetraspores cruciate, amongst cortical cells. Harv. Ner. Bor. Am. 193.
86 **SPYRIDIA**, *Harv.* Frond filiform, decompoundy much branched, of a single articulate thick walled filament, outer cells small, coloured. Ner. Bor. Am. 204.
87 **ERYTHROCLONIUM**, *Sond.* Stem terete, branches constricted as if jointed, an articulated axial filament and three strata, conceptacles sessile. Harv. Phyc. Aust. 86.
88 **ARESCHOUGIA**, *Harv.* Frond linear, compressed, distichous, midribbed, articulate axial filament, three strata of cells, conceptacles immersed. Harv. Phyc. Aust. 13.
89 **THYSANOCLADIA**, *Endl.* Frond flat, distichous, decompound pinnate, three strata, conceptacles half immersed, radiating spore threads. Harv. Phyc. Aust. 211.
90 **HOREA**, *Harv.* Frond fleshy, membranous, three strata, medullary of large empty cells, intermediate of smaller cells, cortical of vertical moniliform, pericarp horned. Harv. Phyc. Aust. 156.
91 **FAUCHEA**, *Bor. et Mont.* Frond gelatinous cartilaginous, warted, creeping, conceptacles in marginal processes, tetraspores quadrigeminate in linear sori. Harv. Phyc. Aust. 97.
92 **CHYLOCLADIA**, *Grev.* Frond terete or sub-compressed, alternately or pinnately decompound, tubular, empty, periphery roundish cells, conceptacles conical. Harv. Ner. Bor. Am. 185.
93 **CHAMPIA**, *Ag.* Frond terete, branched, tubular, constrictions with diaphrams connected by filaments, outer cellules polygonal, conceptacles ovate. Harv. Ner. Bor. Am. 75.
94 **HYMENOCLADIA**, *J. Ag.* Frond softly membranaceous, flat, linear, distichous, decompound pinnate, medullary cells large, cortical cellules minute. Harv. Phyc. Aust. 118.
95 **GLOIOSACCION**, *Harv.* Frond bag-like, filled with gelatine, three layers, large cells, round-angular cells, and minute coloured cellules, globose immersed favillidia. Harv. Phyc. Aust. 259.
96 **CHRYSYMENIA**, *J. Ag.* Frond sub-terete or flat, tubular or solid, sometimes empty, conceptacles half immersed in frond, tetraspores cruciate. Harv. Ner. Bor. Am. 187.
97 **CORDYLICLADIA**, *J. Ag.* Frond filiform, carnoso-cartilaginous, conceptacles sessile on branches, tetraspores in pod-like ramuli, cruciate. Harv. Ner. Bor. Am. 155.
98 **RHODYMENIA**, *Grev.* Frond flat, dichotomous, often proliferous, two layers, inner oblong, cortical minute, conceptacles scattered, sessile. Harv. Ner. Bor. Am. 149.
99 **NEUROPHYLLIS**, *Zan.* Frond 4" long, sub-flabellate, segments a line wide in middle, narrower above, axial tube narrow, cystocarps immersed. J. Ag. 1876. 575. n.
100 **EPYMENIA**, *Kuetz.* Frond ribbed below, caulescent, expanded above, two layers, fructification on fruit leaflets, hemispherical pericarp, tetraspores cruciate. Harv. Phyc. Aust. 89.
101 **PLOCAMIUM**, *Lamx.* Frond sub-cartilaginous, pinnules alternate in pairs, or 3^s or 4^s, conceptacles sessile or pedicellate, tetraspores in stichidia. Harv. Ner. Bor. Am. 152.
102 **DESMIA**, *J. Ag.* Frond compressed, decompound-pinnate, sub-costate, sub-cartilaginous, easy dissolved, an axial tube, oblong cells, cortical minute, cystocarps wart-form. J. Ag. 1876. 354.
103 **RHODOPHYLLIS**, *Kuetz.* Frond flat, pinnately decompound, margined with processes, two strata, conceptacles marginal, external, tetraspores zonate. Harv. Phyc. Aust. 254.
104 **DICTYOPSIS**, *Sond.* Rose-pink, 1" high, inner of large cells, outer of small coloured, conceptacles in much branched fimbria, globose, tusked. J. Ag. 1876. 369.
105 **CRUORIA**, *Fries.* Frond forming a skin on rocks, vertical jointed filaments, one of the joints in each filament larger than the rest, tetraspores at base. Harv. Phyc. Britt. 117.
106 **PEYSSONNELIA**, *Dec.* Frond flat, horizontally expanded, rooting by fibrils, fruit of both kinds in superficial warts, tetraspores cruciate. Harv. Phyc. Aust. 81.
107 **RHODOPELTIS**, *Harv.* Frond parasitic, spreading horizontally, crowded articulate filaments, cystocarps immersed, ovoid, whorled spore threads. Harv. Phyc. Aust. 264.
108 **MELOBESIA**, *Aresch.* Frond calcareous, rigid, branched, stoney, ceramidia conical, sessile, containing transversely parted spores. Harv. Ner. Aust. 40.
109 **LITHOTHAMNION**, *Phil.* Frond stoney, tuberiform, simple or branched, subterete, two layers, cystocarps scattered, immersed or elevated. J. Ag. 1852. 519.
110 **MASTOPHORA**, *Dec.* Frond stipitate, thinly encrusted, flat, flabelliform or dichotomous, conceptacles hemispherical, scattered. Harv. Phyc. Aust. 263.
111 **AMPHIROA**, *Lamx.* Frond calcareous, articulated, pinnate or whorled, conceptacles conical, sessile on disc of articulation. Harv. Phyc. Aust. 230.
112 **CHEILOSPORUM**, *Aresch.* Frond calcareous, compressed, articulate, articulations obcordate, conceptacles immersed on lobes of articulations. Harv. Phyc. Aust. 250.
113 **ARTHROCARDIA**, *Aresch.* Articulations strongly compressed, winged at the sides, cuneate or obcordate, conceptacles conical, Harv. Ner. Bor. Am. 86.
114 **JANIA**, *Lamx.* Frond setaceo-filiform, articulated, dichotomous, conceptacles urn-shaped, horned, with apical pore. J. Ag. 1852. 553.
115 **CORALLINA**, *Lamx.* Frond filiform, articulate, pinnate, calcareous, conceptacles turbinate or obovate, with apical pore. Harv. Phyc. Britt. 201.
116 **NIZYMENIA**, *Sond.* Frond horny membranous, linear, sub-pinnately compound, cystocarps sessile, wrinkled, thick walled. Harv. Phyc. Aust. 165.
117 **PHACELOCARPUS**, *Endl. et Dies.* Frond red, slender, strong midrib, articulated axial tube, with filaments and minute cortical cells. J. Ag. 1876. 397.
118 **CURDIÆA**, *Harv.* Frond flat, coriaceo-cartilaginous, laciniate, two layers, coccidea globose, sessile, thick pericarp, tetraspores intra-marginal. Harv. Phyc. Aust. 210.
119 **MELANTHALIA**, *Mont.* Frond deep purple, linear, flat, dichotomously flabellately branched, conceptacles marginal, hemispheric. J. Ag. 1876. 403.
120 **DICURELLA**, *J. Ag.* Frond decompound dichotomous fastigiate sub-flabellate, very dense axis, inner cells oblong, cystocarps sub-spherical. J. Ag. 1876. 405.
121 **CORALLOPSIS**, *Grev.* Frond articulato-constricted, branches proliferous from the constriction, conceptacles hemispherical, thick pericarp. Harv. Ner. Bor. Am. 111.
122 **GRACILARIA**, *J. Ag.* Frond filiform, carnoso-cartilaginous, inner cells large empty, surface cells minute, coccidia convex tubercles. Harv. Phyc. Britt. 205.
123 **SARCOCLADIA**, *Harv.* Frond flat, firmly fleshy, thick, multifid, medullary spongelike, conceptacles marginal hemispherical, umbilicate. Harv. Phyc. Aust. 217.
124 **TYLOTUS**, *J. Ag.* Frond membranous coriaceous, di-trichotomous, two strata, coccidia sub-immersed, in thick pericarp, tetraspores zonate. J. Ag. 1876. 428.
125 **SARCODIA**, *J. Ag.* Frond rose-red, fleshy, repeatedly dichotomously branched, conceptacles hemispheric, thick-walled, on disc or margins. J. Ag. 1876, 430.
126 **CALLIBLEPHARIS**, *Kuetz.* Frond flat, cartilaginio-membranaceous, margined often with segments or cilia, fruit sessile on segments. Harv. Ner. Bor. Am. 105.
127 **DICRANEMA**, *Sond.* Frond terete, dichotomous, medullary of slender filaments, intermediate of angular cells, cortical cellules coloured. Harv. Phyc. Aust. 74.
128 **HERINGIA**, *J. Ag.* Frond cartilaginous, filiform, sub-dichotomous, fastigiate, two layers of cells surrounding articulated axial tube, zonate tetraspores. Harv. P. Aust. 215.
129 **STENOCLADIA**, *Kuetz.* Frond compressed distichous pinnate, central tube surrounded by filaments, cystocarps external. J. Ag. 1876. 438.
130 **NITOPHYLLUM**, *Grev.* Frond rose-red or purplish, expanded, without midrib, conceptacles sessile, scattered, globose, tetraspores tripartite. Harv. Ner. Bor. Am. 102.
131 **RHODOSERIS**, *Harv.* (Pollexfenia laciniata, Harv. Ner. Aust. 6.) Fronds tufted 6-8 high, ceramidia sessile, generally on the margin. J. Ag. 1876. 475.
132 **DELESSERIA**, *Grev.* Frond rose-red, leaf-like, areolated, midribbed conceptacles sessile on midrib or on a lateral nerve, globose, tetraspores tripartite. Harv. Ner. Bor. Am. 93.
133 **CALOGLOSSA**, *Harv.* Frond dichotomous, articulato-constricted, rooting at the forks, livid purple, coccidia sessile on midrib. J. Ag. 1876. 498.
134 **HELMINTHOCLADIA**, *J. Ag.* Cylindrical gelatinous, branched to all sides, fibrous compound axis, cystocarps immersed in periphery. Harv. Phyc. Aust. 272.
135 **HELMINTHORA**, *J. Ag.* Axis of parallel articulated filaments, periphery of horizontal filaments emitted from axis, nucleus amongst filaments. Harv. Phyc. Britt. 110.
136 **NEMALION**, *Duby.* Frond wormlike, dichotomous, elastic, cord-like axis, periphery of moniliform filaments, nucleus amongst peripheric filaments. Harv. Phyc. Aust. 284.
137 **GLOIOPHLOEA**, *J. Ag.* Frond cylindrical, gelatinous, apparent midrib immersed (axis), peripheric filaments opuntiform, cystocarps suspended in peripheric layer. J. Ag. 1876. 509.
138 **SCINAIA**, *Bivona.* Frond terete or compressed, gelatinous, membranous, fibrous axis, periphery a thin layer of round-angular cells, nucleus in very thin pericarp within walls of frond. N. B. Am. 155.
139 **LIAGORA**, *Lamx.* Frond terete or compressed, dichotomous or pinnate, calcareous, filamentous axis, periphery of articulated moniliform filaments much branched. Harv. Ner. Bor. Am. 137.
140 **GALAXAURA**, *Lamx.* Frond dichotomous, encrusted, constricted, or continuous, interwoven medullary filaments, closely placed peripheric cellules. Harv. Phyc. Britt. 275.
141 **ACTINOTRICHIA**, *Dec.* Fronds tufted, dense intricate filaments, branches terete, intricate, rigid, ringed with short horizontal filaments, obscurely zoned, apices compressed. Kuetz. 531.
142 **ZANARDINIA**, *J. Ag.* Frond encrusted, stipitate, subtubulose, plane, linear, dichotomous, two layers, cystocarps below cortex, cruciate tetraspores. J. Ag. 1876. 533.
143 **BINDERA**, *Harv.* Frond baglike, proliferous, medullary of interwoven filaments, intermediate a row of quadrate cells, cortical of coloured cellules. Harv. Phyc. Aust. 111.
144 **CHÆTANGIUM**, *Kuetz.* Frond corneo-membranous, saccate and simple or complanate and dichotomous, or proliferous, cystocarps immersed in frond, prominent. J. Ag. 1876. 538.
145 **ACROTYLUS**, *J. Ag.* Frond terete or compressed, cartilaginous, two layers, favellæ in wart-like swellings, many together around the apices. Harv. Ner. Bor. Am. 196.
146 **HENNEDYA**, *Harv.* Stems terete, branched, branches dilating into flat dichotomous membranous fronds, three layers, conceptacles umbilicate, near tips of segments. Phyc. Aust. 75.
147 **PTEROCLADIA**, *J. Ag.* Frond linear, flat, strong midrib, or indistinct, pinnate, three layers, conceptacles hemispherical, on surface of frond, cruciate tetraspores. Hook. Hdbk. F.N.Z. 689.
148 **GELIDIUM**, *Lamx.* Frond firmly cartilaginous, decompound-pinnate, axis densely interwoven, conceptacles immersed in ramuli, two-celled, tetraspores cruciate. Harv. Ner. Bor. Am. 115.
149 **SUHRIA**, *J. Ag.* Base shortly stipitate, complanate, cartilaginous, linear or ensiform, rather thick disappearing nerve, ciliiform carpoclonia emitted from margin. Kuetz. 768.
150 **PTILOPHORA**, *Kuetz.* Frond cartilaginous, plane, pinnate, furnished with hyaline filaments at rib and margins of fertile branches, cortex purple-rose. Kuetz. 794.
151 **GATTYA**, *Harv.* Frond distichous, pinnatifid, hollow, tubular, articulated monosiphonous axis, emitting dichotomous ramelli, periphery membranous. Harv. Phyc. Aust. 93.
152 **HYPNEA**, *Lamx.* Frond irregularly much branched, beset with awlshaped ramelli, hemispherical conceptacles on the ramelli, without orifice. Harv. Ner. Bor. Am. 123.
153 **RHODODACTYLIS**, *J. Ag.* Frond filiform, cartilaginous, dendroid, coated with polygonal cells, axis articulate, polysiphonous, ramuli claviform, narrowed at insertion. J. Ag. 1876. 568.
154 **DASYPHLÆA**, *Mont.* Frond rose-red, or purple, covered with microscopic hairs, axis articulate, tetraspores in superficial warts, zonate. J. Ag. 1876. 568.
155 **MYCHODEA**, *Harv.* Frond filiform, cartilaginous, alternately decompound, three layers, conceptacles external, lateral or terminal, tetraspores zonate. Harv. Phyc. Aust. 142.
156 **ECTOCLINIUM**, *J. Ag.* Frond plane, linear, dentate, narrow cells surrounding axilar tube, cystocarps immersed in swollen branches below apices. J. Ag. 1876. 573.
157 **GELINARIA**, *Sond.* Frond thick, fleshy, flat, irregularly pinnatifid, three layers, cortical of vertical closely packed filaments, cruciate tetraspores in periphery. J. Ag. 1876. 581.
158 **MERISTOTHECA**, *J. Ag.* Frond plane, gelatino-membranous, tubercled and toothed, cystocarps in tubercles, evolved from cortical layer, tetraspores cruciate. J. Ag. 1876. 582.
159 **CATENELLA**, *Grev.* Frond sub-tubular, constricted at intervals, nuclei in axile network of minute roundish ramuli, tetraspores in ramuli, zonate. Harv. Ner. Bor. Am. 201.
160 **RHABDONIA**, *Harv.* Frond terete, decompound, tubular, partially filled with filaments, periphery polygonal cellules, conceptacles immersed, spore-threads moniliform. H. N. B. A. 23. A.
161 **SOLIERA**, *J. Ag.* Frond cylindrical, three strata, filaments densely interwoven, conceptacles immersed in branches, spores pear-shaped. Harv. Ner. Bor. Am. 23. B.
162 **EUCHEUMA**, *J. Ag.* Shrub-like, robust, cartilaginous, horny, mostly spinous, tuberculated, conceptacles ovate, sessile, on branches. Harv. Ner. Bor. Am. 118.
163 **MONOSPORA**, *Sol.* Frond filiform, dichotomous, pinnate, articulate, monosiphonous, gemmæ pedicellate obovate ellipsoid, subgranulose. J. Ag. 1876. 608.
164 **BORNETIA**, *Thur.* Frond filiform, branched, monosiphonous, naked, cystocarp evolved from short lateral branches, involucrate. J. Ag. 1876. 612.
165 **WRANGELIA**, *Ag.* Frond filiform, decompound pinnate, articulate, one tubed, nodes with articulate ramelli, nucleus terminal, pyriform spores. Harv. Ner. Bor. Am. 142.
166 **LOMENTARIA**, *Gaill.* Frond tubular, constricted, diaphragmed, periphery of polygonal cells, conceptacles spherical, tetraspores tripartite. Harv. Ner. Bor. Am. 78.
167 **CŒLOCLONIUM**, *J. Ag.* Frond filiform, dendroid, periphery of small polygonal cells, axis articulate, polysiphonous, ramuli claviform. Harv. Phyc. Aust. 147.
168 **CORYNECLADIA**, *J. Ag.* Frond subterete, subcaulescent, branches club-shaped, ceramidia ovate, in transformed branches. J. Ag. 1876. 642.
169 **LAURENCIA**, *Lamx.* Frond solid, cartilaginous, decompound-pinnate, medullary long angular cells, conceptacles ovate. Harv. Ner. Bor. Am. 70.
170 **ASPARAGOPSIS**, *Mont.* Frond filiform, red, panicled, branches penicillate, conceptacles ovoid, pedicellate. J. Ag. 1876. 665.
171 **DELISEA**, *Lamx.* Frond bright-red, cartilaginous, distichously branched, pectinate or serrate, midribbed, conceptackles on midrib, J. Ag. 1876, 669.
172 **PTILONIA**, *J. Ag.* Frond linear, serrato-dentate, three layers, central axis sub-distinct, ceramidia large, on long pedicels. J. Ag. 1876. 673.
173 **LEPTOPHYLLIS**, *J. Ag.* Frond membranous, flat, thin, linear, distichously pinnatifid, ceramidia ovate, spores pyriform. Harv. Phyc. Aust. 144.
174 **CLAUDEA**, *Lamx.* Frond proliferous, forming a network, parallel costate, ceramidia ovate-globose, pedicellate, Harv. Ner. Aust. 15.
175 **MARTENSIA**, *Hering.* Tufted, flabelliform, composed of large polygonal cells, network on upper margin, ceramidia on the net. Harv. Ner. Aust. 73.
176 **DICTYURUS**, *Bory.* Frond stipitate, branches bearing network of confervoid anastomosing ramelli, ceramidia urceolate, stichidia subglobose. Phyc. Aust. 191.
177 **HANOWIA**, *Sond.* Frond cylindrical, dichotomous, branches a complication of callithamnoid filaments, apices free. Kuetz. 672.
178 **CLIFTONÆA**, *Harv.* Frond stipitate, formed of secundly proliferous pectinate phyllodia with diverse sides. Harv. Phyc. Aust. 279.
179 **AMANSIA**, *Lamx.* Frond dull red, flat, membranous, pinnatifid, transversely zoned, midribbed, hexagonal cells, striate, conceptacles ovate or globose. Hook. Hdbk. F.N.Z. 663.
180 **LEVEILLEA**, *Dec.* Filiform, branched, cellulose, polysiphonous, resembling an Hepatic, pinnulæ areolate, circinately involute. Harv. Ner. Aust. 72.
181 **POLYZONIA**, *Suhr.* Parasitic, minute, rose-red, filiform, articulate, distichously branched, branches leaf-like, angular, toothed or pectinate. Hook. Hdbk. F.N.Z. 673.
182 **NEURYMENIA**, *J. Ag.* Frond flat, membranous, midribbed, areolate, alternately decompound or pinnatifid, ceramidia stipitate. Harv. Phyc. Aust. 124.
183 **VIDALIA**, *J. Ag.* Dark red, flat, linear, toothed or ciliate, midrib distichously branched, transversely striate, stichidia lanceolate, on midrib. Harv. Ner. Aust. 9.
184 **KUETZINGIA**, *Sond.* Frond membranous, cartilaginous, midribbed, inner cells in transverse zones, stichidia oblong, pedicellate, on transverse nerves. Harv. Ner. Aust. 23.
185 **LENORMANDIA**, *Sond.* Dull red, leaf-like, proliferous, branches flat, simple, midrib evident, obliquely striate, outer cells minute. Hook. Hdbk. F.N.Z. 662.
186 **POLYPHACUM**, *Ag.* Frond proliferous, plane, thick, midribbed, giving off ramentæ, these are minute, pedicellate, wart-like, brown when dry. Harv. Ner. Aust. 17.
187 **JEANNERETTIA**, *Harv.* Frond proliferous, phyllodia plane, rib vanishing, curved striate, by reason of internal quadrate cells, stichidia in bunches. Harv. Ner. Aust. 20.
188 **MELANOSERIS**, *Zan.* Small, 1in. high, flat, dichotomously flabellate, crispate, margin proliferous, emitting many short processes, areolate. Spec. Nat. Herb. V.
189 **POLLEXFENIA**, *Harv.* Frond plane, membranous, purple-rose, nerveless, areolate, polygonal cells, ceramidia ovate, rising from the frond, stichidia lanceolate. Harv. Ner. Aust. 21.
190 **SARCOMENIA**, *Sond.* Frond plane, fleshy, proliferous from the disc, segments stipitate, subcostate, fruit scattered on disc, Harv. Ner. Aust. 21.
191 **ACANTHOPHORA**, *Lamx.* Filiform, vaguely branched, opaque, cortical minute, furnished with minute tooth-like ramelli. Harv. Ner. Aust. 34.
192 **DICTYMENIA**, *Grev.* Frond plane, linear, midribbed, distichously branched, areolate, stichidia distorted or forked. Harv. Ner. Aust. 28.
193 **HETEROCLADIA**, *Dec.* Frond plane, midrib immersed, tetraspores in subterete fibrillous branches, (fibrils callithamnioid dichotomous) quadrigeminate. Kuetz. 879.
194 **TRIGENEA**, *Sond.* Frond cartilaginous, filiform, branches and stem clothed with filiform ramentæ ½ to 1" long, ceramidia globose, colour brown red. Harv. Ner. Aust. 37.
195 **RHODOMELA**, *Ag.* Frond dull red, inarticulate, cortex of polygonal coloured cells, axis articulate, many large colourless tubes, stichidia of swollen branchlets. Hook. Hdbk. F.N.Z. 664.
196 **RYTIPHLÆA**, *Sond.* Frond dull red, wrinkled when dry, axis articulate, many tubes, branchlets closely transversely striate, tetraspores in proper stichidia often. Harv. Ner. Aust. 14.
197 **ALSIDIUM**, *Ag.* Frond filiform, inarticulate, lax reticulation, polygonal cortical cells, closely transversely striate above, tetraspores in axillary or terminal stichidia. Ner. Aust. 13.
198 **CHONDRIOPSIS**, *J. Ag.* Frond round, branches clavate or fusiform, bases much attenuated, Sonder's catalogue, 34. Harv. Ner. Aust. 85.
199 **DIGENEA**, *Ag.* The habit of Trigenia, except that the ramentœ are jointed. Harv. Ner. Aust. 37. Rabenhorst, 215.
200 **BOSTRYCHIA**, *Mont.* Frond dull red, inarticulate, or an articulate tube surrounded by tessellated cells, stichidia terminal, double row of tetraspores. Hook. Hdbk. F.N.Z. 665.
201 **POLYSIPHONIA**, *Grev.* Frond opaque or reticulate, joints longitudinally striate, internodes hyaline, tetraspores 1-seriate. Hook. Hdbk. F.N.Z. 641.
  ELONGATÆ, Stem opaque, inarticulate, branches articulate. Harv. Ner. Aust. 39.
  DICHOTOMÆ, Frond all pellucid, articulate, subdichotomous, decompound, Harv. Ner. Aust. 39.
  GLOMERULATÆ, Frond all pellucid, articulate, pinnate, densely clothed with ramelli. Harv. Ner. Aust. 39.
  BYSSOIDEÆ, Frond alternately branched, 1-tubed branchlets. Hook. Hdbk. F.N.Z. 666.
  PENNATÆ, Frond rose-colour or purple, often distichously pinnate, branchlets simple, subulate, alternate or 4-farious. Hook. Hdbk. F.N.Z. 666.
  CANCELLATÆ, Frond brown, black when dry, shrubby, furrowed, vaguely branched, branches decompound. Hook. Hdbk. F.N.Z. 666.
202 **DASYA**, *Ag.* Frond articulate or not, cylindric or compressed, emitting fructiferous monosiphonous articulate ramelli. Harv. Ner. Aust. 14.
  COMPSOTEIA, Frond more or less articulate, polysiphonous, crimson, pinnato-dichotomous, monosiphonous in terminal dichotomous filaments. Ner. Aust. 58.
  RHODONEMA, Frond inarticulate, cylindric, vaguely branched, branches and branchlets densely quadrifariously clothed with articulate filaments. Ner. Aust. 58.
  STICHOCARPUS, Frond more or less articulate, polysiphonous, crimson, decompound-pinnate, frequently distichous, ramelli monosiphonous, simple, subulate. Ner. Aust. 58.
  LOPHOTHALIA, Frond articulate or not, tetrasiphonous, virgate, alternately branched, purple, naked or clothed with monosiphonous ramelli. Ner. Aust. 58.

Richd. A. Bastow.

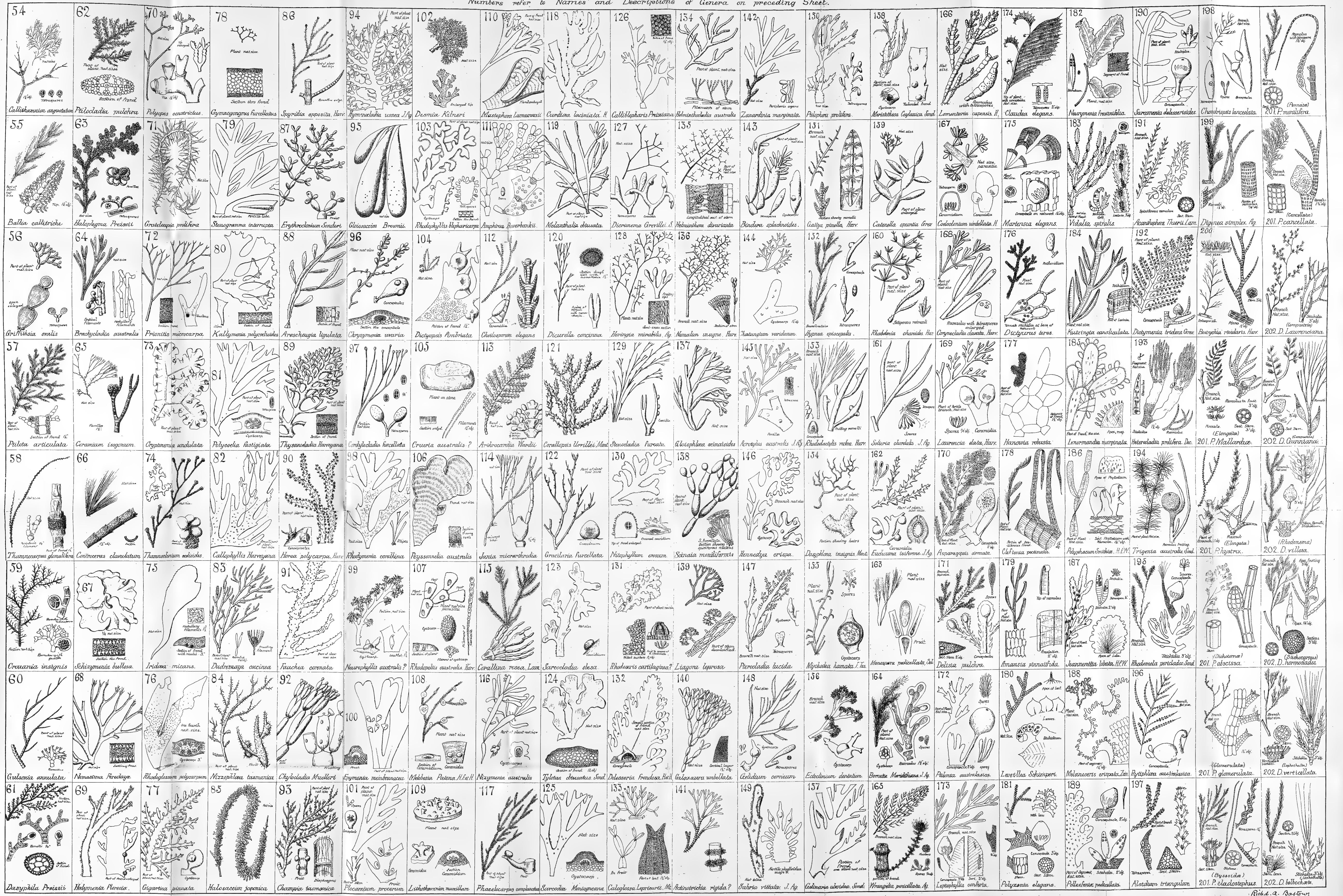
Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.

ol. XXXIII, 1899. Plate II.



ILLUSTRATIONS TO GENERA OF FLORIDEÆ.

Numbers refer to Names and Descriptions of Genera on preceding Sheet.



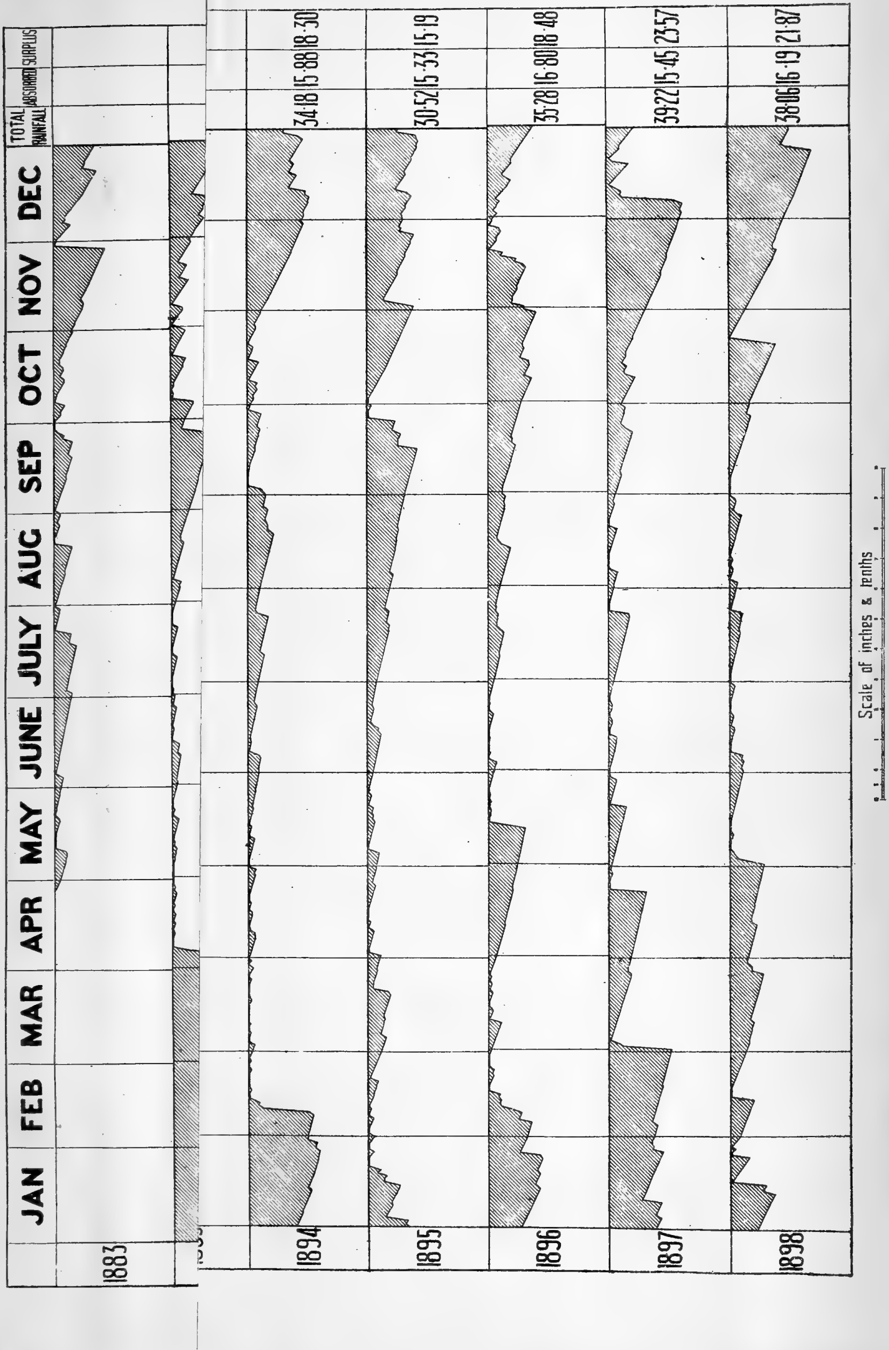
54 Callithamnion angustatum
55 Ballia callitriche
56 Griffithsia ovalis
57 Ptilota articulata
58 Thamnocarpus glomulifera
59 Crouania insignis
60 Gulsonia annulata
61 Dasyphila Preissii
62 Ptilocladia pulchra
63 Haloplegma Preissii
64 Brachycladia australis
65 Ceramium isogonum.
66 Centroceras clavulatum
67 Schizymenia bullosa.
68 Nemastoma Feredayæ.
69 Halymenia Floresia.
70 Polyopes constrictus.
71 Grateloupia prolifera
72 Prionitis microcarpa
73 Cryptonemia undulata
74 Thamnoclonium codioides.
75 Iridæa micans.
76 Rhodoglossum polycarpum
77 Gigartina pinnata
78 Gymnogongrus furcellatus
79 Stenogramma interrupta
80 Kallymenia polycoelioides
81 Polycoelia fastigiata
82 Callophyllis Harveyana
83 Dudresnaya coccinea
84 Nizzophlœa tasmanica
85 Halosaccion japonica
86 Spyridia opposita, Harv.
87 Erythroclonium Sonderi
88 Areschougia ligulata
89 Thysanocladia Harveyana
90 Horea polycarpa, Harv.
91 Fauchea coronata
92 Chylocladia Muelleri
93 Champia tasmanica
94 Hymenocladia usnea J. Ag.
95 Gloiosaccion Brownii.
96 Chrysymenia uvaria
97 Cordylecladia furcellata
98 Rhodymenia corallina
99 Neurophyllis australis?
100 Epymenia membranacea
101 Plocamium procerum
102 Desmia Kilneri
103 Rhodophyllis blepharicarpa
104 Dictyopsis fimbriata
105 Cruoria australis?
106 Peyssonnelia australis
107 Rhodopeltis australis. Harv.
108 Melobesia Patena. H. f. et H.
109 Lithothamnion mamillare.
110 Mastophora Lamourouxii
111 Amphiroa Bowerbankii.
112 Cheilosporum elegans
113 Arthrocardia Wardii
114 Jania micrarthrodia
115 Corallina rosea, Lam.
116 Nizymenia australis
117 Phacelocarpus complanatus
118 Curdiæa laciniata. H.
119 Melanthalia obtusata.
120 Dicurella concinna
121 Corallopsis Urvillei. Mont.
122 Gracilaria furcellata
123 Sarcocladia obesa.
124 Tylotus obtusatus. Sond.
125 Sarcodia Montagneana
126 Calliblepharis Preissiana
127 Dicranema Grevillei. S.
128 Heringia mirabilis, Ag.
129 Stenocladia furcata.
130 Nitophyllum erosum.
131 Rhodoseris cartilaginea?
132 Delesseria frondosa. H. et H.
133 Caloglossa Leprieurii. Mont.
134 Helminthocladia australis
135 Helminthora divaricata
136 Nemalion insigne, Harv.
137 Gloiophlœa scinaioides
138 Scinaia moniliformis
139 Liagora leprosa
140 Galaxaura umbellata
141 Actinotrichia rigida?
142 Zanardinia marginata.
143 Bindera splachnoides.
144 Chætangium variolosum.
145 Acrotylus australis J. Ag.
146 Hennedya crispa.
147 Pterocladia lucida.
148 Gelidium corneum
149 Suhria vittata. J. Ag.
150 Ptilophora prolifera.
151 Gattya pinella, Harv.
152 Hypnea episcopalis.
153 Rhododactylis rubra. Harv.
154 Dasyphlœa insignis. Mont.
155 Mychodea hamata. F. Tas.
156 Ectoclinium dentatum.
157 Gelinaria ulvoidea, Sond.
158 Meristotheca Ceylanica. Sond.
159 Catenella opuntia Grev.
160 Rhabdonia charoides. Harv.
161 Solieria chordalis. J. Ag.
162 Eucheuma isiforme. J. Ag.
163 Monospora pedicellata, Sol.
164 Bornetia Meredithiana. J. Ag.
165 Wrangelia penicillata, Ag.
166 Lomentaria capensis. H.
167 Coeloclonium umbellata. H.
168 Corynecladia clavata. Harv.
169 Laurencia elata, Harv.
170 Asparagopsis armata.
171 Delisea pulchra.
172 Ptilonia australasica.
173 Leptophyllis conferta.
174 Claudea elegans.
175 Martensia elegans.
176 Dictyurus teres.
177 Hanowia robusta.
178 Cliftonia pectinata.
179 Amansia pinnatifida.
180 Leveillea Schimperi.
181 Polyzonia elegans.
182 Neurymenia fraxinifolia.
183 Vidalia spiralis.
184 Kutzingia canaliculata.
185 Lenormandia marginata.
186 Polyphacum Smithiæ. H. f. W.
187 Jeannerettia lobata. H. f. W.
188 Melanoseris crispata. Zan.
189 Pollexfenia pedicellata.
190 Sarcomenia delesserioides.
191 Acanthophora Thierii. Lam.
192 Dictymenia tridens Grev.
193 Heterocladia prolifera. Dec.
194 Trigenia australis. Sond.
195 Rhodomela periclados. Sond.
196 Rytiphlœa australasica.
197 Alsidium triangulare.
198 Chondriopsis lanceolata.
199 Digenea simplex. Ag.
200 Bostrychia rivularis. Harv.
(Pennatæ) 201. P. moritifera.
(Cancellatæ) 201. P. cancellata.
(Elongatæ) 201. P. Mallardiæ.
(Elongatæ) 201. P. hystrix.
(Dichotomæ) 201. P. abscissa.
(Glomerulatæ) 201. P. glomerulata.
(Byssoidea) 201. P. cladostephus.
(Compsoteia) 202. D. Laurenciana.
(Compsoteia) 202. D. Gunniana.
(Rhodonema) 202. D. villosa.
(Stichocarpus) 202. D. hormoclados.
(Lophothalia) 202. D. verticellata.
(Lophothalia) 202. D. bolbochaete.

Richd. A. Bastow.

40543

Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.

Plate III


TOTAL RAINFALL
ABSORBED
SURPLUS
DEC
NOV
OCT
SEP
AUG
JULY
JUNE
MAY
APR
MAR
FEB
JAN
1883
34·18 15·88 18·30
1894
30·52 15·33 15·19
1895
35·28 16·80 18·48
1896
39·22 15·45 23·57
1897
38·06 16·19 21·87
1898
Scale of inches & tenths

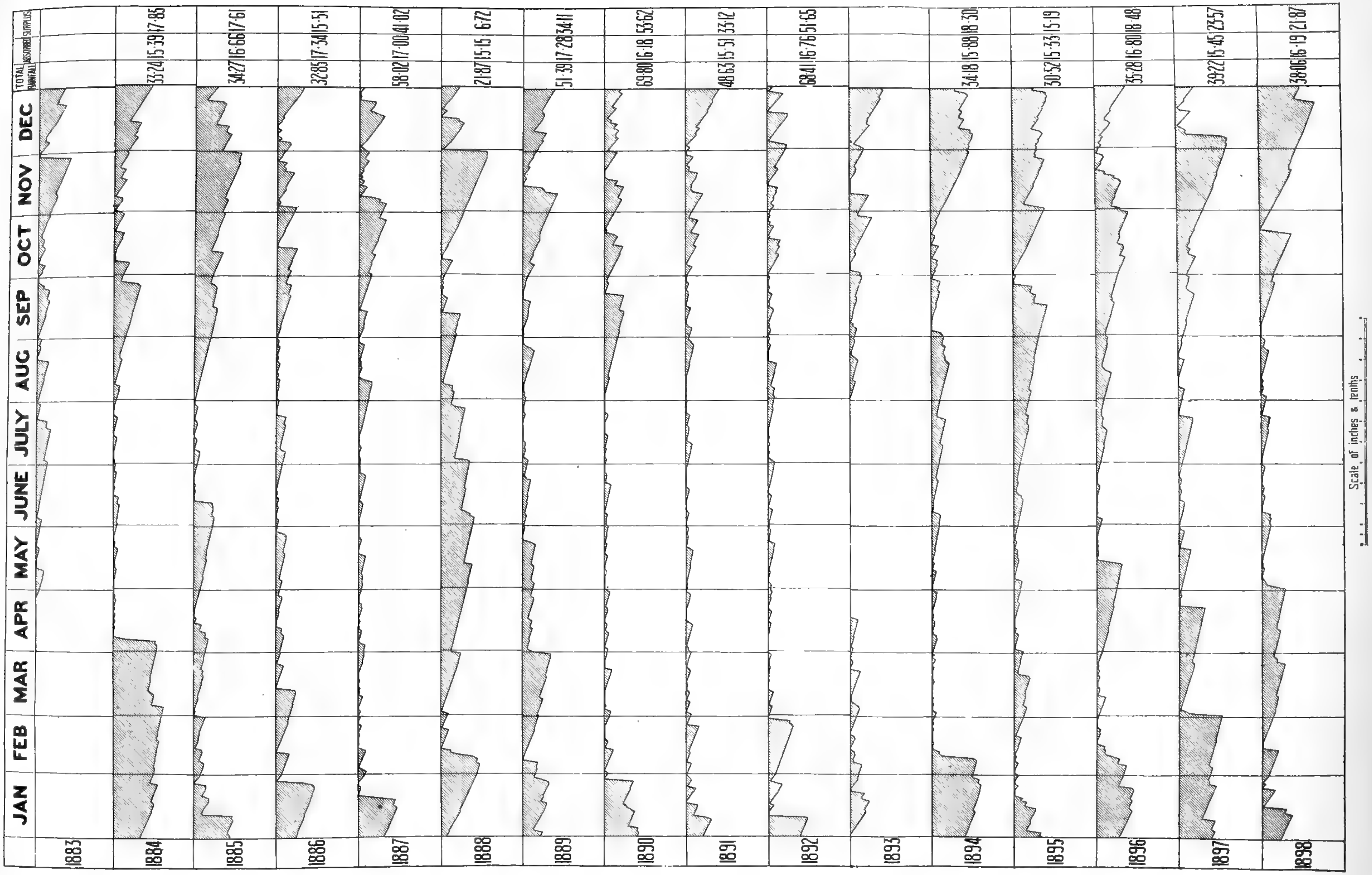
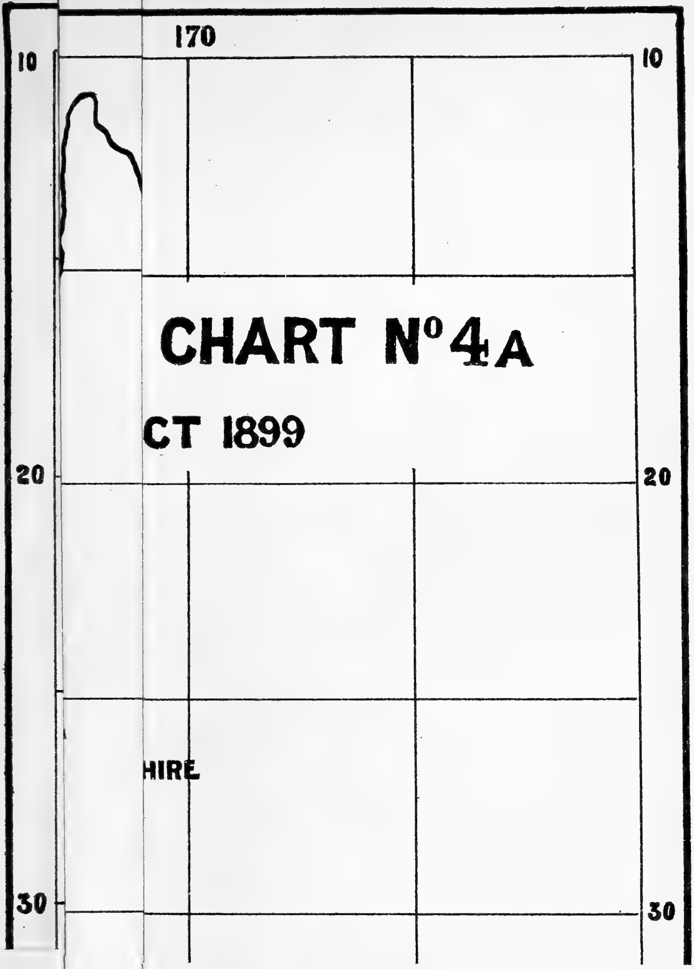

TOTAL RAINFALL
ABSORBED
SURPLUS
DEC
NOV
OCT
SEP
AUG
JULY
JUNE
MAY
APR
MAR
FEB
JAN
1883
1884 33·24 15·39 17·85
1885 34·27 16·66 17·61
1886 32·85 17·34 15·51
1887 58·02 17·00 41·02
1888 21·87 15·15 6·72
1889 51·39 17·28 34·11
1890 69·80 16·18 53·62
1891 48·63 15·51 33·12
1892 68·41 16·76 51·65
1893
1894 34·18 15·88 18·30
1895 30·52 15·33 15·19
1896 35·28 16·80 18·48
1897 39·22 15·45 23·57
1898 38·06 16·19 21·87
Scale of inches & tenths

FIG. 1.

ICE.—Striated Boulder, from Upper Marine Permo-Carboniferous Strata, Branxton, New South Wales. Natural size.

FIG 2.

ICE.—Grooved Boulder, from base of Lower Marine Permo-Carboniferous Strata, Lochinvar, New South Wales. Two-thirds natural size.


170
10
10
CHART N°4A
CT 1899
20
20
HIRE
30
30

CURRENT-PAPERS CHART Nº 4A

SEP 1898 TO OCT 1899

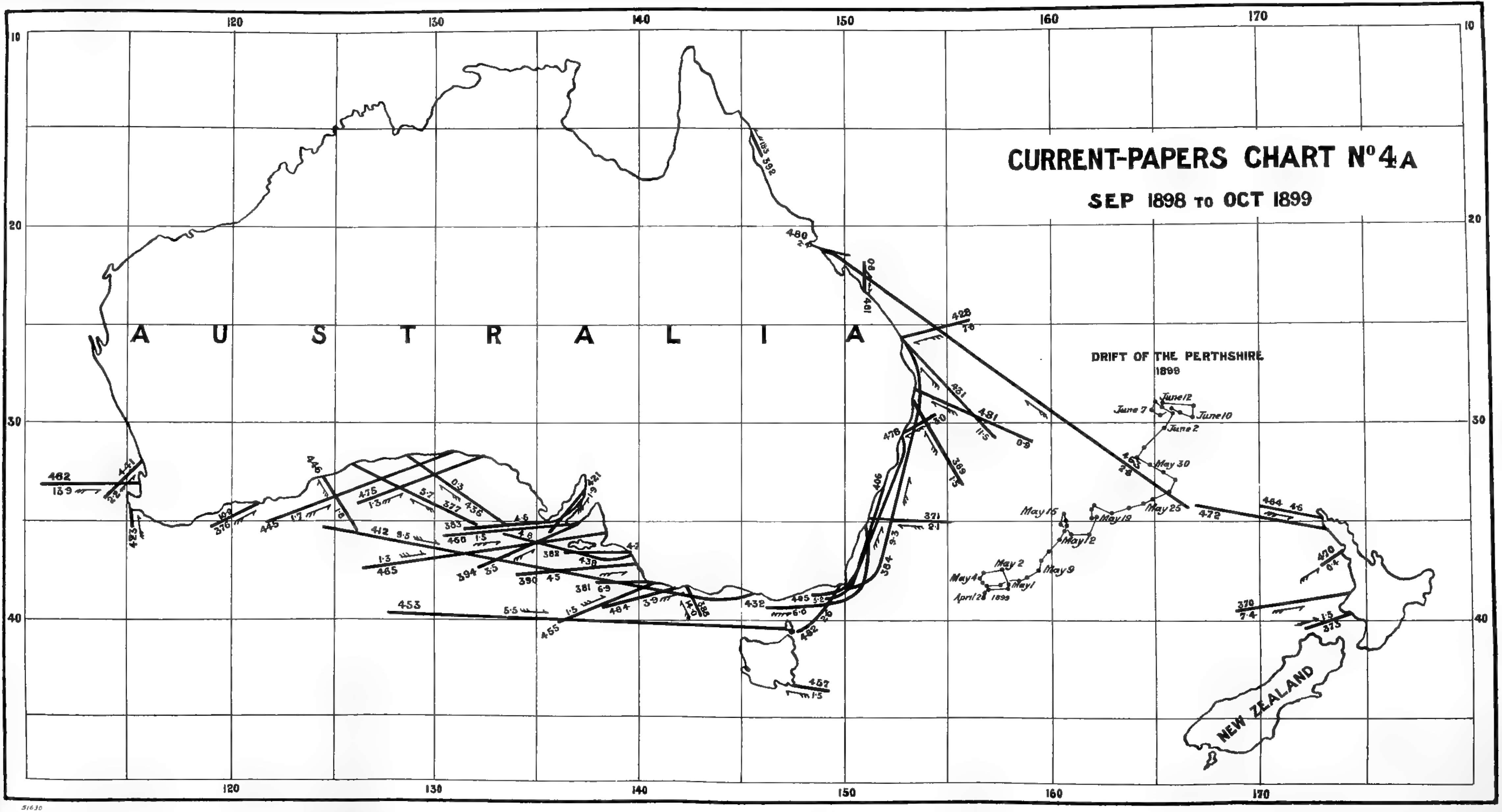


*Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.*

CHART OF THE WORLD

CURRENT-PAPERS CHART No 4B

SEP. 1898 TO OCT. 1899

London..Published at the Admiralty, 21st January 1874 *under the Superintendence of* Rear Admiral G.H. Richards, C.B. F.R.S. *Hydrographer.*

Sold by J.D. Potter, Agent for the sale of the Admiralty Charts. 31 Poultry & 11 King Street Tower Hill.

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

Engraved by Davies & Company
2558

51630

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 3, 1899.

The Annual General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 3rd, 1899.

The President, G. H. Knibbs, F.R.A.S., in the Chair.

Fifty-two members and eight visitors were present.

The minutes of the preceding meeting were read and confirmed.

One new member enrolled his name and was introduced.

The following Financial Statement for the year ended 31st March, 1899, was presented by the Hon. Treasurer, and adopted.

GENERAL ACCOUNT.

	Receipts.	£	s.	d.	£	s.	d.
Subscriptions	One Guinea	109	4	0	556	10	0
	Two Guineas	346	10	0			
	Arrears	97	13	0			
	Advances	3	3	0			
Entrance Fees					23	2	0
Parliamentary Grant on Subscriptions received—							
1898							
June 16, Balance of Vote for 1897-98		152	9	0			
1899							
Feb. 3, Total Vote for 1898-99		500	0	0			
					652	9	0
Rent					11	0	0
Sundries					37	15	0
Total Receipts					1280	16	0
Balance on 1st April, 1898					42	2	1
					£1322	18	1

PAYMENTS.	£	s.	d.	£	s.	d.
Advertisements	20	19	0			
Assistant Secretary	250	0	0			
Books and Periodicals	66	6	9			
Bookbinding	32	4	2			
Conversazione, 1898	1	7	0			
Collector	2	18	10			
Freight, Charges, Packing, &c....	4	19	4			
Furniture and Effects	3	1	9			
Gas	27	10	6			
Housekeeper	10	0	0			
Insurance	11	12	0			
Interest on Mortgage	61	5	0			
Office Boy	21	0	4			
Petty Cash Expenses	10	11	10			
Postage and Duty Stamps	33	5	0			
Printing	42	6	6			
Printing and Publishing Journal	310	3	11			
Printing Extra Copies of Papers	27	8	0			
Rates	49	13	0			
Refreshments and attendance at Meetings ...	23	4	0			
Repairs	47	16	0			
Stationery	17	4	4			
Sundries	12	2	6			
Total Payments				1086	19	9
Repayment to Clarke Memorial Fund... ...				200	0	0
Balance on 31st March, 1899, viz.:—						
Cash in Union Bank, General Account ...	17	17	10			
,, ,, B. & I. Fund ...	8	0	6			
Cash in hand...	10	0	0			
				35	18	4
				£1322	18	1

BUILDING AND INVESTMENT FUND.

RECEIPTS.	£	s.	d.
Loan on Mortgage at 4%	1400	0	0
Clarke Memorial Fund—			
Loan at current Savings Bank rate of interest	208	14	0
	£1608	14	0

PAYMENTS.	£	s.	d.
Advance to General Account 31st March, 1897	8	0	6
Balance 31st March, 1899	1600	13	6
	£1608	14	0

CLARKE MEMORIAL FUND.

RECEIPTS.	£	s.	d.
Loan to Building and Investment Fund, 31 March, 1898 ...	396	15	11
Interest to 31 March, 1899	11	18	1
	£408	14	0

	£	s.	d.
Repayment from General Account deposited in Savings Bank of New South Wales, March 31, 1899	200	0	0
Loan to Building and Investment Fund, March 31, 1899 ...	208	14	0
	£408	14	0

AUDITED AND FOUND CORRECT, DAVID FELL... } *Honorary Auditors.*
H. A. LENEHAN }

SYDNEY, 20th April, 1899.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. T. F. Furber and R. P. Sellors were appointed Scrutineers, and His Honor Judge Docker deputed to preside at the Ballot Box.

A ballot was then taken, and the following gentlemen were elected officers and members of Council for the current year :—

Honorary President:

HIS EXCELLENCY THE RIGHT HON. WILLIAM EARL BEAUCHAMP, K.C.M.G.

President:

W. M. HAMLET, F.C.S., F.I.C.

Vice-Presidents:

PROF. ANDERSON STUART, M.D.
CHARLES MOORE, F.L.S.
PROF. T. W. E. DAVID, B.A., F.G.S.
HENRY DEANE, M.A., M. Inst. C.E.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. H. MAIDEN, F.L.S.
G. H. KNIBBS, F.R.A.S.

Members of Council:

C. O. BURGE, M. Inst. C.E.
J. W. GRIMSHAW, M. Inst. C.E.
F. B. GUTHRIE, F.C.S.
H. A. LENEHAN, F.R.A.S.
Prof. LIVERSIDGE, M.A., LL.D., F.R.S.
F. H. QUAIFE, M.A., M.D.
H. C. RUSSELL, B.A., C.M.G., F.R.S.
HENRY G. SMITH, F.C.S.
J. ASHBURTON THOMPSON, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*
PROF. WARREN, M. Inst. C.E., Wh.Sc.

The certificate of one candidate was read for the third time, of one for the second time, and of two for the first time.

The following gentleman was duly elected an ordinary member of the Society :—

Powys, Arthur Owen, Actuary; North Sydney.

The following announcements were made :—

1. That the Society's Journal for 1898, Vol. XXXII., was in the hands of the binder, and would shortly be ready for delivery; also that *Plate* I. illlustrating the paper on Tribes and Genera of Melanospermeæ (Olive-green seaweeds) was not inserted in the volume. Members wishing to obtain a copy are required to make personal application for the same.

2. That the Officers and Committee of the Engineering Section had been elected for the ensuing Session, and the dates fixed for their meetings as follows :—

SECTION MEETINGS.

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ENGINEERING—Wednesday, (8 p.m.)	17	21	19	16	20	18	15	20

SECTIONAL COMMITTEES—SESSION 1899.

Section K.—Engineering.

Chairman—H. R. Carleton, M. Inst. C.E.

Hon. Secretary and Treasurer—S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E.

Committee—Henry Deane, M. Inst. C.E., Norman Selfe, M. Inst. C.E., Percy Allan, Assoc. M. Inst. C.E., G. R. Cowdery, J. M. Smail, M. Inst. C.E., J. I. Haycroft, M.E., M. Inst. C.E., I.

Past-Chairmen, *ex officio* Members of Committee for three years :— Prof. Warren, M. Inst. C.E., Wh. Sc., C. O. Burge, M. Inst. C.E., and T. H. Houghton, M. Inst. C.E., M. Inst. M.E.

3. That the Officers and Committee of the Medical Section would be elected, and the dates fixed for their meeting on the 19th May.

4. That a letter had been received by the Council urging that more effective means be provided for enabling private members to nominate to the Council; it was stated that the matter is now under the consideration of the Council.

The following letter and enclosures have been received from the President of the Royal Geographical Society. With a view to making the wishes of that body known to members of the Royal Society, these have been reproduced *in extenso:*

1 Savile Row, Burlington Gardens, London, W.,
November, 25th, 1898.

Dear Sir,—A joint Committee of the Royal Society and of the Royal Geographical Society has been formed for the purpose of endeavouring to obtain the necessary funds wherewith to equip a British National Expedition for the exploration of the great unknown Antarctic area. For several years efforts have been made to induce the Imperial Government to send an expedition to complete the work of Sir James Ross sixty years ago. It has at last been definitely intimated that under the present circumstances there is no prospect of the Government undertaking such work; at the same time the Government expressed approval of the movement to obtain funds for an adequate private expedition, and promised to give such an expedition its countenance, and to some extent its support.

The necessity for such an expedition is unanimously admitted by all Scientific Societies; and it is believed that Australasia would benefit more than any other part of the world, from the scientific results which are sure to be obtained. I am sure it is unnecessary to urge upon you and your Society the great importance of Antarctic exploration; the papers which accompany this letter show fully what are the views of scientific men in Europe.

If Great Britain is to maintain her place in the forefront of exploring enterprise there is no time to lose. In 1900 a fully equipped German expedition will leave for the Antarctic area, and if we hold back we should have no part in the last great piece of exploring work that remains to be done. Germany looks to Great Britain for co-operation, and there is ample room for both; the work thus jointly carried out on a common plan would be invaluable, and would probably solve once for all the great problems which await solution in the Antarctic.

This Society contributes £5,000, and Mr. Alfred Harmsworth a like sum, and other smaller sums are promised; but a minimum of £50,000 is required, and further subscriptions are urgently wanted. Antarctic enterprise has special claims upon Australia, and I therefore appeal to your Society to use your influence, both with the Colonial Government and with private individuals to help the joint Committee to obtain the necessary funds.

I am, yours sincerely,
CLEMENT R. MARKHAM,
President, Royal Geographical Society.

President of the Royal Society, Sydney, N. S. Wales.

NEW ZEALAND AND ANTARCTIC EXPLORATION.

In connection with the movement for obtaining funds for a National Antarctic Expedition it is of interest to note the fact, that so long ago as July last the Legislative Council of New Zealand pronounced unanimously in favour of the Colonial Government contributing to support the movement. The Hon. Charles Bowen moved "That the Government be requested to place a sum of money on the estimates as a contribution towards the equipment of an Antarctic expedition which the Royal Geographical and other scientific Societies are promoting, and to provide for a preliminary magnetic survey in New Zealand as far south as possible. The motion was fully discussed in the Council, and received the hearty support of all the speakers except one. The Hon. Dr. Grace thought all Governments should be encouraged to follow previous impulses. People must be worthy of their destiny. It was the destiny of New Zealand to influence largely the history of the future of these seas, and it was unquestionably our duty to be worthy of that destiny." It is to be hoped that the other Australasian Colonies will follow the example of New Zealand and no doubt the President of the Royal Geographical Society will take steps to secure their co-operation.

1 Savile Row, Burlington Gardens, London W.
November 19th, 1898.

APPEAL FOR SUBSCRIPTIONS TO A NATIONAL ANTARCTIC EXPEDITION.

Sir,—May I request permission to appeal through your columns for public support towards a National Antarctic Expedition.

A joint Committee of the Royal Society and the Royal Geographical Society has been formed to promote this object; and there is absolute unanimity among men of science with regard to the scientific importance of the results; while the magnetic survey will be of practical value to navigation.

This appeal has become necessary because Her Majesty's Government is unable to supply funds for the Expedition or to lend officers; but recognises its scientific importance. The Admiralty, on the part of the Government, will aid the outfit of an expedition by a loan of instruments; their Lordships will place at the disposal of its leader any experience which may have been gained in the past; they regard the enterprise as one which is important in the interests of science; and will watch the results with great interest. Subscribers will, therefore, be aiding a great work approved by H.M. Government.

This is strictly a naval enterprise, and we all must regret that the navy is deprived of its right. But if naval officers on the active list cannot be spared, there will be plenty of volunteers from among young officers who have left the service, officers on the retired list, and officers of the naval reserve.

A German Antarctic Expedition will be despatched in 1900, with naval officers, and well equipped in every respect. But the work to be done is very extensive, and must be divided. My German friends, therefore, hope that a British Expedition will co-operate with them, agreeing to take separate regions within the Antarctic circle. This is expected of us. If we hold back, our country will lose credit. For the first time in our history we shall shamefully resign our proud position, so long held, in the fore-front of exploration and discovery. I appeal to the patriotic feeling of all true Britons, and especially to those among my countrymen who possess the power which great wealth supplies.

Subscriptions to the National Antarctic Expedition will be received by Messrs. Cocks Biddulph, 43, Charing Cross, S.W.; or at the office of the Royal Geographical Society, 1 Savile Row, W., addressed to the President.

I am, Sir, your obedient servant,
CLEMENTS R. MARKHAM,
President of the Royal Geographical Society.

Subscriptions already promised or received.

Royal Geographical Society	£5,000
Alfred Harmsworth, Esq.	£5,000
Sir Clements Markham, K.C.B. (President R.G.S.) ...	£100
Philip F. Walker, Esq.	£21
John Prince, Esq.	£10

Mr. G. H. Knibbs, F.R.A.S., then read his address.

The theme of the Anniversary Address delivered by the President, Mr. G. H. Knibbs, F.R.A.S., was the influence of Science upon civilisation. After pointing out that the most abstract forms of science played a far more significant part than was generally realized, the origin and development of mathematics from the time of the Egyptian Ahmes (1700 B.C.) to the present day, was briefly drawn to the characteristic features of the Egyptian, Greek, Hindu and Arabian, as well as the modern influences on that science. The recent developments of applied mathematics were also indicated, it being pointed out that physics, engineering, and practical chemistry, which lie immediately behind the material expression of modern civilisation, are indebted to the more abstract forms of science for great assistance. A brief sketch of the development also of chemistry was given, in which it was shewn that the recondite elements of that science had great practical value, and that the far-reaching powers of technical chemistry depended upon considerations of a theoretical nature. The influence of chemistry on therapeutics was indicated, and it was shewn that the knowledge of the mode in which the atoms were united in a molecule had enabled the therapeutical properties of substances to be predicted with some degree of confidence.

The part science has taken in the national development of Germany and of its industries, was adverted to, and it was urged that the similar stimulation of intellectual and scientific effort was needed, if this country is to occupy an honourable place among the centres of intellectual activity. The necessities of the University, of its science schools, its library, and of the scientific libraries of the colony were referred to. The nuclei of splendid libraries, an absolute necessity to the scientific worker, already exist. The great International Scientific Catalogue is the outcome of the realization of this necessity, that catalogue will prevent any worker being ignorant of what has been done. It must be supplemented however, by the actual records of scientific investigations. Owing to munificent state and private benefactions, the American institutions of learning are rapidly completing their libraries and exhausting the market of sets of scientific periodicals, and the opportunity of properly completing the great series of scientific journals here is rapidly passing away never to return. The time for action is now, but the means are not available. The Royal Society itself has spent during the last twenty years £4,704 on the purchase of books and periodicals, and during the last twelve years £3,602 in publishing its Journal, which not only gives a record of the scientific work done here, but also brings exchanges, the money value of which is greater than what is purchased.

The duty of placing our wants clearly before the community was accentuated, and the belief was expressed that the generous example of men of affluence in America and elsewhere, would not be without parallel in this Colony. It was not that our wealthy citizens, and the State, were less generous, but we had not discharged our duty to science in letting them really understand our wants. To do this was a solemn duty cast upon those who realize what scientific culture means to the world, and who realize how affluence, and the great development of a people is the outcome of the influence of systematized knowledge—in short of Science.

A vote of thanks was passed to the retiring President, and Mr. W. M. Hamlet, F.C.S., F.I.C., was installed as President for the ensuing year.

Mr. Hamlet thanked the members for the honour conferred upon him.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*).

Albany—New York State Library. Annual Reports of the Regents of the University of the State of New York, 109th, Parts i., ii., 1895; 110th, 1896; 111th, 1897. Bulletin, New York State Museum, Vol. iv., Nos. 16 – 18, 1897. Examination Report, Vol. iv., 1896, Vol. v., 1897. Library Report, Vol. lxxviii., 1895; Vol. lxxix., 1896; Vol. lxxx., 1897. State Library Bulletin, Bibliographies Nos. 2 – 4, 1897, Nos. 6 – 14, 1898; Legislation, No. 9, 1898; Library School, No. 2, 1897. State Museum Reports, Vol. xlix., Part i., 1895; Vol. l., Part i., 1896. *The Regents*

Birmingham—Birmingham and Midland Institute. Report of the Council for the year 1898. "The Chemistry of the Stars" an address delivered 26 Oct. 1898, by Sir Norman Lockyer, K.C.B., F.R.S. *The Institute*

Boston, Mass.—American Academy of Arts and Sciences. Proceedings, Vol. xxxiv., Nos. 1 – 14, 1898-99. *The Academy*

Cambridge—Cambridge Philosophical Society. Proceedings, Vol. ix., Part ix.; Vol. x., Part 1, 1898. Transactions, Vol. xvii., Parts i., ii., 1898-9. *The Society*

Kew—Royal Gardens. Hooker's Icones Plantarum, Ser. 4, Vol. vi., Part iv., 1899. *The Trustees*

Leeds—Leeds Philosophical and Literary Society. Annual Report (78th) for 1897-8. *The Society*

Yorkshire College. Annual Report, (24th) 1897-8. *The College*

Liverpool—Literary and Philosophical Society. Proceedings, Vol. lii., 1897-8. *The Society*

London—Anthropological Institute of Great Britain and Ireland. Journal, New Series, Vol. i., Nos. 1, 2, 1898. *The Institute*

Department of Science and Art, South Kensington. Descriptive Catalogue of the Bronzes of European Origin in the South Kensington Museum, 1876. Maiolica by C. Drury E. Fortnum, F.S.A., 1892. *The Department*

Electrical Engineer, Oct. 28, 1898 to March 17, 1899. *The Publisher*

LONDON—*continued.*

Geological Society. Quarterly Journal, Vol. LIV., Part iv., No. 216, 1898; Vol. LV., Part i., No. 217, 1899. List of Fellows, 1898. *The Society*

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXXXIV., Part iv., 1897-98. Brief Subject Index Vols. CXIX. – CXXXIV., Sessions 1894-95 to 1897-98. Charter, Supplemental Charters, By-Laws and List of Members, 1 Oct. 1898. *The Institution*

Institution of Mechanical Engineers. Proceedings, Nos. 1, 2, 3, 1898. ,,

Imperial Institute. Journal, Vol. V., No. 51, 1899. *The Institute*

Iron and Steel Institute. Journal, Vol. LIV., No. 2, 1898. ,,

Linnean Society. Journal, Botany, Vol. XXXIII., No. 234; Vol. XXXIV., No. 235, 1898. Proceedings, Nov. 1897 to June 1898. *The Society*

Meteorological Office. Report of the Meteorological Council for the year ending 31 March, 1898. *The Office*

Pharmaceutical Society of Great Britain. Calendar, 1899. Pharmaceutical Journal, Vol. LXI., Nos. 1479 – 1499, 1898-99. *The Society*

Physical Society of London. Proceedings, Vol. XVI., Parts iii. and iv., 1898-99. Science Abstracts, Vol. I., Parts xi.. xii., and Index 1898; Vol. II., Parts i. – iii., 1899. ,,

Quekett Microscopical Club. Journal, Ser. II., Vol. VI., No. 39, 1896; Vol. VII., No. 43, 1898. *The Club*

Royal Agricultural Society of England. Journal, Ser. 3, Vol. IX., Part iv., No. 36, 1898. *The Society*

Royal Astronomical Society. Monthly Notices, Vol. LVIII., No. 9, and Appendix 1898; Vol. LIX., Nos. 1 – 3, 1898-9. ,,

Royal College of Physicians. List of Fellows, Members, Extra-Licentiates and Licentiates, 1899. *The College*

Royal Geographical Society. *Geographical Journal*, Vol. III., No. 1, 1894; Vol. XII., Nos. 5, 6, 1898; Vol. XIII., Nos. 1 – 3, 1899. Antarctic Exploration: a plea for a national expedition. By Sir Clements R. Markham, K.C.B., F.R.S., 1898. *The Society*

Royal Historical Society. Transactions, New Series, Vol. XII., 1898. ,,

Royal Meteorological Society. Quarterly Journal, Vol. XXIV., No. 108, 1898. Meteorological Record, Vol. XVIII., Nos. 69 – 71, 1898, ,,

Royal Microscopical Society. Journal, Parts ii., v., vi., Nos. 123, 126, 127, 1898; Part i., No. 128, 1899. ,,

Royal Society of Literature. Transactions, Series 2, Vol. XX., Parts i., ii., 1898-9. ,,

Royal United Service Institution. Journal, Vol. XLII., Nos. 246 – 250, 1898. *The Institution*

Sanitary Institute. Journal, Vol. XIX., Parts iii., iv., 1898-9. *The Institute*

Society of Arts. Journal, Vol. XLVI., Nos. 2397 – 2417, 1898-9. *The Society*

Zoological Society of London. Proceedings, Part iii., 1898. Transactions, Vol. XIV., Part viii.; Vol. XV., Part i., 1898. ,,

ABSTRACT OF PROCEEDINGS, JUNE 7, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 7th, 1899.

The President, W. M. Hamlet, F.C.S., in the Chair.

Thirty-nine members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

One new member enrolled his name and was introduced.

The certificate of one candidate was read for the third time, of two for the second time, and of one for the first time.

The following gentleman was duly elected an ordinary member of the Society:—

Atkinson, Alfred Ashley, Department of Mines, Sydney.

The Chairman announced:—

1. That the Society's Journal for 1898, Vol. XXXII., was ready for delivery, and could be obtained on application to the Assistant Secretary.
2. That the Society's congratulations had been cabled so as reach Sir George Gabriel Stokes, Bart. F.R.S., M.A., D.C.L., LL.D., D.Sc., &c., Lucasian Professor of Mathematics at Cambridge, on the occasion of his Jubilee on the 5th instant.
3. That the Officers and Committee of the Medical Section had been elected for the ensuing Session and the dates fixed for their meetings as follows:—

SECTION MEETINGS.

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
MEDICAL—Friday, (8·15 p.m,)...	19	16	21	18	15	20	17	15

SECTIONAL COMMITTEES—SESSION 1899.

Section H.—Medical.

Chairman—Walter Spencer, M.R.C S. *Eng.*, L.R.C.P. *Edin.*, M.D. *Brux.*

Hon. Secretaries—J. Adam Dick, B.A. *Syd.*, M.D. *Edin.*, and F. Tidswell, M.B. *Syd.*, and D.P.H., *Camb.*

Committee—F. H. Quaife, M.A., M.D., *Glas.*, Sydney Jamieson, B.A. *Syd.*, M.B., *Edin.*, M R C.S., *Eng.*, Roland Pope, B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, L. E. F. Neill, B.A. M.B. *Syd.*

Meetings held on the Third Friday in each Month, at 8·15 p.m.

(Provided sufficient material is obtainable.)

THE FOLLOWING PAPERS WERE READ:—

1. "Key to Tribes and Genera of the Florideæ (Red or purple Marine Algæ)" by R. A. Bastow.

This paper was read, and was explanatory of two large charts of this group of sea-weeds, prepared by the author.

2. "On the metamorphosis of the young form of *Filaria Bancrofti*, Cobb, [*Filaria sanguinis hominis*, Lewis; *Filaria nocturna*, Manson] in the body of *Culex ciliaris*, Linn., 'House Mosquito' of Australia," by Thos. L. Bancroft, M.B. *Edin.*

In this paper the metamorphosis of *Filaria nocturna* in the body of the mosquito is shewn to take from sixteen to twenty days for its completion, instead of seven days as was thought; previous observers, endeavouring to follow Manson, were unable to keep their mosquitoes alive sufficiently long; the writer discovered a means by which mosquitoes may be kept alive in suitable glass vessels for upwards of two months; he feeds them on ripe banana. He explains how it occurred that Manson saw the final stage of the metamorphosis occasionally in what he thought were seven days old mosquitoes; these particular mosquitoes had imbibed filariated blood weeks before the time when they were captured and already contained advanced stages of the metamorphosis. Anyone may now easily verify Manson's work by merely placing two or three "house mosquitoes" under the mosquito net curtains of the bed in which a filarious person sleeps, preferably late at night, and when the person is asleep; the next morning the mosquitoes, which have sucked blood, are transferred to a large glass vessel and fed on banana, in twenty days every one of them will contain actively moving filariæ.

EXHIBITS.

1. Ferruginous geodes, one containing liquid, by Henry G. Smith, F.C.S.

2. Dr. Erdmenger's specific gravity apparatus was exhibited and described by Professor Warren, M. Inst. C.E., Wh. Sc.

3. A form of the Wehnelt electrolytic interrupter for induction coils, the action of which was demonstrated by Professor J. A. POLLOCK, B.E., B.Sc.

4. A series of recent photographs of the moon, taken at the Paris Observatory, were exhibited by H. C. RUSSELL, B.A., C.M.G., F.R.S.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics.*)

BRISTOL—Bristol Naturalists' Society. Proceedings, New Series, Vol. VIII., Part iii., 1897. *The Society*

CHICAGO—University of Chicago Press. Astrophysical Journal, Vol. IX., Nos. 1 - 3, 1899. *The University*

DUBLIN—Royal Irish Academy. Proceedings, Series 3, Vol. v., No. 1, 1898. *The Academy*

EASTON, PA.—American Chemical Society. Journal, Vol. XX., No. 11, 1898; Vol. XXI., Nos. 1 - 4, 1899. *The Society*

EDINBURGH—Highland and Agricultural Society of Scotland. Transactions, Series 5, Vol. XI., 1899. ,,

Royal Scottish Geographical Society. *Scottish Geographical Magazine,* Vol. XIV., Nos. 10 - 12, 1898; Vol. XV., Nos. 1 - 4, 1899. ,,

Scottish Microscopical Society. Proceedings, Vol. II., No. 3, Session 1897-98. ,,

FORT MONROE, Va.—U. S. Artillery School. Journal of the U.S. Artillery, Vol. X., Nos. 1 - 3, Whole Nos. 33 - 35, 1898. *The School*

LONDON—" Electrical Engineer," N.S., Vol. XXIII., Nos. 12, 13, 15, 1899. *The Publisher*

Imperial Institute. Imperial Institute Journal, Vol. v., No. 52, April 1899. *The Institute*

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXXXV., Part i., Session 1898-99. *The Institution*

Linnean Society. Journal, Zoology, Vol. XXVI., No. 172, 1898. List of Fellows, 1898-99. *The Society*

Mineralogical Society. *Mineralogical Magazine and Journal,* Vol. XII., No. 55, 1899. ,,

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, Vol. LXII. (Fourth Series, Vol. VIII,) Nos. 1500 - 1503, 1899. ,,

Physical Society. Science Abstracts, Vol. II., Part iv., No. 16, 1899. ,,

Royal Agricultural Society of England. Journal, Third Series, Vol. X., Part i., No. 37, 1899. ,,

LONDON—*continued.*

Royal Astronomical Society. Monthly Notices, Vol. lix., Nos. 4, 5, 1899. *The Society*

Royal Geographical Society. Geographical Journal, Vol. xiii., No. 4, 1899. Year-Book and Record 1899. ,,

Royal Meteorological Society. Quarterly Journal, Vol. xxv., No. 109, 1899. ,,

Royal Microscopical Society. Journal, Part ii., No. 129, 1899. ,,

Royal Society of Literature. Transactions, Series 2, Vol. xx., Part iii., 1899. ,,

Royal United Service Institution. Journal, Vol. xlii., Nos. 246 – 250, 1898; Vol. xliii., Nos. 251 – 253, 1899. *The Institution*

Sanitary Institute. Journal, Vol. xx., Part i., 1899. *The Institute*

Society of Arts. Journal, Vol. xlvii., Nos. 2418 – 2421, 1899. *The Society*

Zoological Society. Proceedings, Part iv., 1898. ,,

MANCHESTER—Conchological Society of Great Britain and Ireland. Journal of Conchology, Vol, ix., Nos. 5, 6, 1899. ,,

Manchester Geological Society. Transactions, Vol. xxv., Parts xx., xxi., 1897-98. ,,

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. xlii., Part v., 1897-98. ,,

MELBOURNE—*Australasian Journal of Pharmacy,* Vol. xiii., No. 156, 1898; Vol. xiv., Nos. 157 - 162, 1899. *The Editor*

Field Naturalists' Club of Victoria. *The Victorian Naturalist,* Vols. xv., Nos. 8 – 12; Vol. xvi., Nos. 1,2, 1898-99. *The Club*

Government Statist. Abstract of the Statistics of Victoria, 1893 – 1898. *Government Statist*

Royal Geographical Society of Australasia (Victoria). Report of the Council for the fifth triennial period ending 31st December, 1898. *The Society*

Royal Society of Victoria. Proceedings, Vol. xi., N.S., Part ii., 1899. ,,

University. Annual Examination Papers, October and December, 1898. Final Honour, Degrees &c., Examination Papers, February 1899. Matriculation Examination Papers, November 1898 and May 1899. *The University*

NEWCASTLE-UPON-TYNE—North of England Institute of Mining and Mechanical Engineers. Annual Report of the Council etc., 1897-8. Transactions, Vol. xlvii., Parts vi., vii.; Vol. xlviii., Part i., 1898. *The Institute*

NEW YORK—American Institute of Mining Engineers. Transactions, Vol. xxvii., 1897. ,,

PARIS—Académie des Sciences de l'Institut de France. Comptes Rendus, Vol. cxxvii., Nos. 16 – 26, 1898; Vol. cxxviii., Nos. 1 – 20, 1899. *The Academy*

PERTH, W.A.—Department of Mines. Geological Survey, Bulletin No. 3, 1899. Gold Mining Statistics, Jan. - April, 1899. Western Australia, its position and prospects, by Trant Chambers, 1898. *The Department*

ABSTRACT OF PROCEEDINGS, JULY 5, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 5th, 1899.

The President, W. M. Hamlet, F.C.S., in the Chair.

Forty members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the third time, of one for the second time, and of twenty-two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Durack, J. J. E., B.A. *Syd.*; St. John's College, University.
Hawker, Herbert, Demonstrator in Physiology, University of Sydney; Toxteth Road, Glebe Point.

THE FOLLOWING PAPERS WERE READ:—

1. "Suggestions for depicting diagrammatically the character of Seasons as regards Rainfall, and especially that of Drought," by H. Deane, M.A., M. Inst. C.E.

The author calls attention to the inadequacy of the ordinary methods of judging of the dryness or otherwise of seasons by using the totals of the rainfall and comparing them with the average. He explains that the proper way of exhibiting the character of any period is by showing diagrammatically the progressive dryness that takes place in the soil after rainfall ceases. This is marked by a descending line, and being from time to time more or less compensated for by falls of rain, these are indicated by rises. The only useful rain to the soil itself is what soaks in and tends to saturate it, all beyond this, although it may be useful for conservation and for keeping up the flow of rivers, is waste so far as the particular ground, on which the rain has fallen, is concerned. The diagrams exhibited show the effect of this "loss and compensation" system and the dryness of the years and parts of years given in the series 1883 to 1898 inclusive are rendered visible and measurable.

2. "The Initiation Ceremonies of the Aborigines of Port Stephens, New South Wales," by W. J. ENRIGHT, B.A. *Syd.* (Communicated by R. H. MATHEWS, L S.)

The author briefly dealt with what is popularly known as "man making." On approaching the age of puberty, a youth is taken away from the maternal control by the elders, or chief men, instructed in the traditions and laws of his tribe, and made familiar with occult rites which are kept secret from the uninitiated, and from women. Until he passes through this ordeal he is not permitted to fraternize with the men, or to join in certain songs and dances known only to initiates. Thenceforth he is qualified to take his part as a man of the tribe, to attend the councils of the men, and so listen to and participate in all discussions relating to matters of tribal concern.

EXHIBITS.

1. A comparison of the various modes of artificial lighting, by Mr. J. L. BRUCE, Technical College.

2. A new form of Spectrometer, by Professor LIVERSIDGE, M.A., LL.D., F.R.S.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*)

ADELAIDE—Observatory. Meteorological Observations during 1895. *The Observatory*

Public Library, Museum, and Art Gallery. Report of the Board of Governors for 1897-8. *The Board*

Royal Society of South Australia. Transactions, Vol. XXII., Part ii., 1898. *The Society*

AUCKLAND—Auckland Institute and Museum. Annual Report for 1898-99. *The Institute*

BOSTON—American Academy of Arts and Sciences. Proceedings, Vol. XXXIV., Nos. 15 - 17, 1899. *The Academy*

BRISBANE—Department of Agriculture. Extracts from Queensland Agricultural Journal, Vol. IV., 1899:—i. Contributions to the Flora of Queensland and New Guinea, by F. Manson Bailey, F.L.S. ii. Economic Botany by F. Manson Bailey, F.L.S. iii. Tick Fever, by C. J. Pound, F.R.M.S. *The Department*

ABSTRACT OF PROCEEDINGS, AUGUST 2, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 2nd, 1899.

The President, W. M. Hamlet, F.C.S., in the Chair.

Thirty-two members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of one candidate was read for the third time, of twenty-two for the second time, and of four for the first time.

The following gentleman was duly elected an ordinary member of the Society :—

Levy, Albert Lewis, L.R.C.P., L.R.C.S. Edin., L.P.S. Glas.; Church-street, Newtown.

THE FOLLOWING PAPERS WERE READ :—

1. "On the crystalline camphor of Eucalyptus Oil (Eudesmol) and the natural formation of Eucalyptol," by Henry G. Smith, F.C.S., Technological Museum, Sydney.

In August, 1897, the author, with Mr. R. T. Baker, F.L.S., in a paper before this Society, announced the discovery of a crystalline camphor or stearoptene in Eucalyptus oil. They named this substance *eudesmol*. The present paper deals with the chemistry of this camphor and its relation to eucalyptol. Eudesmol has been found in the oil of many species of Eucalyptus, and should be present at certain times of the year in all those Eucalyptus oils that are eventually rich in eucalyptol. Eudesmol has a formula $C_{10}H_{16}O$, is isomeric with ordinary camphor, but has the oxygen atom combined in a different manner. It does not appear to be ketonic, and it cannot be reduced by sodium in alcohol or by other methods. It is optically inactive. It forms a dinitro-compound and a dibromide, but does not form a nitrosochloride. It melts at 79-80° when perfectly pure, but has a tendency to form products having a lower melting point. On oxidation with dilute nitric acid, camphoronic acid is formed, but no camphoric acid. A large amount of evidence is brought forward to show eudesmol to be intermediate in the formation of eucalyptol, and that eucalyptol is derived directly from the fraction containing eudesmol if the oil be kept in the crude condition for some time under ascertained conditions. Oxygen is necessary to this alteration. It is shown that the oxygen atom enters the eucalyptol molecule during the formation of eudesmol, and that by the natural alteration of the high boiling fraction of oils containing eudesmol (*E. macrorhyncha*, for instance) eucalyptol is formed. *Eucalyptus camphora* oil was found to be rich in eudesmol at the time of year when distilled. The probable reason why Eucalyptus oils allied to *E. globulus* do not contain phellandrene is described, and it is shown that the oils from other groups of eucalypts are dextrorotatory when their maximum eucalyptol content is reached, and that they do not at that time contain phellandrene, although at certain times of the year phellandrene may be present.

The synthesis by Perkin and Thorpe[1] shows camphoronic acid to be trimethyl tricarballylic acid, as was first suggested by Bredt, and as eucalyptol is derived from eudesmol, and eudesmol forms camphoronic acid, the question is raised whether Brühl's formula for eucalyptol is correct. It is suggested that the oxygen atom in eudesmol is quadrivalent, and that the peculiarity of eucalyptol may be thus accounted for. From the formula suggested for eudesmol camphoronic acid, as trimethyl tricarballylic acid, can be constructed.

2. "Observations on the determination of the Intensity of Drought," by G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney.

The paper was really a continuation of the subject of Mr. H. Deane's paper, read at a previous meeting. It was shown that if the degree of saturation of ground was, as suggested by Mr. Deane, taken as the reciprocal of the measure of drought intensity, then, theoretically, it was determinable. The essential features

---

[1] Journ. Chem. Soc., 1897, 1169.

of Mr. Deane's solution and of the nature of the problem were discussed. The laws of permeable flow, and the relation of these to the ascertainment of the amount flowing off from soil—a question of some importance to engineers—and that absorbed for any given rate of rainfall were pointed out. The physical circumstances which affect percolation, it was stated, must be considered in the general question, and formulæ were given for obtaining the necessary constants for the soil. Evaporation, the effect of solar radiation, the law of diffusion, the effect of air temperature, humidity, and of atmospheric motion and drainage had to be considered in estimating losses; and the complexity of the general expression for the degree of saturation showed that the exact solution would be difficult. The study of elementary cases might afford some indication of a practical solution for various conditions naturally occurring. The paper closed with some remarks on graphs representing natural phenomena, the phenomena to be observed, and the mode of shewing them.

3. "Divisions of Some Aboriginal Tribes, Queensland," by. R. H. Mathews, L.S.

Mr. R. H. Mathews read a short paper dealing with the social organisation of some native tribes of Queensland. He illustrated the different types of divisional systems adopted by the aborigines for the purpose of regulating the intersexual relations. In some tracts of country the community is segregated into two intermarrying groups; in other geographic areas there are four divisions of the inhabitants; whilst in other districts there are eight intermarrying divisions. In these several types of social structure the men of a certain section or group marry the women of another prescribed section, and the resulting offspring inherit a section name which is in all cases determined through the mother. The author drew attention to the great value of a knowledge of these social divisions in all ethnological investigations among the native tribes of Australia.

EXHIBIT.

Examples of the Joly natural-colour Photographs, by Mr. P. Caro, exhibited by Mr. S. H. **Barraclough,** M.M.E., Assoc. M. Inst. C.E.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The names of the Donors are in *Italics.*)

ANNAPOLIS, Md.—U.S. Naval Institute. Proceedings, Vol. XXIV., Nos. 3, 4. 1898; Vol. XXV., No. 1, 1899. *The Institute*

BALTIMORE—Johns Hopkins University. Circulars, Vol. XVIII., Nos. 137 - 140, 1898-99. *The University*

BERKELEY, Cal.—University of California. Annual Report of the Secretary to the Board of Regents for the years ending June 30, 1897 and June 30, 1898. Adjustment of Engineering Field Instruments by H. H. Hirst, B.S., 1898. Beiträge zur Kometenbahnbestimmung by A. O. Leuschner, A.B., 1897. Biennial Report of the President of the University 1896 - 1868. Bulletin, Nos. 120, 121, 1898. Bulletin of the Department of Geology, Vol. II., No. 4, pp. 109 - 118, 1898. Partial report of the Agricultural Experiment Stations for the years 1895-6; 1896-7. Registrar, 1897-98. The Principle and the Method of the Hegelian Dialectic by E. B. McGilvary, Parts i, ii., 1897. The University of California, by Charles S. Greene, 1898. University Chronicle, Vol. I., Nos. 2 - 6, 1898. Utility of University Education, address by Hon. J. A. Waymire, 1898. *The University*

BRISBANE—Surveyor General. Map of Queensland, showing the principal stock routes and main roads, railway lines, telegraph lines and stations, stock trucking yards and Government artesian bores and tanks.—Compiled and published at the Survey Department, Brisbane, June, 1899. *The Surveyor General*

Geological Survey Office. Report on the Geology of the Country round Stanthorpe and Warwick, South Queensland, with especial reference to the Tin and Gold Fields and the Silver Deposits, by Sydney B. J. Skertchly. The Mesozoic Coal Measures of Stanwell and Associated Formations, by B. Dunstan, F.G.S. *The Office*

Royal Geographical Society of Australasia (Queensland Branch). Proceedings and Transactions, Vol. XIII., 1897-98. *The Society*

Royal Society. Proceedings, Vol. XIV., 1898-99. International Catalogue of Scientific Literature (Queensland Volume) by John Shirley, B.Sc., *Lond.*, 1899. ,,

BROOKVILLE—Indiana Academy of Science. Proceedings, 1897. *The Academy*

CAMBRIDGE (Mass.)—Museum of Comparative Zoölogy at Harvard College. Annual Report of the Curator for 1897-98. Bulletin, Vol. XXXII., No. 9, 1899. *The Museum*

DUBLIN—Royal Irish Academy. Transactions, Vol. XXXI., Part vii., 1899. *The Academy*

EDINBURGH—Royal Geographical Society. *The Scottish Geographical Magazine,* Vol. XV., No. 5, 1899. *The Society*

EDINBURGH—*continued*

Royal Physical Society. Proceedings, Vol. XIV., Part i., Session 1897-98. *The Society*

GEELONG—Gordon Technical College. *The Wombat,* Vol. IV., Nos. 1 – 3, 1898-99. *The College*

HOBART—Office of Mines. The Progress of the Mineral Industry of Tasmania for the Quarter ending 31 Dec. 1898, and 31 March 1899. *The Office*

Royal Society of Tasmania. Proceedings, March 27 and April 11, 1899. Historical and Geographical Section of the Royal Society of Tasmania, Rules and Regulations 1899. *The Society*

LONDON—Geological Society. Geological Literature added to the Library during 1898. Quarterly Journal, Vol. LV, Part ii., No. 218, 1899. „

Institution of Mechanical Engineers. Proceedings, No. 4, 1898. *The Institution*

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, Ser. 4, Vol. VIII., Nos. 1504 - 1507, 1509, 1899. *The Society*

Physical Society. Proceedings, Vol. XVI., Part v., 1899. List of Officers and Fellows, April 1, 1899. Science Abstracts, Vol. II., Part v., No. 17, 1899. „

Royal Agricultural Society of England. Journal, Third Series, Vol. X., Part ii., No. 38, 1899. „

Royal Astronomical Society. Monthly Notices, Vol. LIX., Nos. 6, 7, 1899. „

Royal Geographical Society. *The Geographical Journal,* Vol. XIII., No. 5, 1899. „

Royal Meteorological Society. Quarterly Journal, Vol. XXV., No. 110, 1899. Meteorological Record, Vol. XVIII., No. 72, 1898. „

Royal Microscopical Society. Journal, Part iii., No. 130, 1899. „

MELBOURNE—Mining Department. Annual Report of the Secretary for Mines (and Water Supply) for 1835 - 1891. Geological Survey of Victoria—Reports of Progress by R. Brough Smyth, F.G.S., Nos. 2, 3, 4, 5, 7, 1874-84. Gold Fields of Victoria—Reports of the Mining Registrars, Quarters ending 30 June, 30 Sep. and 31 Dec. 1884; 30 June, 30 Sept. and 31 Dec., 1885, 1886 – 1888; and Quarters ending 31 March, 30 Sept. and 31 Dec., 1889. Mineral Statistics of Victoria for the years 1874 - 1888. Reports of the Chief Inspector of Mines for the years 1874 – 1883. Reports of the Mining Surveyors and Registrars, 1881 – 1883, and Quarter ending 31 March, 1884. Reports and Statistics of the Mining Department Quarter ending 30 June, 1890. Special Reports:—On the treatment of tailings by the Lührig system, by J. Cosmo Newbery, 1892; On the Victorian Coal Fields (Nos. 2, 3, 4) by James Stirling, F.G.S., 1892 - 1895; On the Bendigo Gold Field (Nos. 1, 2) by E. J. Dunn, F.G.S., 1896. *The Department*

University. Calendar 1900. *The University*

Oxford—Radcliffe Library. Catalogue of Books added to the Library during 1898. *The Trustees*

Paris—Académie des Sciences de l'Institut de France. Comptes Rendus, Vol. cxxviii., Nos. 21 – 24, 1899. *The Academy*

Philadelphia—Academy of Natural Sciences. Proceedings, Parts ii, iii., 1898. ,,

American Entomological Society. Transactions, Vol. xxv., Nos. 2, 3, 4, 1898-9. *The Society*

American Philosophical Society. Proceedings, Vol. xxxvii., No. 158, 1898. ,,

Franklin Institute. Journal, Vol. cxlvi., Nos. 5, 6, 1898; Vol. cxlvii., Nos. 1 – 6, 1899. *The Institute*

Philadelphia Commercial Museum. The State of Nicaragua of the Greater Republic of Central America by Gustavo Niederlein, 1898. *The Museum*

Scranton, Pa.—Colliery Engineer Co. Mines and Metals, Vol xix., Nos. 3 – 5, 1898. *The Proprietors*

Sydney—Anthropological Society of Australasia. 'Science of Man,' New Series, Vol. i., No. 11, 1899; Vol. ii., Nos. 1 – 5, 1899. *The Society*

Australian Museum. Memoir iii., Part vii., 1899. Records, Vol. iii., No. 5, 1899. *The Trustees*

Botanic Gardens. Report on the Botanic Gardens and Domains, etc., for 1898. *The Director*

Department of Agriculture. *Agricultural Gazette,* Vol. ix., Part xii., 1899; Vol. x., Parts i., ii., iv., v., 1899. *The Department*

Department of Public Instruction. Results of Rain, River, and Evaporation Observations made in New South Wales during 1897 by H. C. Russell, B.A., C.M.G., F.R.S. New South Wales Educational Gazette, Vol. viii., Nos. 6 – 12, 1898-99. ,,

Engineering Association of N.S.W. Minutes of Proceedings, Vol. x., 1894-95. *The Association*

Government Printer. Annual Report on British New Guinea from 1 July, 1896 to 30 June 1898 with appendices. Report upon Sea Fisheries, 1898. Statutes of New South Wales (public and private) passed during the Session of 1898. *Government Printer*

Government Statistician. New South Wales Statistical Register for 1898 and previous years, Parts i. – vi. The Seven Colonies of Australasia 1897-8. Wealth and Progress of New South Wales 1897-8, Eleventh Issue, by T. A. Coghlan. *Government Statistician*

Health Department. Report of the Board of Health for 1897. Report on Leprosy in New South Wales for the year 1897. Report on Protective Inoculation against Tick Fever by Dr. F. Tidswell. *The Department*

Linnean Society of New South Wales. Abstract of Proceedings, Mar. 29, April 26, May 31, June 28, July 26, Aug. 30, 1899. Proceedings, Vol. xxiii., Parts iii., iv., Nos. 91, 92, 1898; Vol. xxiv., Part i., No. 93, 1899. *The Society*

ABSTRACT OF PROCEEDINGS, SEPTEMBER 6, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 6th, 1899.

The President, W. M. Hamlet, F.C.S., in the Chair.

Twenty-eight members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of twenty-two candidates were read for the third time, and of four for the second time.

The following gentlemen were duly elected ordinary members of the Society :—

Gummow, Frank M., C.E.; 82 Pitt-street.
Harper, H. W., Assoc. M. Inst. C.E.; 63 Pitt-street.
Henderson, S., M.A., Assoc. M. Inst. C.E.; 63 Pitt-street.

Australian Economic Association.

Black, R. J., J.P.; Chatswood.
Cameron, R. B.; 87 Pitt-street.
Cullen, Hon. W. P., M.A., LL.D., M.L.C.; "Trygoyd," Mosman.
Dallen, R. A.; Sydney University.
Duckworth, A.; 87 Pitt-street.
French, J. R.; Bank of New South Wales.
Garran, Hon. A., M.A., LL.D., M.L.C.; 'Roanoke,' Roslyn Avenue.
Garran, R. R., M.A.; Wigram Chambers, Phillip-street.
Gelling, B. R.; Wynyard-street.
Halloran, A., B.A., LL.B.; 20 Castlereagh-street.
Henderson, J.; City Bank of Sydney, Pitt-street.
Landau, F. W.; 79 King-street.
Pearse, William; Union Club.
Perkins, E. W.; 122 Pitt-street.
Petersen, T. T.; Mercantile Mutual Chambers, 118 Pitt-street.
Plummer, John; 'Northwood,' Lane Cove River.
Russell, F. A. A., M.A.; Denman Chambers, Phillip-street.
Teece, R., F.I.A., F.F.A.; 87 Pitt-street.
Walker, J. T.; 'Rosemont,' Ocean-street, Woollahra.

The Chairman announced that a request for the formation of an Anthropological and Ethnological Section of the Society had been received by the Council, and it was desired that members who were willing to attend the meetings and take an active part in the working of the Section, would send in their names to the Hon. Secretaries at an early date, so that the Council might be in a position to deal with the matter.

The following letter from Sir George Gabriel Stokes, Bart M.A. D.C.L., LL.D., F.R.S., was read:—

Lensfield Cottage, Cambridge,
15 July, 1899.

To the Secretary, Royal Society of New South Wales.

Dear Sir,—I write to thank, through you, the Royal Society at Sydney, for their kind congratulations, sent me by telegraph, on the occasion of the celebration of the Jubilee of my professorship. The telegram was duly received just at the time of the celebration.

Truly I have been rewarded, as I feel quite beyond my deserts, by the kind congratulations I have received from so many places, some of them far distant from England.

Will you kindly convey my thanks to the Royal Society?

I remain dear Sir, yours very faithfully,
G. G. STOKES.

THE FOLLOWING PAPERS WERE READ :—

1. "Sailingbirds are dependent on Wave-power," by L. Hargrave.

The author points out that sailing birds passed most of their time over the face or rising side of waves, and that by so doing they abstracted power from the moving water as the progress of the wave raised the air above it at a velocity proportional to its speed and slope. He used Prof. S. P. Langley's results to show that the uplift of a moderate swell was amply sufficient to support a plane and keep it moving at about thirty-five miles per hour in a calm.

2. "Some applications and developments of the Prismoidal Formula," by G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney.

Starting with a demonstration that the prismoidal formula was rigorously applicable to solids with parallel plane ends, whose mantles were ruled surfaces, the paper shewed how the volumes of series of longitudinally contiguous solids, with plane ends, and skew or warped—ruled quadric—surfaces on the other sides, could most conveniently be calculated. The determination of the volumes of solids whose longitudinal axes were plane-curves, or curves of double curvature, was also considered, and it was shewn that the prismoidal formula was also rigorously applicable to circularly warped solids, the centre of gravity in such changing its position linearly with the distance along the curved longitudinal axis. When the change of the centre of gravity of a right section is a non-linear function of the distance along the curved axis, or when the radius of curvature is not constant, the prismoidal formula is not rigorously applicable. The paper closed with suggestions as to the application of the formulæ.

EXHIBITS.

(*a*) Twenty-four mounted photographs, including a series of photographs of aboriginals representing two types, male and female, a few illustrative of camp life and corroborrees, and a special series illustrating some of the details of an Aboriginal Bora Ceremony. The photographs were taken and exhibited by Mr. Charles H. Kerry, and afterwards kindly presented to the Society. Following is a note by Mr. Kerry:—

"The photographs of an Aboriginal Bora Ceremony which I have forwarded to the Royal Society form part of a series secured by me in the Winter of 1898, locality Lower Macquarie River, N.S.W. I was indebted to Mr. F. W. Hill, the owner of the adjoining station "Quambone," for the privilege of being present on the occasion. Many of the natives were in his employ, and all were under heavy obligations to him for protection and kindness extending over many years. He was probably the only white man who could have both gained entrance to the Bora ground and introduced a friend. Enormous difficulties, however, had to be overcome to break down the prejudice against allowing a white man to see this secret ceremony, and even when successful in gaining admittance to the scene of operations we were frequently requested, sometimes ordered, to leave again.

"The actual Bora ground, situate about a quarter of a mile from the main camp, was a space one hundred yards long, and forty yards wide, surrounded by a close packed bush fence ten feet high. To permit of the cutting of the various figures and designs on the ground, all small bushes and grass had been removed, and in some parts the smaller trees. Two narrow circled passages, also protected by packed bushwood, were the entrance and exit. These were guarded day and night by warriors. The young members of the tribe who were to be initiated, arrived each in charge of an older warrior, who appeared to act as sponsor, the candidates having their heads shrouded in blankets. The proceedings commenced at the end of the enclosure where a couple of large figures —male and female—had been cut in the ground and terminated at the other end where a huge mound figure of a man had been made. Before and around these and the various other symbols and figures shown in the photographs, the warriors went through certain marching and posturing, which in many instances seemed to have no connection with the device round which they were grouped. Such information as I could glean from an interpreter present, also appeared to have very little bearing on the ceremony, and the final impression I gathered was that I was being wilfully misled, or else that the ceremony itself was almost meaningless. After leaving the Bora ground the novices were taken away into a remote part of the forest, where the removing of a front tooth, and the placing of tribal marks on each was to be effected."

(*b*) Mr. R. H. Mathews, L.S., exhibited some relics of the aborigines as follows :—

A block of stone cut from the wall of a cave in Howe's Valley, County of Hunter, containing the imprint of a hand, done in splashwork or stencil, with white paint.

Several stone knives found on digging into the floor of a cave or rock shelter on the Hawkesbury River, about a mile and a half below Wiseman's Ferry.

Part of a skull of an aboriginal native found in the same cave. The flat surface of the teeth shewed wear by the life-long habit of chewing.

A stone axe found on a tributary of the Namoi River above Narrabri.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*.)

Cambridge—Cambridge Philosophical Society. Proceedings, Vol. x., Part ii., 1899. Transactions, Vol. xvii., Part iii., 1899. *The Society*

Cambridge University Library. Report of the Library Syndicate for the year ending December 31, 1898. *The University*

Chicago—Field Columbian Museum. Anthropological Series, Vol. ii., No. 3, Pub. 28, 1898. Report Series, Vol. i., No. 4, Pub. 29, 1898. *The Museum*

University of Chicago Press. Astrophysical Journal, Vol. ix., Nos. 4, 5, 1899. Journal of Geology, Vol. vi., No. 8, 1898 ; Vol. vii., Nos. 1 - 3, 1899. *The University*

Des Moines—Iowa Geological Survey. Annual Report, Vol. viii., 1897. *The Survey*

Dublin—Royal Dublin Society. Scientific Proceedings, (N.S.) Vol. viii., Part vi., 1898. Scientific Transactions, (Ser. 2) Vol. vi., Nos. 14 - 16 ; Vol. vii , No. 1, 1898. *The Society*

Royal Irish Academy. Proceedings, (Third Series) Vol. v., No. 2, 1899. *The Academy*

Easton, Pa.—American Chemical Society. Journal, Vol. xxi., No. 5, 1899. *The Society*

Edinburgh—Royal Scottish Geographical Society. *The Scottish Geographical Magazine*, Vol. xv., Nos. 6, 7, 1899. ,,

University. Calendar, 1899 - 1900. *The University*

Fort Monroe, Va.—U. S. Artillery School. Journal, Vol. xi., No. 1, Whole No. 36, 1899. *The School*

Glasgow—University. Calendar, 1899 - 1900. *The University*

Kew—Royal Gardens. Hooker's Icones Plantarum, Vol. vii., Part i., 1899. *The Trustees*

London—Anthropological Institute of Great Britain and Ireland. Journal, New Series, Vol. i., Nos. 3, 4, 1899. *The Institute*

Imperial Institute. Journal, Vol. v., Nos. 53 - 55, 1899. ,,

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, 4 Ser., Vol. viii., Nos. 1510 - 1513 ; Vol. ix., 1514 - 1516, 1899 *The Society*

Physical Society of London. Proceedings, Vol. xvi., Part vi., 1899. Science Abstracts, Vol. ii., Parts vi., vii., Nos. 18, 19, 1899. ,,

London—*continued.*

Royal Astronomical Society. Monthly Notices, Vol. LIX., No. 8, 1899. *The Society*

Royal Geographical Society. *The Geographical Journal,* Vol. XIII., No. 6, 1899; Vol. XIV., No. 1, 1899. ”

Royal Society. Proceedings, Vol. LV., No. 335, 1894. Philosophical Transactions, Vol. CLXXXVIII. B; Vol. CLXXXIX. A and B, 1897; Vol. CXC. A and B; Vol. CXCI. A, 1897-8. List of Fellows, Nov. 30, 1898. ”

Society of Arts. Journal, Vol. XLVII., Nos. 2422 – 2434, 1899. ”

The Electrical Engineer, N.S., Vol. XXIII., Nos. 16 – 26 1899; Vol. XXIV., Nos. 1, 2, 1899. *The Publisher*

Zoological Society of London. Proceedings, Part i., 1899. *The Society*

Madison—Wisconsin Geological and Natural History Survey. Bulletin, No. 1—Economic Series No. 1, 1898; No. 2—Scientific Series No. 1, 1898. *The Survey*

Manchester—Conchological Society of Great Britain and Ireland. Journal of Conchology, Vol, IX., No. 7, 1899. *The Society*

Manchester Geological Society. Transactions, Vol. XXVI., Parts i. – iii., Session 1898-99. ”

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. XLIII., Part ii., 1898-99. ”

Scranton—Colliery Engineer Co. Mines and Minerals, Vol. XIX., Nos. 6 – 11, 1899. *The Colliery Engineer Co.*

New York—American Geographical Society. Bulletin, Vol. XXX., Nos. 4, 5, 1898; Vol. XXXI., Nos. 1, 2, 1899. *The Society*

American Museum of Natural History. Bulletin, Vol. X., 1898; Vol. XI., Part i., 1898. *The Museum*

New York Academy of Sciences. Annals, Vol. X., 1898; Vol. XI., Parts i., ii., 1898. *The Academy*

School of Mines, Columbia College. The School of Mines Quarterly, Vol. XX, Nos. 1 – 3, 1898-9. *The School*

Washington—Department of Agriculture. Division of Biological Survey—Bulletin, Nos. 9, 10, 11, 1898; North American Fauna, No. 14, 1899. Division of Statistics—New Series, Report No. 156; Crop Circular for Nov. 1898, and May 1899. Division of Vegetable Physiology and Pathology—Farmers' Bulletin, No. 68, 1898; No. 91, 1899; Circular No. 17, Report No. 59, 1899. Monthly Weather Bureau, Vol. XXVI., Aug. to Dec. and Annual Summary 1898; Vol. XXVII., Nos. 1 – 4, 1899. Preliminary Report of the Secretary of Agriculture, 1898. *The Department*

Navy Department—Office of Naval Intelligence. Battles and Capitulation of Santiago de Cuba by Lieut. José Müller y Tejeiro [War Notes No. 1]. Comments of Rear Admiral Plüddemann, German Navy on the main features of the war with Spain, [War Notes No. 2]. Effect of the gun fire of the United States Vessels in the Battle of Manila Bay (May 1, 1898) by Lieut. J. Ellicott, U.S.N. Sketches of the Spanish-American War by Commander J. [War Notes, Nos. 3 and 4]. Views of Admiral Cervera regarding the Spanish Navy in the late War 1898. *The Department*

ABSTRACT OF PROCEEDINGS, OCTOBER 4, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 4th, 1899.

Professor T. W. E. David, B.A., F.G.S., Vice-President, in the Chair.

Forty-three members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of four candidates were read for the third time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

De Coque, John Vincent; Department of Public Works.
Rae, J. Livington Campbell; Balmain.
Schmidlin, F.; Elizabeth-street.
Woolnough, W. George, B.Sc.; University of Sydney.

The Chairman announced at the last meeting of the Society that a request for the formation of an Anthropological and Ethnological Section had been received by the Council. In order that the Council might be in a position to deal with the matter it was requested that every member of the Society who was willing to attend the meetings and take an active part in the work of such a section, whether he had signed the requisition or not, would send in his name to the Hon. Secretaries. This request was made last meeting, but so far but one response had been received in reply.

He also stated that the Abstract for October would contain the following alterations to the Rules which are proposed by the Council with a view to enabling nominations to that body by members of the Society to be more effectually submitted to the vote of the Society. These proposed alterations will be finally submitted at the next General Monthly Meeting (November 1st):

That Rule III. be amended so as to read as follows :—

III. The other Officers of the Society shall consist of the President, who shall hold office for not more than one year continuously, but shall be eligible for re-election after the lapse of one year ; four Vice-Presidents, a Treasurer and two Secretaries, who, with ten other members, shall constitute the Council for the management of the affairs of the Society.

That the last clause of Rule V., be repealed ; and that the following stand in lieu thereof :—

Such list shall be suspended in the Society's Rooms at least one calendar month before the day appointed for the Annual General Meeting. Any member of the Society not disqualified by Rules XIII., XIV., or XIVA., and not included in such list may be nominated for the position of President, Vice-President, Treasurer, Secretary, or Member of the Council, provided that his candidature shall have been notified to the Honorary Secretary or Secretaries under the hands of two qualified voters—such notification being countersigned by the nominee—at least fourteen days before the day appointed for the Annual General Meeting.

A complete list showing the names of those recommended for election by the Council, and those nominated as in the last preceding clause, shall be sent to each Member of the Society, at least seven days before the day appointed for the Annual General Meeting.

That Rule VA. be repealed.

That Rule VI. be amended as follows :—In lieu of the first paragraph of the above Rule, read :—

The balloting list for the election of Officers and Members of Council shall contain a list of the names of those recommended by the Council and also of those otherwise nominated as provided for in Rule V. Heading the former, the words " Recommended by Council " shall be inserted, and opposite the latter the names of the nominators.

THE FOLLOWING PAPERS WERE READ:—

1. "Current Papers, No. 4," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

This paper began by calling attention to the fact that during the years 1896 and 1897 the prevalent winds over Australia and the Indian Ocean were north-west, and that as a result, comparatively few current papers were received, because the wind forced the bottles, carrying current papers, towards the south and in this way prevented them from resting in the Australian Bight, the great dumping ground for bottles. It was also shewn that during the past year north-west winds had been few and light, while southerly winds had been frequent, and as a consequence, current papers had been frequently received. On many days they came in pairs, and on one day three current papers had been seen, which is the maximum for one day, and during the past year 105 had been received. Referring to the drift of the disabled steamer *Perthshire*, it was shewn that the direction the steamer took was just that which the author had found to be the course of bottle-papers, and that although the *Perthshire* was driven by many winds, it would appear that the final result did not produce any deviation from the drift-line of that part of Tasman Sea. Reference was made to the unusual number of breaks in propeller shafts, and to the greater speed of current papers and the great number of violent storms which the author thought all pointed to unusual energy in the sea and atmosphere, which may have caused the unusual strains on propeller shafts.

2. "Note on the occurrence of Glaciated Pebbles in the Permo-Carboniferous Coal-field near Lochinvar, N. S. Wales," by Professor T. W. E. DAVID, B.A., F G.S.

Strong evidence of glacial action was observed in this part of the Permo-Carboniferous coal-field of N. S. Wales, by the late Government Geologist, Mr. C. S. Wilkinson, over sixteen years ago. In 1885, Mr. R. D. Oldham, Assoc. R.S.M., of the Geological Survey of India, discovered a faintly scratched and slightly polished pebble in the neighbourhood of Branxton near Greta. Absolutely conclusive evidence, however, of ice-action in this neighbourhood was not forthcoming until the beginning of this year, when Mr. W. G. Woolnough, B.Sc. Demonstrator in Geology at Sydney University, discovered a beautifully striated, polished, and facetted pebble in the Upper Marine Beds of the Permo-Carboniferous system in a railway cutting near Branxton Railway Station. A few days later a number of glaciated pebbles were discovered by myself in company with Mr. O. Trickett and Mr. E. C. Andrews, B.A., of the Geological Survey of N.S. Wales, and Mr. W. G. Woolnough.

These glaciated pebbles occur on a geological horizon over 1000 feet below the level of the Greta Coal Seams, whereas the horizons, where Mr. Woolnough and Mr. Oldham discovered their glacial pebbles, are from 1,500 to about 2,000 feet above the level of the Greta Coal Seams. These glacial beds at Lochinvar are at the very base of the Permo-Carboniferous System, and in general appearance closely resemble the Bacchus Marsh Glacial beds of Victoria, a locality where there is evidence of ice action on a grand scale over a wide area. These last belong probably to about the same geological age as the beds near Lochinvar. The height of the glacial beds at Lochinvar is about 200 feet above the sea, and the thickness of the beds probably not less than 200 feet. The pebbles were probably transported by floating ice. Those at Lochinvar were carried to their present resting place before the Greta Coal-seams were formed, and those at Branxton some time subsequent to the formation of the Greta Coal, in either case at times when this part of the Hunter Coal-field was submerged under the sea, as marine shells of Permo-Carboniferous age occur immediately above the glacial beds.

EXHIBITS.

(*a*) Models of ruled surfaces, and of solids whose bounding surfaces are ruled, by G. H. KNIBBS, F.R.A.S., Lecturer in Surveying, University of Sydney.

(*b*) First of the photographic charts from the Paris Observatory by H. C. Russell, B.A., C.M.G., F.R.S.

(*c*) Examples of the Ives natural-colour photographs by Mr. Mark Blow.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*).

Aachen—Meteorologische Station I. Ordnung. Ergebnisse der Meteorologischen Beobachtungen. Jahrgang iii., 1897. *The Director*

Agram (Zagreb)—Société Archéologique Croate. Vjesnik hrvatskoja Arkeoloskoga Drustva, (N.S.) Godina iii., 1898. Vjestnik kr. hrvatsko-slavonsko-Dalmatinskog, Zemaljskog Arkiva, Godina i., Svezak 1 – 3, 1899. *The Society*

Berlin—Gesellschaft für Erdkunde. Verhandlungen, Band xxv., Nos. 5 – 10, 1898; Band xxvi., No. 1, 1899. Zeitschrift, Band xxxiii., Nos. 3 - 5, 1898. ,,

Königlich preussische Akademie der Wissenschaften. Sitzungsberichte, Nos. 40 - 54, 1898; Nos. 1 – 38, 1899. *The Academy*

Königlich preussische Meteorologische Instituts. Bericht über die Thätigkeit im Jahre, 1898. Ergebnisse der Beobachtungen an den Stationen II. und III. Ordnung im Jahre, 1894, Heft 3; 1898, Heft 1, 2. *The Institute*

Königlich preussische Geodästische Institutes. Bestimmungen von Azimuten in Harzgebiete, 1887 – 1891. Beiträge zur Theorie des Reversionspendels von F. R. Helmert, 1898. Beiträge zur Berechnung von Lotabweichungssystemen von Pröf. Dr. L. Krüger, 1898. Die Polhöhe von Potsdam, Heft 1, 1898. Jahresbericht des Direktors, April 1897, bis April 1898. ,,

Bologna—R. Accademia delle Scienze dell' Istituto di Bologna. Memorie, Serie V., Tome vi., 1896-97. *The Academy*

Bonn—Naturhistorischer Verein der preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück. Verhandlungen, Jahrgang lv., Hälfte 1, 2, 1898. *The Society*

Niederrheinische Gesellschaft für Natur-und Heilkunde. Sitzungsberichte, Hältte 1, 2, 1898. ,,

Bremen — Naturwissenschaftlicher Verein. Abhandlungen, Band xvi., Heft 1, 1898. ,,

Meterologische Observatorium zu Bremen. Ergebnisse der Meteorologischen Beobachtungen, Jahrgang ix., 1898. *The Observatory*

Caen—Académie Nationale des Sciences, Arts et Belles-Lettres. Mémoires, 1897. *The Academy*

Carlsruhe—Grossherzoglich-Badische Polytechnische Schule. Programm 1898-99. Inaugural Dissertations (3). *The Director*

Cassell—Vereins für Naturkunde zu Kassel. Abhandlungen und Bericht xliii., 1897-8. *The Society*

Cracow—Académie des Sciences. Bulletin International, Nos. 8 – 10, 1898; Nos. 1 – 5, 1899. *The Academy*

Dresden—Königl. Mineralogisch-Geologisches und Prä-Historisches Museum. Mittheilungen, Heft 12 1897; Heft 14, 1898. *The Museum*

K. Statistische Bureau des Ministeriums des Innern. Zeitschrift, Jahrgang xliv., Heft 3, 4, 1898. *The Bureau*

Vereins für Erdkunde. Jahresbericht, xxvi., 1898. *The Society*

Elberfeld—Naturwissenschaftlicher Verein. Jahres-Berichte, Heft 9, 1899. „

Florence—Società Italiana di Antropologia, Etnologia &c. Archivio, Vol. xxviii., Fasc. 2, 3, 1898. „

Frankfurt a/m—Senckenbergische Naturforschende Gesellschaft. Abhandlungen, Band xxi., Heft 2, 3, 1898; Band xxiv., Heft 2, 3, 4, 1898. Bericht, 1898. Katalog der Reptilien-Sammlung im Museum, Teil 2, 1898. „

Freiberg—Berg-und Hüttenwesen im Königreiche Sachsen. Jahrbuch 1898. *The Academy*

Göttingen—Königliche Gesellschaft der Wissenschaften. Nachrichten, Geschäftliche Mittheilungen, Heft 2, 1898; Heft 1, 1899. Mathematisch-physikalische Klasse, Heft 4, 1898; Heft 1, 1899. *The Society*

Gratz—Naturwissenschaftliche Vereins für Steiermarck. Mittheilungen, Jahrgang, 1897, 1898. „

Halle, a.s.—Kaiserliche Leopoldino-Carolinische Akademie der Deutschen Naturforscher. Nova Acta, Bande lxx., lxxi., 1898. Leopoldina, Heft xxxiv., 1898. *The Academy*

Hamburg—Deutsche Seewarte. Jahres-Bericht (20th) für das Jahr 1897. Archiv, Band xxi., 1898. Deutsche Ueberseeische Meteorologische Beobachtungen, Heft 7. Ergebnisse der Meteorologischen Beobachtungen, Jahrgang xx., 1898. *The Observatory*

Geographische Gesellschaft in Hamburg. Mittheilungen, Band xv., Heft 1, 1899. *The Society*

Naturhistorische Museum. Mitteilungen, Jahrgang xv., 1897. *The Museum*

Heidelberg—Naturhistorisch-Medicinischer Verein. Verhandlungen, N.F. Band vi., Heft 1, 1898. *The Society*

Jena—Medicinisch-Naturwissenschaftliche Gesellschaft. Jenaische Zeitschrift für Naturwissenschaft, Band xxxii. (N.F. Band xxv.,) Heft 3, 4, 1898; Band xxxiii., (N.F. Band xxvi.,) Heft 1, 2, 1899. Namen-und Sachregister Bande i. – xxx. „

Leipzig—Königl. Sächsische Gesellschaft der Wissenschaften. Berichte über die Verhandlungen Mathematisch-physische Classe, Band l., Math. Theil 1 – 5, 1898; Band l., Naturw. Theil, 1898. „

Vereins für Erdkunde. Mitteilungen, 1898. Wissenschaftliche Veröffentlichungen, Band iii., Heft 3, (Schluss) 1899. „

Lille—Société Géologique du Nord. Annales xxvi., 1897. *The Society*

Marburg—University. Inaugural Dissertations (81) 1897-8. *The University*

Marseilles—Faculté des Sciences de Marseille. Annales, Tome ix., Fasc. 1 - 5. *The Faculty*

Institut Colonial de Marseille. Annales, Tome iii., 1896; Tome iv., 1897; Tome v., Fasc. 1, 1898. *The Institute*

Melbourne—*Australasian Journal of Pharmacy,* Vol. xiv., No. 163, 1899. *The Editor*

Broken Hill Proprietary Company, Ltd. Reports and Statements of Account for Half Years ending 30 Nov., 1898, and 31 May, 1899. *The Secretary*

Field Naturalists' Club of Victoria. *The Victorian Naturalist,* Vol. xvi., No. 3, 1899. *The Club*

Public Library, Museums, and National Gallery of Victoria. Letters from Victorian Pioneers, 1899 (2 copies) *The Trustees*

Royal Geographical Society of Australasia (Victoria). Transactions, Vol. xvi., 1898. *The Society*

Metz—Vereins für Erdkunde. Jahresbericht, xx., 1897-98. „

Milan—Reale Istituto Lombardo di Scienze e Lettere. Rendiconti, Serie 2, Vol. xxxi., 1898. *The Institute*

Società Italiana di Scienze Naturali. Atti, Vol. xxvii., Fasc. 4, 1898; Vol. xxxviii., Fasc. 1, 2, 1899. Memorie. Vol. vi., Fasc. 2, 1898. *The Society*

Mulhouse—Société Industrielle de Mulhouse. Bulletin, Aug. - Dec., 1898; Jan. - April, 1899. „

Munich—Bayerische Botanische Gesellschaft. Berichte, Band vi., 1899. „

Nantes—Société des Sciences Naturelles de l'Ouest de la France. Bulletin, Tome vii., Trimestre 4, 1897; Tome viii., Trimestre 1, 2, 1898. „

Naples—Società Reale di Napoli. Rendiconto dell' Accademia delle Scienze Fisiche e Matematiche, Ser. 3, Vol. iv., Fasc. 8 - 12, 1898; Vol. v., Fasc. 1 - 5, 1899. „

Zoological Station. Mittheilungen, Band xiii., Heft 4, 1899. *The Station*

Newcastle-upon-Tyne—North of England Institute of Mining and Mechanical Engineers. Transactions, Vol. xlviii., Parts ii., iii., iv., 1898-99. *The Institute*

Nuremberg—Naturhistorische Gesellschaft. Abhandlungen, Band xi., 1897. *The Society*

Paris—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome cxxviii., Nos. 25, 26; Tome cxxix., Nos. 1 - 8, 1899. *The Academy*

Ecole d' Anthropologie de Paris. Revue Mensuelle, Année vii., No. 11, 1897; Année viii., Nos. 10 - 12, 1898; Année ix., Nos. 1 - 7, 1899. *The Director*

Ecole Nationale des Mines de Paris. Statistique de l'Industrie Minérale et des appareils à vapeur en France et en Algérie pour l'année 1879. *Ministère des Travaux Publics*

PARIS—*continued.*

Ecole Polytechnique. Journal, Série II., Cahier 3, 4, 1897-8. *The School*

Feuille des Jeunes Naturalistes. Catalogue de la Bibliothèque Fasc. Nos. 25, 26, 1898-99. Catalogue Spécial, Nos. 1, 2, 1898-99. Revue Mensuelle, Tome XXIX., Nos. 337 - 346, 1898-99. *The Editor*

Muséum d'Histoire Naturelle. Bulletin, Année 1897, Nos. 7, 8; Année 1898, Nos. 1 - 6. *The Museum*

Observatoire de Paris. Rapport Annuel pour l'année 1898. *The Observatory*

Société d'Anthropologie de Paris. Bulletins, Série 4, Tome VIII., Fasc. 5, 6, 1897; Tome IX., Fasc. 1 - 3, 1898. Mémoires, Série 3, Tome II., Fasc. 2, 1898. *The Society*

Société de Biologie. Comptes Rendus, Série 10, Tome V., Nos. 31 - 42, 1898-99; Tome VI., Nos. 1 - 13; Série 11, Tome I., Nos. 14 - 26, 1899. ,,

Société Entomologique de France. Annales, Vol. LXV., Trimestre 1 - 4, 1896. Bulletin, Année 1896. ,,

Société Française de Minéralogie. Bulletin, Tome XXI., Nos. 6 - 8, 1898; Tome XXII., Nos. 1, 2, 1899. ,,

Société Française de Physique. Bulletin Bimensuel, Nos. 121 - 127, 129 - 136, 1898-99. Recueil des données numériques, Fasc. 2, 1899 (Optique par H. Dufet). Seances Année 1898, Fasc. 1, 3, 4. ,,

Société de Géographie. Bulletin, Sér. 7, Tome XIX., Trimestre 3, 4, 1898; Tome XX., Trimestre 1, 2, 1899. Comptes Rendus des Séances, Nos. 8, 9, 1898; Nos. 1 - 5, 1899. ,,

Société Géologique de France. Bulletin, Sér. 3, Tome XXV., Nos. 7 - 9, 1897; Tome XXVI., Nos. 1 - 4, 1898. ,,

Société Zoologique de France. Bulletin, Tome XXII., 1897. Mémoires, Tome X., 1897. ,,

PISA—Società Italiana di Fisica. Il Nuovo Cimento Periodico, Ser. 4, Tomo VIII., Sept. 1898; Tomo IX., Jan. 1899. ,,

Società Toscana di Scienze Naturali. Memorie, Vol. XVI., 1898. Processi Verbali, Vol. XI., pp. 57 - 158, 1898-9. ,,

ROME—Accademia Pontificia de' Nuovi Lincei. Atti, Anno LII., Sessione 1, 2, 1898-9. *The Academy*

Ministero dei Lavori Pubblici. Giornale del Genio Civile, Anno XXXVI., Fasc. 6 - 12, 1898; Anno XXXVII., Fasc. 1 - 4, 1899. *Minister for Public Instruction, Rome*

Reale Accademia dei Lincei. Annuario, 1899. Rendiconti, Serie Quinta, Vol. VII., Semestre 2, Fasc. 8 - 12, 1898; Vol. VIII., Semestre 1, Fasc. 1 - 12, Semestre 2, Fasc. 1 - 3, 1899. *The Academy*

SYDNEY—Anthropological Society of Australasia. *Science of Man*, N.S., Vol. II., Nos. 6, 7, 1899. *The Society*

Australasian Association for the Advancement of Science. Report of the Seventh Meeting held at Sydney 1898. *The Association*

Australian Museum. Annual Report (54th) of the Trustees for the year 1898. Catalogue No. 17, 1899. Memoir III., Parts viii., ix., 1899. *The Trustees*

ABSTRACT OF PROCEEDINGS, NOVEMBER 1, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 1st, 1899.

The President, W. M. HAMLET, F.C.S., F.I.C., in the Chair.

Forty members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the second time, and of one for the first time.

The President for the third time requested that those members who desired the formation of an Anthropological and Ethnological Section and who were willing to attend the meetings and take an active part in the work of such a Section, would send in their names to the Hon. Secretaries.

He also announced that Prof. Liversidge had kindly promised to deliver a lecture on "Liquid Air," to the members of the Royal Society, to take place at the University; if possible, on the 8th instant, but that was dependent on the satisfactory repair of the Compressive Engine. Due notice would however be given.

The following alterations of the rules were passed at the last meeting of the Society (November 1st, 1899), and will be submitted for confirmation at the next Annual General Meeting. Members are requested to accept this as an official notice of the alterations proposed to be confirmed. Rule III. was amended to read as follows:—

III. The other Officers of the Society shall consist of the President, who shall hold office for not more than one year continuously, but shall be eligible for re-election after the lapse of one year; four Vice-Presidents, an Honorary Treasurer, and two Honorary Secretaries, who, with ten other members, shall constitute the Council for the management of the affairs of the Society.

The last clause of Rule V., was repealed; and the following substituted in lieu thereof:—

Such list shall be exhibited in the Society's Rooms at least one calendar month before the day appointed for the Annual General Meeting. Any member of the Society not disqualified by Rules XIII., XIV., or XIVA., may be nominated for the position of President, Vice-President, Honorary Treasurer, Honorary Secretary, or Member of the Council, provided that his candidature shall have been notified to the Honorary Secretary or Secretaries under the hands of two qualified voters—such notification being countersigned by the nominee—at least fourteen days before the day appointed for the Annual General Meeting.

A complete list showing the names of those recommended for election by the Council, and those nominated as in the last preceding clause, shall be sent to each member of the Society, at least seven days before the day appointed for the Annual General Meeting.

Rule VA. was repealed.

Rule VI. was amended as follows:—In lieu of the first paragraph of the above Rule, read :—

The balloting list for the election of Officers and Members of Council shall contain a list of the names of those recommended by the Council and also of those otherwise nominated as provided for in Rule V. Heading the former, the words "Recommended by Council" shall be inserted, and opposite the latter the names of the nominators.

It was stated that if possible, the rules as amended would be put into operation at the next Annual General Meeting.

Mr. RUSSELL read a letter received from Professor Pickering of the Harvard Observatory, U.S.A., and gave some information with regard to the expected stream of meteors on the 15th inst.

Professor ANDERSON STUART, M.D., gave a demonstration on the formation of the retina of the ox's eye.

EXHIBITS.

Mr. GUTHRIE and Mr. DENSON showed preparations of micro-organisms occurring in milk and other dairy products, also some preparations of pathogenic organisms.

Mr. R. T. BAKER, F.L.S., exhibited specimens of timber of a new *Casuarina* recently described by him. It is known throughout its distribution—from the Darling River to Main Dividing Range—as "Belah." The timber is pale coloured, very hard and much resembles Hornbeam of Europe in appearance and texture.

Mr. H. G. SMITH, F.C.S., exhibited a remarkable Eucalyptus oil. Owing to the large quantity of eudesmol present, this oil solidified shortly after being obtained from the still. Eudesmol is the solid camphor of Eucalyptus oil.

He also exhibited Graptolites (*Diplograpsus* sp.) in slates, obtained four miles from Cadia, N. S. Wales. These graptolites were found by Mr. R. H. Cambage, and the locality recorded is only one hundred and fifty miles of Sydney.

Dr. F. H. QUAIFE showed specimens of analysing crystals. These act like tourmalines, that is, let a ray vibrating in one of their axes pass, and check all the others proportionally more as their azimuths approach the perpendicular to the first ray. Hence they shew white or partial light or black, without an analysing prism. A quartz of proper thickness causes varied colours to appear in the crystals, according to their thickness, when placed behind them. Notable specimens are citric acid, boracic acid, herapathite or iodosulphate of quinine, platino-cyanide of magnesium, etc., etc. Several of these were shown.

Mr. GRIMSHAW exhibited a large collection of fulgurites ranging from $\frac{1}{16}'' - 1\frac{1}{2}''$ in diameter, found on the sand hills at Kensington.

Exhibits were shewn by Mr. HAMLET—a collection of photographs of the human stomach in cases of poisoning—and also by Prof. LIVERSIDGE.

The meeting was then adjourned to the first Wednesday in December, and an informal Conversazione was held.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*)

ABERDEEN—University. Minutes of the General Council, Vol. I., Meetings 1 - 74, 1860 - 1897. *The University*

AGRAM—Direction des Archives des Royaumes Croatie, Slavonie et Dalmatie. Vjestnik kr. Hrvatsko-Slavonsko-Dalmatinskog Zemaljskog Arkiva, Godina I., Svezak 4, 1899. *The Director*

ALBANY N.Y.—University of the State of New York. Annual Report (49th) of the Regents New York State Museum, Vol. II., 1895. State Library Bulletin, Legislation No. 10, 1899. *The University*

AMSTERDAM—Nederlandsche Maatschappij ter bevordering van Nijverheid. Tijdschrift, Nieuve Reeks, Deel II., Nov. Dec., 1898; Deel III., Jan. - Mar., June - Sept., 1899. *The Association*

ANNAPOLIS, Md.—U.S. Naval Institute. Proceedings, Vol. XXV., No. 2, Whole No. 90, 1899. *The Institute*

EDINBURGH—Edinburgh Geological Society. Transactions, Vol. VII., Part iv., 1899. *The Society*

Royal Scottish Geographical Society. *The Scottish Geographical Magazine,* Vol XV., Nos. 8, 9, 1899. „

GLASGOW—University. A Roll of the Graduates of the University of Glasgow, from 31 Dec. 1727 to 31 Dec. 1897. With short biographical Notes compiled by W. Innes Addison, 1898. *The University*

LONDON—British Museum (Natural History). A Hand-List of the genera and species of Birds [Nomenclator avium tum fossilium tum viventium] by R. Bowdler Sharpe, LL.D. Vol. I., 1899. List of the genera and species of Blastoidea, 1899. *The Museum*

Geological Society. Quarterly Journal, Vol. LV., Part iii., No. 219, 1899. *The Society*

Institute of Chemistry of Great Britain and Ireland. Regulations for admission to Membership and Register of Fellows &c., 1899 - 1900. *The Institute*

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXXXVI., Part ii., 1898-99. *The Institution*

Institution of Mechanical Engineers. Proceedings, No. 1, 1899. „

Iron and Steel Institute. Journal, Vol. LV., No. 1, 1899. Rules and List of Members, 1899. *The Institute*

Physical Society. Science Abstracts, Vol. II., Parts viii., ix., Nos. 20, 21, 1899, *The Society*

Royal Astronomical Society. Monthly Notices, Vol. LIX., June 1899. „

Royal Geographical Society. The Geographical Journal, Vol. XIV., Nos. 2, 3, 1899. „

Royal Microscopical Society. Journal, Part iv., No. 131, August 1899. „

Royal Society. The Record of the Royal Society, No. 1, 1897. „

Royal Society of Literature. Transactions, Series 2, Vol. XX., Part iv., 1899. Report and List of Fellows, 1899. „

Sanitary Institute. Journal, Vol. XX., Part ii., 1899. *The Institute*

ABSTRACT OF PROCEEDINGS, DECEMBER 6, 1899.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 6th, 1899.

The President, W. M. Hamlet, F.C.S., F.I.C., in the Chair.

Thirty-four members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the third time, of one for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

McTaggart, J. N. Campbell, Bachelor of Engineering (*Syd.*), 16 Lugar Street, Waverley.

Smith, R. G., M. Sc. *(Dur.)*, B. Sc. *(Edin.)*, Macleay Bacteriologist; Linnean Society's House, Elizabeth Bay.

THE FOLLOWING PAPERS WERE READ:—

1. "On the Darwinias of Port Jackson and their Essential Oils," By R. T. Baker, F.L.S., and H. G. Smith, F.C.S., Technological Museum, Sydney.

The authors show that one of the species of the genus—the shrub, botanically known as *Darwinia fascicularis*, A. Rudge—which occurs plentifully on the sandstone formation around Port Jackson, is a plant of great commercial importance in regard to its essential oil. This plant belongs to the natural order Myrtaceæ, a genus so prolific in oil yielding species. The oil consists principally of the important ester geranyl acetate, the least amount of this constituent being 56·7 per cent. and the greatest 65·1 per cent., obtained from the oil distilled in November. Besides this ester 13·11% of free alcohol was determined, calculated as geraniol. The average yield of oil determined on several distillations from material obtained in March, September, October and November was 0·318 per cent. It was shown that by careful clipping on cultivated plants a yield of oil should be obtainable of not less than 0·5 per cent. The oil is obtained from the leaves of the plant, these are, however, very small. The colour of the crude oil is reddish-brown. The specific gravity was ·9154 at 19° C., the rotation in 100 mm. tube after removing the colour was + 1–2°, it was not soluble in 70 per cent. alcohol, but was so in 90 per cent. On distillation only 5 per cent. came over below 222°, showing an absence of terpenes, cineol, and other constituents having a low boiling point, between 222° and 240°, 64 per cent. distilled. The saponification was readily carried out in the cold, using semi-normal alcoholic potash. The alcohol distilled at 228 - 230° under atmospheric pressure formed a solid compound with calcium chloride, formed citral on oxidation, (proved by its odour and the formation by Doebner's reaction of the alcyl-β-naphtocinchoninic acid melting 197 – 198°) and had a fine rose odour, had no rotation, was soluble in 55 per cent. alcohol to a clear solution. The acid was principally acetic acid, but contained a minute quantity of a higher acid. Geraniol is the principal constituent of the liquid portion of rose oil, and is found in Geranium oil obtained from *Pelargonium sp.*, also in the so called geranium oil obtained from the grass *Andropogon sp.* It has been also found in a few other plants. The essential oil from *D. taxifolia* was shown to differ considerably in its properties and constituents from *D. fascicularis*; in comparison it has apparently little commercial value.

2. "On N. S. Wales Copper Ores containing Iodine," by ARTHUR DIESELDORFF, M.E. (Communicated by A. J. BENSUSAN, Assoc. R.S.M., F.C.S.)

The author (who was on a visit to N. S. Wales a few years ago) was interested in the discovery of iodine in a sample of cuprite from Cobar by Dr. W. Autenrieth of the University of Freiberg, Baden. He made further investigations himself as shewn by the paper, resulting in his proving the presence of iodine in several different samples sent to him from the colony. He points out that the subject is not of commercial interest, the iodine being present in such small percentages, but he thinks should copper ores be found with only 0·1 per cent. of iodine, it might be profitable to extract the same by sublimation. The value of the iodine in a ton giving 0·1 per cent., would be 30/-, and he estimates the cost of extraction at 3/-. The total value, however, of the world's production of iodine in 1896 was only £350,000.

3. "Orbit Elements Comet I. 1899 (Swift)," by C. J. Merfield, F.R.A.S.

This paper contains the results of an investigation of the orbit of the comet. In the prefatory remarks the author directs attention to several interesting physical aspects of this apparition. During 1899 May, the comet was seen with a double nucleus, the observed distance between the components increasing to some extent during an interval of a few days; part of this recession from one another may have been due to an actual separation of the nuclei, but the author has not examined the question critically. Photographs of great value were taken at the Lick Observatory, California; these show some interesting changes in the appearance of coma and tail of the comet, that will be of interest to those who work in this department of astronomy. The orbit elements have been deduced from the observations taken at most of the leading observatories. Sixteen equations of condition have been employed in finding the corrections to the assumed parabolic elements. The result of the investigation seems to indicate that the geometrical figure described by this comet is an hyperbola. Firstly, it has been taken for granted that no correction is necessary to the eccentricity unity of the assumed elements, thus another set of parabolic elements is obtained, and it is shewn that these are more satisfactory, the sum of the squares of the residuals reducing from $10^4 \times 15{\cdot}5$ to $10^4 \times 04{\cdot}1$. Secondly, in this case the author has made no assumption as to the form of the orbit, and finds that a positive correction is required to the assumed eccentricity, viz., unity, indicating therefore hyperbolic motion; the sum of the squares of the residuals being most satisfactory, and reduced to $10^4 \times 0{\cdot}01$. In his concluding remarks the author states, that the perturbations have been excluded from the calculation, as they will be of a low order, and should a definitive discussion of the orbit be undertaken, then the results deduced will not require material alteration.

4. "On the composition of N. S. Wales Labradorite and Topazes, with a comparison of methods for the estimation of Fluorine," by G. Harker, B. Sc. (Communicated by Professor A. Liversidge, M.A., LL D., F.R.S.)

The paper gives the composition and properties of a typical labradorite from New England, N. S. Wales, and also the composition including the water of constitution of two varieties of topazes found in N. S. Wales, one from the Mudgee the other from the New England district. The composition of the first is silica 31·87, alumina 56·71, fluorine 17·30, water on ignition ·25, water of constitution ·75; and of the second, silica 31·83, alumina 55·53, fluorine 16·11, water on ignition ·38, water of constitution 1·07, the mean of two analyses in each case. It describes also the results obtained for the percentage of fluorine in topaz by three different methods, viz., by fusing the topaz with alkaline carbonates alone (Wöhler), by liberating the fluorine as silicon tetra-fluoride and weighing as potassium silicon-fluoride (Liversidge), and by decomposing with alkaline carbonates and silica (Berzelius-Rose). The last method gave the best results, and very probably the whole of the fluorine is obtained by this method.

5. "Note on a remarkable increase of temperature after dark at Seven Oaks, Macleay River," by Hugh Charles Kiddle, F. R. Met. Soc.

During a moderate heat wave on 25, 26, and 27 November, the maximum thermometer recorded 90° to 91·8° at about 10 a.m.; then a sea breeze came in, and by midday the temperature fell to what it had been at 7·30 a.m., and continued to fall under the same influence till at 7 p.m. it stood at 75°. On the 27th shortly after 7 p.m., a thunderstorm which had been working up from the west for half an hour, reached us, but instead of the usually cool breeze which a thunderstorm brings, we experienced a blast as from a furnace. In a few minutes the temperature rose from 75° to 86°, and during the blast reached 95·5°, or three and a half degrees higher than it had been at the hottest part of the day. The phenomenon is the more remarkable when it is remembered that it occurred after dark. This hot wind came from W.N.W., and reached a force from fresh to strong. In the attached table will be seen the shade temperature readings at 8 a.m., dry and wet bulbs at 9 a.m., the daily shade maximum, and also the maximum reading in the sun's rays:—

Date.	Shade Temperature in Louvred Screen.				Maximum reading in Sun's rays.
	8 a.m.	9 a.m., Dry.	9 a.m., Wet.	9 a.m., Max.	
27	81°	83°	69°·4	92°	159°·8
28	84°	86°·8	72°·1	91°·8	153°
29	87°	87°·4	76°·4	95°·5	150°

The thermometers have all been tested at Kew. I may add that this observing station is situated on the Macleay River, approximately in Lat. 31° 2′ S., Long. 151° 3′ E., and is about seven miles in a direct line from the coast.

6. "Records of Rock Temperatures at Sydney Harbour Colliery Birthday Shaft, Balmain, Sydney," by J. L. C. Rae, E. F. Pittman, Assoc. R.S.M., and Professor T. W. E. David, B.A., F.G.S.

The deep sinking now being carried on at the Sydney Harbour Colliery, Balmain, with which one of the authors is actively associated, affords a very favourable opportunity of noting the nature and temperatures of the various rocks underlying the neighbourhood of Sydney, and this the authors are utilizing. The paper read deals with the temperatures noted to a depth of 1,450 feet, which was the depth reached in the shaft at the middle of November. The thermometers used were specially supplied by Professor Everett, F.R.S., Secretary of the British Association Committee on the subject of underground temperatures. The sinking of the Birthday Shaft had reached a depth of 600 feet before the thermometers were available, but since then, observations have been made at intervals of practically, 50 feet, and an opportunity will be got of recording temperatures at less depth than 600 feet, when the sinking of the Jubilee Shaft is gone on with. From 600 feet down to 1,100 feet two slow action thermometers were used, and the horizontal holes, which were drilled into the walls of the shaft for their reception, were put in a distance of 3 feet down to 950 feet, and 4 feet from that to the 1,100 feet level. Beginning at the 1,150 feet level two maximum thermometers were used, in addition to the slow-action instruments, and the practice has been to place one instrument of each type in each of the holes, which have been put in to a distance of 5 feet. The plugging in each case consisted of about six inches of greasy cotton waste, placed next to the thermometers, the remainder of the hole being filled up with plastic clay rammed into the hole. Every precaution was taken to ensure accuracy of results. If the mean annual temperature of Sydney be taken as 63° Fahr., the rate of increase is shown, by the observations made, to be at the rate of 1° Fahr. for every 90½ feet, which is fairly low, and may be taken as a favourable indication for the future ventilation of the mine. A remarkable increase of temperature was noted as the sinking passed from the Hawkesbury Sandstones into the Narrabeen Beds, the upper section of which consists of chocolate shales. These shales, which outcrop on the sea coast at Narrabeen some eight miles to the north of Manly, were struck in the shaft at a depth of 1,024 feet 9 inches, or at practically the same depth from the surface as in the Cremorne Bore, the exact difference being 59 feet 7½ inches, measured from mean low-tide level in Sydney harbour, the shaft being the deeper of the two. This is a very slight difference in three and a quarter miles, which is the distance from the shaft to the bore, the bearing being N. 67° 15′E. A section of the strata, already passed through in the sinking of the shaft, and a table, giving full particulars of the nature of the rocks in which the temperatures were observed, time allowed for heat generated by drilling to escape between completion of holes and insertion of thermometer, time thermometers were left in the holes, readings, corrections etc., were given along with the paper.

7. "Note on the Edible Earth from Fiji," by the Hon. B. G. Corney, M.D., Prof. David, B.A., F.G.S., and F. B. Guthrie, F.C.S.

The sample of edible earth, a soft, pale pink, clayey material, with occasional lumps of chalcedony was collected by Dr. Corney, near the northern coast of Vanua Levu. In addition to the chalcedony it contains numerous angular and rounded quartz crystals, from $\frac{1}{8}''$ to $\frac{1}{6}''$ in diameter, and small octahedral crystals of magnetite. The earth is probably formed by decomposition of a dacite tuff. Its analysis, by F. B. Guthrie, gave the following results:—

Moisture at 120° C...	2·45
Combined water	12·78
Silica	41·53
Alumina	35·09
Oxide of Iron, Fe_2O_3	7·66
	99·51

The oxide of iron can be dissolved out with hydrochloric acid. The silica, alumina and combined water are present in approximately the proportion required by the formula $Al_2O_3(SiO_2)_2(H_2O)_2$; the substance appears therefore, to be a silicate of that composition —probably kaolinite—with about 7·6 per cent. of uncombined ferric oxide as mechanical impurity.

EXHIBITS.

Mr. J. L. C. Rae exhibited portion of a pipe conducting water down Birthday Shaft, Balmain, from the "water ring," shewing the pipe incrusted with calcium and barium carbonates. The incrustations had formed in about two weeks.

Professor David exhibited a Phillips Maximum Thermometer, with copper case, for observing and recording rock temperatures. At the Balmain Shaft similar protecting cases of copper and glass are used, but the thermometers are Negretti and Zambra's maximum type, recommended by the Underground Temperature Committee of the British Association.

Samples of the "bursting" sandstone, portions of which burst away as if the stone were under great pressure, from Birthday Shaft, Balmain, were shewn by Messrs. J. L. C. Rae and T. Cater.

Specimens of edible earth from Fiji, illustrative of the paper on that subject, were exhibited by Prof. David.

Geological photographs illustrating the glacial nature of the Dwyka Beds, taken in the district of Priska, Cape Colony, by Messrs. Rogers and Schwartz, of the Geological Commission, Cape of Good Hope, were exhibited by Mr. George W. Card.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The names of the Donors are in *Italics.*)

Adelaide—Royal Geographical Society of Australasia, South Australian Branch. Proceedings, Vol. iii., 1888-9 to 1897-8. *The Society*

Royal Society of South Australia. Transactions, Vol. xxiii., Part i., 1899. Memoirs, Vol. i., Part i., 1899. ,,

Observatory. Meteorological Observations during 1896. *The Observatory*

Baltimore—Johns Hopkins University. American Chemical Journal, Vol. xx., Nos. 4 – 10, 1898 ; Vol. xxi., Nos. 1 – 5, 1899. American Journal of Mathematics, Vol. xx., Nos. 2 – 4, 1898 ; Vol. xxi., Nos. 1, 2, 1899. American Journal of Philology, Vol. xix., Nos. 1 – 4, 1898. Circulars, Vol. xviii., No. 141. 1899. Hospital Reports, Vol. vii., Nos. 1 – 4, 1898. Studies in Historical and Political Science, Vol. xvi., Nos. 5 – 12, 1898 ; Vol. xvii., Nos. 1 – 5, 1899. *The University*

Maryland Geological Survey Commission. Maryland Geological Survey, Vols. i., ii., 1897-1898. *The Commission*

Batavia—Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië. Natuurkundig Tijdschrift voor Nederlandsch-Indië, Deel lviii., Tiende Serie Deel ii., 1898. *The Society*

Directeur de l'Instruction Publique, des Cultes et de l'Industrie aux Indes Néerlandaises. Kort Verslag over de Aardbeving Te Ambon of—6 Januari 1898 door Dr. R. D. M. Verbeck 1899. *The Department*

Bergen—Bergens Museum. Aarbog for 1898 including Aarsberetning for 1898. An account of the Crustacea of Norway, Vol. ii., Isopoda, Parts xi. – xiv., 1898-9. *The Museum*

Berlin — Centralbureau der Internationalen Erdmessung. Bericht über den stand der Erforschung der breitenvariation am schlusse des Jahres 1898 von Th. Albrecht. Resultate aus den Polhöhenbestimmungen in Berlin ausgeführt in den Jahren 1891 und 1892 am universaltransit der Königl. Sternwarte von Dr. H. Battermann, 1899. *The Bureau*

Berlin—*continued.*

Gesellschaft für Erdkonde zu Berlin. Verhandlungen, Band xxvi., Nos. 2 – 4, 1899. Zeitschrift, Band xxxiii., No. 6, 1899. Siebenter Internationaler Geographen-Kongress Berlin 1899, Vorläufige Mittheilungen über Organization und Programm. *The Society*

Königlich Preussische Geodätisches Institut. Bestimmung der Intensität der Schwerkraft auf Fünf und Fünfzig Stationen von Hadersleben bis Koburg und in der Umgebung von Göttingen bearbeitet von L. Haasemann 1899. *The Institute*

Berne—Départment de l'Interieur de la Confédération Suisse Section des Travaux Publics. Tableaux graphiques des Observations hydrométriques suisses ainsi que des températures de l'air et des hauteurs pluviales pour l'année 1898. *The Department*

Boston, Mass.—American Academy of Arts and Sciences. Proceedings, Vol. xxxiv., Nos. 18 – 23, 1899. *The Academy*

Boston Society of Natural History. Memoirs, Vol. v., Nos. 4, 5, 1899. Proceedings, Vol. xxviii., Nos. 13 – 16, 1899. *The Society*

Bremen—Naturwissenschaftliche Verein zu Bremen. Abhandlungen, Band xvi., Heft 2, 1899. ,,

Brisbane—Geological Survey Office. Annual Progress Reports of the Geological Survey for the Years 1896.98, C.A. 8 – 1899. Reports on—A visit to the Palmer Gold Field, by R. L. Jack, F.G.S., Govt. Geologist, C.A. 2—1899; Mount Clifford and other Mines near Anakie, Central District, by B. Dunstan, C.A. 4—1898; Mount Morgan and other Mines in the Crocodile Gold Field with maps, R.L. Jack, F.G.S., C.A. 51—1898; The Delimitation of the Artesian Water Area North of Hughenden by A. Gibb Maitland, and note by R. L. Jack, F.G.S., Govt. Geologist, C.A. 123—1898; The Geology of Collaroy and Carmilla, near Broad Sound, with notes on the mining operations and mineral resources of the district, by B. Dunstan, F.G.S., C.A. 122—1898; The Geology of Rodd Peninsula, Port Curtis, by B. Dunstan, F.G.S., C.A. 34—1898. *The Survey*

Queensland Representative 'Greater Britain Exhibition.' The British Australasian and New Zealand Mail with Special Illustrated Supplement of the Queensland Court at the Greater Britain Exhibition 1899. *The Publisher*

Royal Geographical Society of Australasia (Queensland Branch). Proceedings and Transactions, Vol. xiv., 1898-9. Some critical notes on the Queensland Volume of the International Catalogue of Scientific Literature. *The Society*

Royal Society of Queensland. Proceedings, Vol. viii., Parts ii. – iv., 1890-91. ,,

Brussels—Société Royale Malacologique de Belgique. Annales, Tome xxxii., 1897. Bulletins des Séances, Tome xxxiv., 1899 pp. 33 – 96. ,,

Bucharest—Institutul Meteorologic al Roumăniei. Annalele Institutului Meteorologic al Romăniei, Tomul xii., xiii., Anul 1896-7. *The Institute*

Buenos Aires—Museo Nacional de Buenos Aires. Communicaciones, Tome i., Nos. 1, 2, 1898. *The Museum*

Instituto Geográfico Argentino. Boletin, Tomo xix., Núms 9 – 12, 1898; Tome xx., Núms 1 – 6, 1899. *The Institution*

Caen—Académie Nationale des Sciences, Arts et Belles-Lettres. Mémoires, 1898. *The Academy*

Calcutta—Asiatic Society of Bengal. Journal, Vol. lxvii., Part i., Nos. 2 - 4. Part ii., Nos. 1, 2 and Index, Part iii., Nos. 1, 2, 1898. Proceedings, Nos. 8 – 11, 1898; Nos. 1 – 3, 5 – 7, 1899. The Kaçmīraçabdāmrta a Kāçmīrī Grammar by G. A. Grierson, c.i.e., ph.d., i.c.s., Part ii., 1898. *The Society*

Geological Survey of India. General Report on the work carried out for the period from 1st April 1898 to 31st March 1899. Manual of the Geology of India, Economic Geology, Part i., Corundum by T. H. Holland, a.r.c.s., f.g.s., 1898. Memoirs, Vol. xxviiii., Part i. Memoirs, Palaeontologia Indica, Ser. 15, Vol. i., Part iii., 1897. *The Survey*

Cambridge (Mass.)—Museum of Comparative Zoölogy at Harvard College. Annual Report of the Assistant in Charge, 1898-9. Bulletin, Vol. xxxii., No. 10; Vol. xxxiii., Nos. 1, 2, 1899. *The Museum*

Cape Town—Department of Agriculture. Annual Report of the Geological Commission 1897. *The Department*

South African Philosophical Society. Transactions, Vol. x., Parts 2, 3, 1897-8. *The Society*

Chicago—Chicago Academy of Sciences. Annual Report (40th) for the year 1897. Bulletin of the Geological and Natural History Survey, No. 2, 1897. *The Academy*

Field Columbian Museum. Geological Series, Vol. i., Nos. 3, 4, 1899. Zoological Series, Vol. i., Nos. 11 – 15, 1899. *The Museum*

University of Chicago Press. Astrophysical Journal, Vol. x., Nos. 1, 2, 1899. Journal of Geology, Vol. vii., Nos. 4, 5, 1899. *The University*

Christiania—Université Royale de Norvége. Jahrbuch des Norwegischen Meteorologischen Instituts für 1896 and 1897. Universitets-Program for 2nd Semester 1897. „

Videnskabs-Selskabet i Christiania. Forhandlinger, 1897, Nos. 1 - 6, and Oversigt 1898; No. 1, 1899. Skrifter 1 Math-naturv. Klasse 1897, Nos. 1 – 12, 1898; Nos. 2, 3, 4, 6, 7, 1899. *The Society*

Coolgardie—Coolgardie Chamber of Mines. Gold Mining Statistics, April, May, June, August, 1899. Supplement to Government Gazette, 27 Oct., 1899. The Western Australian Goldfields Mining Record for 1898. *The Secretary*

Colombo—Royal Asiatic Society. Journal of the Ceylon Branch Vol. xv., No. 49, 1898. *The Society*

Copenhagen—Société Royale des Antiquaires du Nord. Mémoires, Nouvelle Série, 1898. „

Cordoba—Academia Nacional de Ciencias. Boletin, Tome xvi., Entrega 1, 1899. *The Academy*

Denver—Colorado Scientific Society. The Self-cooling Condenser by T. L. Wilkinson, 1899. 'The Sunset Trachyte' from near Sunset, Boulder County, Colorado, by Robert S. Breed, 1899. *The Society*

Dijon—Académie des Sciences, Arts et Belles-Lettres. Mémoires, Serie 4, Tome vi., Années 1897-98. *The Academy*

Dresden—K. Sächs. Statistische Bureau. Zeitschrift, Jahrgang xlv., Heft. 1, 2, and Supplement 1899. *The Bureau*

Easton, Pa.—American Chemical Society. Journal, Vol. xxi., Nos. 6 – 10, 1899. *The Society*

Edinburgh—Botanical Society Edinburgh. Transactions and Proceedings, Vol. xxi., Parts 1 – 3, 1896-98. ,,

Royal Scottish Geographical Society. The Scottish Geographical Magazine, Vol. xv., No. 10, 1899. ,,

Fort Monroe, Va.—U.S. Artillery School. Journal of the U.S. Artillery, Vol. xi., Nos. 2, 3, 1899. *The School*

Freiburg (Baden)—Naturforschende Gesellschaft. Berichte, Band xi., Heft. 1, 1899. *The Society*

Geelong—Gordon Technical College. *The Wombat,* Vol. iv., No. 4, 1899. *The College*

Giessen—Oberhessische Gesellschaft für Natur-und-Heilkunde. Bericht, Band xxxii., 1897-99. *The Society*

Halifax, N.S.—Nova Scotian Institute of Science. Proceedings and Transactions, Vol. ix., Part iv., Session 1987-8. *The Institute*

Hamburg—Geographische Gesellschaft. Mittheilungen, Band xv., Heft. 2, 1899. *The Society*

Hamilton, Ont.—Hamilton Association. Journal and Proceedings, Vol. xiv., Session 1897-8. *The Association*

Haarlem—Colonial Museum. Bulletin, Nos. 20, 21, 1899, Extra Bulletin 1896. Catalogus der Nederlandsche West-Indische Tentoonstelling te Haarlem 1899. *The Museum*

Musée Teyler. Archives, Ser. 2, Vol. vi., Partie ii., iii., 1898-9. ,,

Société Hollandaise des Sciences à Haarlem. Archives Néerlandaises des Sciences Exactes et Naturelles, Serie 2, Tome ii., Liv. 2 – 5; Tome iii., Liv. 1, 1899. *The Society*

Heidelberg—Naturhistorisch-Medicinische Vereins zu Heidelberg. Verhandlungen N.F. Band vi., Heft 2, 1899. ,,

Heligoland—Königliche Biologische Anstalt. Zur Kenntniss der Gottungen *Margelopsis* und *Nemopsis* von Dr. Clemens Hartlaub 1899. ,,

Hobart—Mining Department. Report of the Secretary for Mines for 1898-9. The Progress of the Mineral Industry of Tasmania for the Quarters ending 30 June and 30 Sep. 1899. Volunteer Gold Mining Co., Report of the Government Geologist on the Deep Shaft 1899. *The Department*

Royal Society of Tasmania. Abstract of the Proceedings, 1898. *The Society*

Honolulu—Bernice Pauahi Bishop Museum. Fauna Hawaiiensis, Vol. i., Parts i., ii., 1899. *The Museum*

Indianapolis—State of Indiana, Department of Geology and Natural Resources. Annual Report (22nd), W. S. Blatchley, State Geologist, 1897. *The Department*

Kingston—Institute of Jamaica. Journal, Vol. ii., No. 6, 1899. *The Institute*

Königsberg, I. Pr.—Physikalisch-ökonomische Gesellschaft. Schriften, Jahrgang xxxix., 1898. *The Society*

Lausanne—Société Vaudoise des Sciences Naturelles. Bulletin, 4 Ser., Vol. xxxiv., Nos. 128 – 131, 1898 „

Leipzig—K. Sächs. Gesellschaft der Wissenschaften zu Leipzig. Berichte Math-phys. Classe, Heft. 1 – 3, 1899. Jahresbericht der Fürstlick Jablonowski'chen Gesellschaft, Mar. 1899. „

Liége—Société Géologique de Belgique. Annales, Tome xxiv., Liv. 3; Tome xxv., Liv. 2; Tome xxvi., Liv. 1 - 3, 1897-9. „

Société Royale des Sciences de Liége. Mémoires, Série 3, Tome i., 1899. „

Lille—Société Geologique du Nord. Annales, Tome xxvii., 1898. „

London—Imperial Institute. Journal, Vol. v., Nos. 56 – 58, 1899. *The Institute*

Institution of Civil Engineers. Minutes of Proceedings, Vol. cxxxvii., Part iii., 1898-9. *The Institution*

Institution of Naval Architects. Transactions, Vol. xli., 1899. „

Linnean Society. Journal, Botany, Vol. xxxiv., Nos. 236 - 238, 1899. Zoology, Vol. xxvii., Nos. 173 – 175, 1899. *The Society*

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, Fourth Ser., Vol. ix., Nos. 1517 – 1530, 1899. „

Physical Society of London. Science Abstracts, Vol. ii., Part x., No. 22, 1899. „

Quekett Microscopical Club. Journal, Vol. vii., No. 44, 1899. *The Club*

Royal Agricultural Society of England. Journal, Ser. 3, Vol. x., Part iii., No. 39, 1899. *The Society*

Royal College of Surgeons of England. Calendar 1899. *The College*

Royal Colonial Institute. Proceedings, Vol. xxx., 1898-9. *The Institute*

Royal Geographical Society. The Geographical Journal, Vol. xiv., No. 4, 1899. *The Society*

Royal Meteorological Society. Quarterly Journal, Vol. xxv., No. 3, 1899. „

Royal Society. Proceedings, Vol. lxv., No. 419. Year Book of the Royal Society 1899. „

Royal United Service Institution. Journal, Vol. xliii., Nos. 254 – 259, 1899. *The Institution*

Sanitary Institute. Journal, Vol. xx., Part iii., 1899. *The Institute*

Society of Arts. Journal, Vol. xlvii., Nos. 2435 – 2438, 2440 – 2448, 1899. *The Society*

The Chemical News, Vol. lxxix., Nos. 2041 – 2066; Vol. lxxx., Nos. 2067 – 2082, 1899. *The Editor*

The Electrical Engineer, N.S., Vol. xxiv., Nos. 3 – 16 1899. „

Zoological Society of London. Proceedings, Parts ii., iii., 1899. Transactions, Vol. xv., Parts ii., iii., 1899. List of Fellows, May 31, 1899. *The Society*

Madras—Madras Government Museum. Bulletin, Vol. ii., No. 3, 1899. *The Museum*

Madras Observatory. Report for the year 1897-98, and on the Eclipse Expedition of January 1898. *The Observatory*

Manchester—Manchester Geological Society. Transactions, Vol. xxvi., Parts 4 – 8, 1898-9. *The Society*

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. xliii., Parts iii., iv., 1898-9. „

Melbourne—Australasian Journal of Pharmacy, Vol. xiv., Nos. 165 – 167, 1899. *The Publishers*

Field Naturalists' Club of Victoria. The Victorian Naturalist, Vol. xvi , Nos. 6, 7, 1899. *The Club*

Public Library, Museums, and National Gallery of Victoria. Report of the Trustees for 1898. *The Trustees*

Royal Geographical Society of Australasia (Victorian Branch). Transactions, Vol. xvii., 1899. *The Society*

Mexico—Instituto Geológico de Mexico. Boletin, Num 11, 1898. *The Institution*

Sociedad Cientifica "Antonio Alzate" Memorias y Revista, Tomo xi., Núms 9 – 12, 1897-98; Tomo xii., Núms 1 – 8, 1898-99. *The Society*

Mirfield—Yorkshire Geological and Polytechnic Society. Proceedings, N.S., Vol. xiii., Part iv., 1899. „

Mons—Société des Sciences, des Arts et des Lettres du Hainaut. Mémoires et Publications Serie 5, Tome x., 1898. „

Montevideo—Museo Nacional de Montevideo. Anales, Tomo ii., Fasc. 11, 1899; Tomo iii., Fasc. 10, 1898. *The Museum*

Montpellier—Académie des Sciences et Lettres de Montpellier. Mémoires de la Section des Sciences, 2nd Série, Tome ii , No. 5, 1898. *The Academy*

Montreal—Natural History Society of Montreal. Canadian Record of Science, Vol. vii., No. 8, 1898; Vol. viii., No. 1, 1899. *The Society*

Royal Society of Canada. Proceedings and Transactions, Second Series, Vol. iii., 1897. „

Moscow—Observatoire Météorologique de l'Université Impériale de Moscou. Observations made July – Aug., Oct., Dec , 1896; Jan., Feb., April – June, Aug., Oct., Nov., 1897, Jan. – June, Aug. – Nov., 1898. Pamphlets (2) 1896 – 1897. *The Observatory*

Société Impériale des Naturalistes de Moscou. Bulletin, Nouvelle Série, Tome xii., Nos. 1 – 4, 1898. Nouveaux Mémoires, Tome xv., Liv. 7, 1898; Tome xvi., Liv. 1, 1898. *The Society*

Mulhouse—Société Industrielle de Mulhouse. Bulletin, May – July, 1899. Programme des Prix, 31 May, 1899. „

Munich—Königlich Bayerische Akademie der Wissenschaften. Abhandlungen der Mathematisch-physikalischen Classe Band xix., Abth. 3, Band xx., Abth. 1, 1899. Pamphlets (2), Sitzungsberichte, Band xxvii., Heft 3, 1898; Band xxviii., Heft 1 – 4, 1898-9; Band xxix., Heft 1, 1899. *The Academy*

Nantes—Société des Sciences Naturelles de l'Ouest de la France. Bulletin, Tome viii., Trimestres 3, 4, 1898; Tome ix., Trimestres 1, 2, 1899. *The Society*

Naples—Società Reale di Napoli. Rendiconto dell'Accademia delle Scienze Fisiche e Matematiche, Ser. 3, Vol. v., Fasc. 6, 7, 1899. „

Neuchatel—Société des Sciences Naturelles de Neuchatel. Bulletin, Tome xxi. – xxv., 1893 – 1897. „

Newcastle-upon-Tyne—Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne. Natural History Transactions, Vol. xii., Part i., 1899. „

New Haven—Connecticut Academy of Arts and Sciences. Transactions, Vol. x., Part i., 1899. *The Academy*

New York—American Geographical Society. Bulletin, Vol. xxxi., No. 3, 1899. *The Society*

American Institute of Electrical Engineers. Transactions, Vols. x. – xv., 1893 – 1898; Vol. xvi., Nos. 1 – 5, 1899. *The Institute*

American Museum of Natural History. Annual Report of the President etc. for the year 1895. *The Museum*

New York Academy of Sciences. Annals, Vol. xii., Part i., 1899. *The Academy*

School of Mines, Columbia University. The School of Mines Quarterly, Vol. xx., No. 4, 1899. *The School*

The Mineral Industry, its statistics, technology and trade, in the United States and other countries to the end of 1898, Vol. vii., Edited by Richard P. Rothwell. *The Editor*

Ottawa—Geological Survey of Canada. Annual Report (New Series) Vol. ix., 1896. *The Survey*

Ottwa Literary and Scientific Society. Transactions, No. 1, 1897-8. *The Society*

Oxford—Radcliffe Observatory. Astronomical and Meteorological Observations, 1890-91, Vol. xlvii., 1899. *The Observatory*

Paris—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome cxxxix., Nos. 9 – 15, 1899. *The Academy*

Ecole d'Anthropologie de Paris. Revue, Année ix., Nos. 8, 9, 1899. *The Director*

La Feuille des Jeunes Naturalistes. Revue Mensuelle d' Histoire Naturelle, Ser. 3, Année xxix., Nos. 347, 348, 1899. *The Editor*

Museum d' Histoire Naturelle. Bulletin, Nos. 7, 8, 1898, Nos. 1 – 5, 1899. *The Museum*

Société d'Anthropologie de Paris. Bulletins, 4 Série, Tome ix., Fasc. 4, 6, 1898; Tome x., Fasc. 1, 2, 1899. *The Society*

Société de Biologie. Comptes Rendus Hebdomadaires, Serie xi., Tome i., Nos. 27, 28, 1899. „

Société Entomologique de France. Annales, Vol. lxvi., Année 1897. Bulletin, Année 1897. „

Société Française de Minéralogie. Bulletin, Tome xxii., Nos. 3 – 6, 1899. „

Société Française de Physique. Séances, Fasc 1, Année 1899. „

Paris—*continued.*

Société de Géographie. Bulletin, Série 7, Tome xviii., Trimestre 4, 1897. Comptes Rendus des Séances, No. 6, 1899. *The Society*

Société Géologique de France. Bulletin, 3 Série, Tome xxvi., Nos. 5, 6, 1898; Tome xxvii., Nos. 1. 2, 1899. ,,

Société de Spéléologie. Bulletin. Tome iv., Nos. 13 - 16, 1898. ,,

Société Zoologique de France. Bulletin, Tome xxiii., 1898. Mémoires, Tome xi., 1898. ,,

Perth, W.A.—Geological Survey Office. Annual Progress Report of the Geological Survey for 1898. *Government Geologist*

Department of Mines. Gold Mining Statistics 1898, April – August 1899. Supplement to Government Gazette of Western Australia, 11 August and 27 October 1899. The Golden West, her Mines and Industries 1899 as represented at the Coolgardie Exhibition. *The Department*

Observatory. Meteorological Observations during the year 1897 (No. 46), 1898 (No. 33). *Government Astronomer*

Philadelphia—Academy of Natural Sciences. Proceedings, Part i., Jan. – March, 1899. *The Academy*

American Entomological Society. Transactions, Vol. xxvi., No. 1, 1899. *The Society*

American Philosophical Society. Proceedings, Vol. xxxviii., No. 169, 1899. ,,

Franklin Institute. Journal, Vol. cxlviii., Nos. 1 – 4, 1898. *The Institute*

The Philadelphia Commercial Museum. The Republic of Costa Rica, by Gustavo Niederlein. *The Museum*

University of Pennsylvania. Annual Report of the Provost to the Board of Trustees 1897-8, Theses (3). Catalogue of the University, 1898-9. Contributions from the Laboratory of Hygiene, Nos. 1, 2, 1898. University Bulletin. Vol. iii., Nos. 1 – 9, 1898-9. *The University*

Wagner Free Institute of Science. Transactions, Vol. iii., Part iv., 1898. *The Institute*

Zoological Society. Annual Report (27th) of the Board of Directors, 27 April, 1899. *The Society*

Pola—Hydrographische Amt der Kund K. Kriegs-Marine in Pola. Relative Schwerebestimmungen durch Pendelbeobachtungen, Heft. 2, 1898. *The Director*

Port Louis—Royal Alfred Observatory. Annual Report of the Director for the year 1897. Mauritius Magnetical Reductions 1875 – 1897, edited by T. F. Claxton, F.R.A.S., 1899. *The Observatory*

Prague—Königl. Böhmische Gesellschaft der Wissenschaften in Prag. Norbert Heermann's Rosenberg'sche chronik herausgegeben von Dr. Matthäus Klimesch, 1898. Jahresbericht für das Jahr 1898. Sitzungsberichte, Math.-phys. Classe 1898; Classe für philos. gesch. philol. 1898. *The Society*

ROCHESTER, N.Y.—Geological Society of America. Bulletin, Vol. IX., 1898. *The Society*

RIO DE JANEIRO—Observatorio do Rio de Janeiro. Annuario, 1899. *The Observatory*

ROME—Academia Pontificia dei Nuovi Lincei. Atti, Anno LII., Sessione 3 - 7, 1899. *The Academy*

Ministero dei Lavori Pubblici. Giornale del Genio Civile, Anno XXXVII., Fasc. 5, 6, 1899. *Minister for Public Instruction, Rome*

Reale Accademia dei Lincei. Atti, Serie Quinta, Rendiconti, Vol. VIII., Fasc. 4 – 7, Semestre 2, 1899. *The Academy*

Revista Geografica Italiana. Annata, V., Fasc. 7 – 10, 1898; Annata, VI., Fasc. 1 – 3, 5 – 8, 1899. *The Publisher*

R. Ufficio Centrale Meteorologico e Geodinamico Italiano. Annali, Serie 2, Vol. XVI., Parte 2, 1894, Parte 2, 1895; Vol. XVII., Parte 1, 1895; Vol. XVIII., Parte 2, 1896. *The Office*

Società Geografica Italiana. Bollettino, Ser. 3, Vol. XI., Nos. 11, 12, 1898; Vol. XII., Nos. 1 – 9, 1899. Memorie, Vol. VIII., Parte 2, 1898. *The Society*

SALEM—American Association for the Advancement of Science. Proceedings, Meeting held at Boston, Mass., Vol. XLVII., 1898. *The Association*

Essex Institute. Bulletin, Vol. XXVIII., Nos. 7 – 12, 1896; Vol XXIX., Nos, 7 – 12, 1897; Vol. XXX., Nos. 1 – 12, 1898. Historical Collections, Vol. XXXIV., Nos. 1 – 12, 1898; Vol. XXXV., Nos. 1, 2, 1899. *The Institute*

SAN FRANCISCO—California Academy of Sciences. Proceedings, Third Series—Botany, Vol. I., Nos. 3 – 5, 1898; Geology, Vol. I., No. 4, 1898; Math-Physics, Vol. I., Nos. 1 - 4, 1898; Zoology, Vol. I., Nos. 6 – 10, 1898. *The Academy*

SCRANTON, Pa.—Colliery Engineer Co. Mines and Minerals, Vol XIX., No. 12; Vol. XX., Nos. 1, 2, 1899. *The Company*

SINGAPORE—Royal Asiatic Society. Journal of the Straits Branch, No. 32, June 1899. *The Society*

STOCKHOLM—Kongl. Svenska Vetenskaps Akademiens. Accessions-Katalog 13, 1898. Bihang, Band XXIV., Heft 1 – 4, 1899. Ofversigt, Band LV., 1898. Handlingar, Bande XXX., XXXI., 1897 – 1899. *The Academy*

Kongl. Vitterhets Historie och Antiqvitets Akademiens. Antiqvarisk Tidskrift för Sverige, Vol. XIV., Part i., 1899. Manadsblad, Arg. XXIV., 1895. „

ST. ANDREWS—University. Calendar for the year 1899-1900. *The University*

ST. LOUIS—Academy of Science of St. Louis. Transactions, Vol. VII., Nos. 17 – 20, 1897-8; Vol. VIII., Nos. 1 – 12, 1898; IX., Nos. 1 – 5, 7, 1899. *The Academy*

Missouri Botanical Garden. Annual Report (10th) 1899. *The Director*

STRASSBURG, i.E.—Meteorologischer Landesdienst von Elsass-Lothringen. Verhandlungen der Internationalen Aëronautischen Commission, 31 March – 4 April, 1898. „

STUTTGART—Königliches Statistisches Landesamt. Erganzungsband II, zu den Württembergischen Jahrbüchern für Statistik und Landeskunde 1898. Württembergische Jahrbücher für Statistik und Landeskunde, Jahrgang 1898, Teil I.; Teil II, 1899. *The 'Landesamt'*

Vereins für Vaterländische Naturkunde in Württemberg. Jahreshefte, Jahrgang LIV., 1898; Jahrgang LV, 1899. *The Society*

ST. PETERSBURG—Académie Impériale des Sciences. Bulletin, Serie 5, Tome VII., Nos. 3 - 5, 1897; Tome VIII., Nos. 1 - 4, 1898. Mémoires, Serie 8, Classe Historico-Philologique, Tome III., Nos. 1, 2, 1898; Classe Physico-Mathématique, Tome VI., Nos. 4, 6 - 13, 1898, Tome VII., Nos. 1 - 3, 1898. *The Academy*

Comité Géologique (Institut des Mines). Bulletins, Vol. XVII., Nos. 4 - 10, 1898; Vol. XVIII., Nos. 1, 2. Mémoires, Vol. VIII., No. 4, 1898; Vol. XII., No. 3, 1899; Vol. XVI., No. 1, 1898. *The Committee*

Russisch-Kaiserliche Mineralogische Gesellschaft. Verhandlungen, Serie 2, Band XXXVI., Lief. 1, 1899. *The Society*

SYDNEY—Anthropological Society of Australasia. 'Science of Man,' New Series, Vol. II., Nos. 8 - 10, 1899. *The Society*

Department of Mines and Agriculture. *Agricultural Gazette*, Vol. x., Parts vi. - xi., 1899. Annual Report of the Department of Mines and Agriculture, N.S.W. for the year 1898. Mineral Resources, Nos. 5, 6, 1899. Records of the Geological Survey, Vol. VI., Parts ii., iii., 1899. *The Department*

Department of Public Instruction. N.S. Wales Educational Gazette, Vol. IX, Nos. 1 - 6, 1899. "

Government Printer. The Statutes of New South Wales (Public) passed during the First and Second Sessions of 1899. *Government Printer*

Government Statistician. Childbirth in New South Wales, a study in Statistics 1899. New South Wales Statistical Register for 1898 and previous years, Parts vii., viii, ix., xii. Statistics of the Seven Colonies of Australasia, 1861 - 1898. *Government Statistician*

Institution of Surveyors, N.S. Wales. List of Surveyors licensed to practice in New South Wales, 1899. 'The Surveyor,' Vol. XI., No. 12, 1898; Vol. XII, Nos. 1 - 11, 1899. *The Institution*

Linnean Society of New South Wales. Abstract of Proceedings, Sept. 27, Oct. 25, Nov. 29, 1899. Proceedings, Vol. XXIV., Part ii., No. 94, 1899. *The Society*

New South Wales Branch of the British Medical Association. The Australasian Medical Gazette, Vol. XVII., No. 12, 1898; Vol. XVIII., Nos. 1 - 10, 1899. *The Association*

N. S. Wales Chamber of Mines. Journal, Vol. I., Nos. 1, 2, 1899. Mine Returns for 1898. Three Letters on the Australian Mining Laws 1897. *The Chamber*

Public Library of N.S. Wales. Annual Report (28th) of the Trustees for 1898. *The Trustees*

SYDNEY—*continued.*

Royal Geographical Society of Australasia. Journal and Proceedings, Vol. V., 1891-2; Vol. VI., Nos. 1 – 6, 1896-8. *The Society*

United Service Institution of New South Wales. Journal and Proceedings, Vol. IX., 1897. *The Institution*

University. Calendar of the University of Sydney for the year 1899. *The University*

TAIPING—Perak Government Gazette, Vol. XI., Nos. 31 - 38, 1898 and Index; Vol. XII., Nos. 1 – 8, 11 – 30, 1899. *The Secretary*

TOKIO—Asiatic Society of Japan. Transactions, Vol. XXV., 1897; Vol. XXVI., 1898. *The Society*

Imperial University of Tokio. Calendar, 1897-98. Journal of the College of Science, Vol. IX., Part iii., Vol. X, Part iii., 1898; Vol. XI., Parts i. – iii., 1898-9; Vol XII., Parts i. – iii., 1898. *The University*

TORONTO—Astronomical and Physical Society of Toronto. Transactions for the year 1898 including Ninth Annual Report. *The Society*

Canadian Institute. Proceedings, N. S., Vol. I., Part vi., No. 6, 1898; Vol. II., Parts i., ii., Nos. 7, 8, 1899. *The Institute*

TOULOUSE—Académie des Sciences, Inscriptions et Belles-Lettres. Bulletin, Tome I., Nos. 1 - 3, 1897-8. Mémoires, Série 9, Tome IX, 1897. *The Academy*

TROMSO—Tromso Museum. Aarsberetning for 1984 and 1897. Aarshefter, Vol. XVIII., 1895; Vol. XX., 1897. *The Museum*

TUNIS—Institut de Carthage. Revue Tunisienne, Année VI., Nos. 21 - 24, 1899. *The Institute*

TURIN—R. Accademia delle Scienze di Torino. Atti, Vol. XXXIV., Disp. 1 – 14, 1898-9. Effemeridi del Sole e delle Luna 1897-8. Osservazioni Meteorologiche 1897-98, 1898-99. Sulla-Eclisse Totale di Luna, 27 Dec. 1898. *The Academy*

UPSALA—Kongliga Vetenskaps Societeten. Nova Acta, Series 3, Vol. XVIII, Fasc. 1, 1899. *The Society*

VENICE—R. Istituto Veneto di Scienze, Lettere ëd Arti. Atti, Tomo LV., Dispensa 3 - 10, 1896-7; Tomo LVI., Dispensa 1 – 7, 1897-8. Memorie, Vol. XXVI., Nos. 1, 2, 1897. *The Institute*

VIENNA—Anthropologische Gesellschaft in Wien. Mittheilungen, Band XXVIII., Heft 3 – 6, 1898. *The Society*

Kaiserliche Akademie der Wissenschaften. Expedition S. M. Schiff 'Pola' in das Rothe Meer Nördliche Hälfte (Oct 1895 – Mai 1896) Parts i. – v., Beschreibender Theil Sitzungsberichte, math-naturw. Classe—

Abtheilung	I.,	Band	CVI.,	Heft	1 – 10,	1897
,,	II*a*	,,	,,	,,	1 – 10,	,,
,,	II*b*	,,	,,	,,	1 – 10,	,,
,,	III.,	,,	,,	,,	1 – 10,	,,
,,	I.,	,,	CVII.,	,,	1 – 5,	1898
,,	II*a*	,,	,,	,,	1 – 2,	,,
,,	II*b*	,,	,,	,,	1 – 3,	,,

Register, Sitzungsberichte, Bande CI. – CV., math-naturw. Classe, Vol. XIV., 1897. *The Academy*

VIENNA—*continued.*

K.K. Central-Anstalt für Meteorologie und Erdmagnetismus. Jahrbücher, N.F., Band XXXI., Jahrgang 1894; Band XXXIV., Jahrgang 1897. *The Station*

K. K. Geographische Gesellschaft. Mittheilungen, Band XLI., 1898. *The Society*

K. K. Geologische Reichsanstalt. Jahrbuch, Band XLVIII., Heft 1, 2, 1898. Verhandlungen, Nos. 13 – 18, 1898; Nos. 1 – 8, 1899. *The Reichsanstalt*

K. K. Gradmessungs-Bureau. Astronomische Arbeiten, Band X., 1898 Längenbestimmungen. *The Bureau*

Section für Naturkunde des Österreichischen Touristen-Club. Mittheilungen, Jahrgang X., 1898. *The Section*

VIZAGAPATAM—G. V. Juggarow Observatory. Report of condition and progress including results of observations for the year 1897. Notes on the Meteorology of Vizagapatam, Part i., Rainfall by W. A. Bion 1898. *The Observatory*

WANGANUI—Public Museum. Annual Report (4th) for the year ending 30 June, 1899. *The Museum*

WASHINGTON—American Historical Association. Annual Report for the year 1897. *The Association*

Bureau of Education. Report of the Commissioner of Education for the year 1896-7, Vol. II. *The Commissioner*

Engineer Department, U.S. Army. Annual Report of the Chief of Engineers for the Fiscal Year ended June 30, 1898, Parts i. – vi. inclusive. *The Department*

National Academy of Sciences. Memoirs, Vol. VIII., Nos. 2 and 3, 1898-9. *The Academy*

Smithsonian Institution. Annual Report of the Board of Regents to July 1896 and to July 1897. Report of U.S. National Museum, year ending 30 June 1896. Smithsonian Contributions to Knowledge, Vol. XXIX., No. 1126, 1898. Smithsonian Miscellaneous Collections, Vol. XXXIX., Nos. 1125, 1170, 1171, 1898-9. The Smithsonian Institution, 1846 – 1896, the History of the First Half Century, edited by George Brown Goode, 1897. *The Institution*

U.S. Coast and Geodetic Survey. Bulletin, Vol. III., Nos. 37 - 40, 1899. Report of the Superintendent for Fiscal Year ending with June 1897. *The Survey*

U.S. Department of Agriculture. Division of Biological Survey, North American Fauna, No. 15, 1899. Division of Statistics, Crop Circular, June – Oct., 1899. Monthly Weather Review, Vol. XXVII., Nos. 5 – 7, 1899. Weather Bureau, Bulletins Nos. 24, 26. *The Department*

U.S. Geological Survey. Annual Report (18th) 1896-7, Parts i. – v. and v. continued; (19th) 1897-8, Parts i., iv., vi., and vi. continued. Bulletins, Nos. 88, 89, 149, 1897-8. Monographs, Vols. XXIX. – XXXI., XXXV., 1898. *The Survey*

U.S. Hydrographic Office. Notices to Mariners, Nos. 32 – 34, 36 – 39, 41 - 53, 1898; Nos. 1 - 13, 15 – 37, 1899. *U.S. Hydrographer*

U.S. Navy Department. Notes on Naval Progress, April 1899 *The Department*

Wellington—Education Department. The Students' Flora of New Zealand and the Outlying Islands by Thomas Kirk, F.L.S., 1899 (Text). *The Department*

Mines Department. Annual Report (32nd) of the Colonial Laboratory, 1897-98. „

New Zealand Institute. Transactions and Proceedings, Vol. XXXI., 1898. *The Institute*

Polynesian Society. Journal, Vol. VII., Nos. 2 and 4, 1898; Vol. VIII., Nos. 1, 2, 3, 1899. *The Society*

Winnipeg—Historical and Scientific Society of Manitoba. Annual Reports for the years 1897 and 1898. Transactions, Nos. 51 – 54, 1898-9. „

Zurich—Naturforschende Gesellschaft. Neujahrsblatt, Stuck 101, 1899. Vierteljahrsschrift, Jahrgang XLIII., Heft 4, 1898; Jahrgang XLIV., Heft 1, 2, 1899. „

Miscellaneous.

(The Names of the Donors are in *Italics.*)

Australian Technical Journal, Vol. III., No. 2, 1899. *The Publishers*

Barr, Archibald, D. Sc., M. Inst. C.E.—The application of Mechanics to Engineering Practice, 1899. *The Author*

Bashforth, Francis, B.D.—Replica di Krupp alla protesta del Signor Bashforth translated with notes by, 1898. „

Bernier, Julien—Etude sur les Dialectes Neo-Calédoniens, Australiens et autres, 1899. „

Boletin de Estadistica del Estado de Puebla, Epoca II., Num 13, 14, 1899. *The Director*

British Refrigeration and allied interests, Vol I., Nos. 1 – 3, 1899. *Messrs. J. Wildridge and Sinclair*

Brough, Bennett H.—Historical Sketch of the First Institution of Mining Engineers, 1899. The Jubilee of the Austrian Society of Engineers, 1899. *The Author*

Colomb, Capt. J. C. R., F.S.S., F.R.G.S.—The Defence of Great and Greater Britain with a map, 1880. *Sir John Colomb,* K.C.M.G., M.P.

Cudmore, P., B.H.—Cudmore's Prophecy of the Twentieth Century 1899. *The Author*

Curran, Rev. J. Milne—The Geology of Sydney and the Blue Mountains 1898. „

Dangeard, P. A.—Théorie de la Sexualité, 1898. *The Author*

Diario Oficial—Republica de el Salvador, Tomo XVLI., Núm 51 – 73, 75, 1899. *The Director*

Fritsche, Dr. H.—Die Elemente des Erdmagnetismus für die Epochen, 1600, 1650, 1700, 1780, 1842 und 1885. *The Author*

Handbook of Information for Western Pacific Islands issued by Burns, Philp & Co. Ld, 8° Sydney, 1899. *Charles Hedley,* F.L.S.

Howell, Price—Comparative Statistics of Australasian Railways 1899. [Journ. Roy. Statis. Soc., Vol. LXII., Part i., 1899] *The Author*

Janet, Charles—Etudes sur les Fourmis les Guepes et les Abeilles Notes 14, 15, 16, 1897. Les Habitations a Bon Marché dans les Villes de Moyenne Importance, 1897. Notice sur les Travaux Scientifiques présentés par M. Charles Janet à l'Academie des Sciences au Concours de 1896

Janet, Charles—*continued.*
pour le prix Thore. Sur l'emploi de Desinences caracteristiques dans les denominations des groupes ètablis pour les classifications zoologiques 1898. Sur les limites morphologiques des anneaux du tégument et sur la situation des membranes articulaires chez les Hyménoptères arrivés à l' état d' imago, 1898. Sur une cavité du tégument servant, chez les *Myrmicinæ*, à étaler, au contact de l' air, un produit de sécrétion, 1898. *The Author*

Kyngdon, F. B., M.R.A.C.—Wine Culture in New South Wales, 1898. ,,

Locomotive (The), Vol. XIX., Nos. 8, 9, 11, 12, 1898; Vol. XX., Nos. 1 - 8, 1899. *Kegan Paul, Trench, Trübner & Co. Ld.*

Mathew, John, M.A., B.D.—Eaglehawk and Crow, a study of the Australian Aborigines, including an inquiry into their origin and a survey of Australian languages 1899. *The Author*

Mingaye, John C. H., F.C.S.—The occurrence of Phosphatic Deposits in the Jenolan Caves, New South Wales. Notes and Analyses of some New South Wales Phosphatic Minerals and Phosphatic Deposits. ,,

New Spalding Club (Aberdeen)—Twelfth Report by the Council 1898. *The Club*

New South Wales Sheepbreeders' Year Book 1899, *The Association*

Pound, C. J., F.R.M.S.—Notes on the Cattle Tick 1898. Tick Fever 1899. Tuberculin, its History, Preparation and Use, 1898. *The Author*

Scientific Australian, March 20, 1899. *The Publishers*

Seaman, Henry B., M. Am. Soc. C.E.—The Launhardt Formula, and Railroad Bridge Specifications 1898. *The Author*

Tebbutt, John, F.R.A.S., etc.—Report of Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales, for the year 1898. ,,

Waters, Arthur Wm.—Bryozoa from Madeira 1898. Observations on *Membraniporidæ*, 1898. ,,

Whymper, Edward—A new mountain Aneroid Barometer, 1898. ,,

White, Rev. James S., M.A., LL.D.—The Rights of Man. ,,

PERIODICALS PURCHASED IN 1899.

American Journal of Science, (Silliman).
Analyst.
Annales des Chimie et de Physique.
Annales des Mines.
Annals of Natural History.
Astronomische Nachrichten.
Australian Mining Standard.

British Medical Journal.
Building and Engineering Journal of Australia and New Zealand.

Chemical News.

Dingler's Polytechnisches Journal.

Electrical Review.
Engineer.
Engineering.

Engineering and Mining Journal.
Engineering Record and Sanitary Engineer.
English Mechanic.

Fresenius Zeitschrift für Analytische Chemie.

Geological Magazine.
Glacialists' Magazine.

Industries and Iron.

Journal of Anatomy and Physiology.
Journal of Botany.
Journal of Morphology.
Journal of the Chemical Society.
Journal of the Institution of Electrical Engineers.
Journal of the Royal Asiatic Society of Great Britain and Ireland.
Journal of the Society of Chemical Industry.

Knowledge.

L' Aéronaute.
Lancet.

Medical Record of New York.
Mining Journal.

Nature.
Notes and Queries.

Observatory.

Petermann's Ergänzungsheft.
Petermann's Geographischen Mittheilungen.
Philosophical Magazine.
Photographic Journal.
Proceedings of the Geologists' Association.

Quarterly Journal of Microscopical Science.

Sanitary Record.
Science.
Scientific American.
Scientific American Supplement.

Zoologist.

Books Purchased in 1899.

Australian Handbook, 1899.

Biedermann's Technisch Chemisches—Jahrbuch. Vol. xx., 1897-8.
Braithwaite, R.—British Moss Flora, Parts xviii., xix.
Braithwaite's Retrospect of Medicine, Vols. cxviii., cxix., 1898-9.
British Association Report, 1898.

Cassell's Latin Dictionary 1896.
Chemical Society of London—Collective Indexes of the Transactions and Abstracts, 1841 - 1892.

Evolution by Atrophy. (*Int. Sci. Ser.*, Vol. lxxxvii.)

Helferich's Hand Atlas of Fractures and Dislocations. (*New Syd. Soc.*, Vol. CLXVII.)

International Scientific Series, Vols. LXXXIV., LXXXVI., LXXXVII.

Jahres-bericht Chemischen Technologie 1897 and 1898, General Register, Bande 31 – 40.

Lexicon of Medicine and the Allied Sciences, Parts xxiv., xxv. (*New Syd. Soc.*, Vols. CLXV., CLXVIII.)
Liddell and Scott's Greek English Lexicon (Abridged) 1896.
Lubbock's Buds and Stipules. (*Int. Sci. Ser.* Vol. LXXXVI.)

Medical Officers' Annual Report (26th) 1896-97; (27th) 1897-8.
Medico-Chirurgical Society, Transactions, Vol. LXXXI , 1898.
Morphology, Journal of, Vol. XIV., No. 3; Vol. XV., Nos. 1, 2.

New Sydenham Society's Publications, Vols. CLXV., CLXVI., CLXVII., CLXVIII.

Obstetrical Society—Transactions, Vol. XL., 1899.
Official Year Book of Scientific and Learned Societies, 1899.

Palæontographical Society, Vol. LII.
Pathology, Atlas of Illustrations of, Fasc. XII. (*New Syd. Soc.*, Vol. CLXVI.)
Pathological Society, Transactions, Vol. XLVIII., 1897; Vol. XLIX., 1898.

Schmidt's Atlas der Diatomacean Kunde, Heft 54.

Vincent, R. H.—Elements of Hypnotism. (*Int. Sci. Ser.* Vol. LXXXIV.)

Whitaker's Almanack 1899.

PROCEEDINGS OF SECTIONS.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

ENGINEERING SECTION.

The first monthly meeting of the Session was held in the Large Hall of the Society's House on May 17th, 1899 at 8 p.m., when there were present Mr. NORMAN SELFE, M. Inst. C.E., (in the Chair) and thirty-four members and visitors.

The acting Chairman, Mr. N. SELFE, delivered his presidential address, making sympathetic reference in his opening remarks to the continued ill-health of the Chairman of the Section, Mr. H. R. CARLETON.

A vote of thanks to the acting Chairman was moved by Mr. C. O. BURGE, seconded by Mr. SMAIL, and carried by acclamation.

Interesting exhibits were supplied by Mr. C. O. BURGE, Prof. T. W. E. DAVID, Mr. C. DARLEY, Mr. H. DEANE, Mr. G. H. KNIBBS, Dr. F. TIDSWELL, and Prof. W. H. WARREN.

Monthly meeting held June 21.

There were present Mr. T. H. HOUGHTON (in the Chair), and thirty-two members and visitors.

Mr. J. DAVIS read a paper on "The Sewerage Systems of North Sydney and Double Bay."

The Hon. Secretary read a paper by Mr. F. M. GUMMOW on "The manufacture of Monier Pipes."

Monthly meeting held July 19.

There were present Mr. T. H. HOUGHTON (in the Chair) and a large attendance of members and visitors.

The joint discussion of the papers by Mr. J. DAVIS and Mr. F. M. GUMMOW, read at the previous meeting was then taken up.

The Hon. Secretary read a contribution to the discussion by Mr. Griffith, and the following members took part, Messrs. J. Bruce, J. H. Cardew, J. Davis, H. Deane, F. B. Guthrie, W. M. Hamlet, J. M. Smail, and Dr. Quaife.

The Chairman announced that an excursion to the Ultimo Power House would be held, at the invitation of Mr. H. DEANE, on Friday July 21st, at 4 p.m.

Monthly meeting held August 16.

This meeting was held in the Lecture Room of the University Chemical Laboratory. All formal business was postponed.

Prof. A. LIVERSIDGE delivered a lecture, illustrated by many experiments, on "Liquid Air."

A very cordial vote of thanks to the lecturer was moved by Mr. C. O. BURGE, seconded by Prof. A. STUART, and carried by acclamation.

The meeting then adjourned to the P. N. Russell School of Engineering, where refreshments had been provided.

Monthly meeting held September 20.

There were present Mr. NORMAN SELFE (in the Chair) and eighteen members and visitors.

Mr. J. I. HAYCROFT read a paper on "*Le Pont Vierendeel.*"

Mr. G. H. KNIBBS made some remarks on "Ruled Surfaces," and on the applications of the Prismoidal Formula.

The discussion on Mr. KNIBBS' paper entitled "Some applications and developments of the Prismoidal Formula," read at the previous meeting of the Royal Society was opened by Mr. J. I. Haycroft, and continued by Mr. C. Merfield and Mr. H. Deane.

Exhibits were supplied by Mr. H. DEANE and the Chairman.

The Hon. Secretary reported that at the invitation of Mr. J. DAVIS a most successful excursion to the Sewerage works at North Sydney and Double Bay had been held.

Monthly meeting held October 18.

There were present Mr. G. R. Cowdery (in the Chair) and eight members. The meeting immediately adjourned.

Final meeting held November 29.

There were present Mr. Norman Selfe (in the Chair) and thirty-six members and visitors.

The following members were elected as Officers and Committee for the following year:—Chairman: Norman Selfe, M. Inst. C.E. Hon. Secretary: S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E. Committee: Henry Deane, M.A., M. Inst. C.E., Percy Allan, Assoc. M. Inst. C.E., G. R. Cowdery, Assoc. M. Inst. C.E., J. M. Smail, M. Inst. C.E., J. I. Haycroft, M.E., M.I.C.E.I., H. H. Dare, M.E., Assoc. M. Inst. C.E., T. J. Bush, Lee Murray, M.C.E.

Mr. J. I. Haycroft, made some additional remarks on "*Le Pont Vierendeel.*"

Contributions to the discussion were made by Messrs. Allan, Bowman, Cook, Dare, and the Chairman.

Exhibits of apparatus were provided by Messrs. Edge and Edge, Mr. J. H. D. Brearley, Mr. B. Wallach, and the Hon. Secretary.

A hearty vote of thanks was accorded to the acting Chairman, Mr. Norman Selfe.

MEDICAL SECTION.

I.

A Special Meeting of the Section was held at the Society's House, on Friday, May 19th, 1899, at 8 p.m., for the election of officers for the year. In the absence of the Chairman, Dr. W. H. Goode, was unanimously voted to the Chair.

The minutes of the preceding meeting were read and confirmed.

The ballot resulted in the election of officers as follows:—Chairman: Dr. Walter Spencer. Committee: Drs. F. H. Quaife, Sydney Jamieson, Roland Pope, and L. E. F. Neill. Honorary Secretaries: Drs. J. A. Dick and Frank Tidswell.

The retiring officers were thanked for their services. The meeting then terminated.

II.

The first General Meeting was held at the Society's House, immediately after the close of the Special meeting, on Friday, May 19th, 1899, at 8·20 p.m. There was a fair attendance of members.

Dr. WALTER SPENCER, the Chairman of the Section, presided.

Dr. SPENCER thanked the Section for electing him Chairman, and read a paper upon "An outbreak of Dermatitis exfoliativa neonatorum." Dr. GOODE occupied the Chair during the reading of the paper by Dr. Spencer.

The paper was discussed by Drs. Frank Tidswell, Goode, McKay, and J. F. Deck.

A demonstration of specimens illustrative of Tick Fever was given by Dr. FRANK TIDSWELL. Drs. Sydney Jamieson, Goode, McKay, Quaife, and Chisholm discussed the subject.

Dr. SYDNEY JAMIESON exhibited several recent additions to the University Museum of Normal and Morbid Anatomy.

Dr. FRANK TIDSWELL exhibited several new pieces of laboratory apparatus. The meeting then terminated.

III.

The second meeting of the Section was held at the Society's House on Friday, August 18th, at 8·15 p.m. There was a fair attendance of members and visitors. Dr. WALTER SPENCER, the Chairman of the Section presided.

The following papers were read:—"Bubonic Plague in 1141 B.C." by the joint Hon. Secretaries. "The Water Supply and Sewerage Systems of Sydney," with numerous lantern illustrations and diagrams, by Mr. J. M. SMAIL, M. Inst. C.E., Chief Engineer Metropolitan Board of Water Supply and Sewerage.

Drs. Quaife, Spencer, Tidswell and Dick discussed the paper. A vote of thanks to Mr. Smail was carried unanimously.

Dr. W. F. LITCHFIELD per the Hon. Secretaries, exhibited a maldeveloped young pig showing an elephant-like proboscis.

Dr. SYDNEY JAMIESON exhibited several recent additions to the University Museum of Normal and Morbid Anatomy. The meeting then terminated.

IV.

The third meeting of the Section was held at the Society's House on Thursday, December 21st, 1899, at 8·15 p.m. There was a good attendance of members. Dr. WALTER SPENCER, the Chairman of the Section, presided.

At the invitation of the Secretaries, Drs. SYDNEY JONES and G. E. RENNIE, gave an account of their observations during recent visits to Europe. Dr. Sydney Jones spoke on the sanitorium treatment of consumption, and Dr. Rennie upon medical matters in England. Cordial votes of thanks were unanimously given to both gentlemen for their interesting and valuable remarks.

Dr. FRANK TIDSWELL exhibited and explained the hæmatocrit.

Dr. SYDNEY JAMIESON exhibited several recent additions to the University Museum of Normal and Morbid Anatomy. The meeting then terminated.

ANNUAL ADDRESS.

By Norman Selfe, M. Inst. C.E., M.I. Mech. E.

[*Delivered to the Engineering Section of the Royal Society of N.S. Wales, May 17th, 1899.*]

Gentlemen,

We are opening the Annual Session of this Section of the Royal Society under unusual and rather painful conditions. I cannot, as is customary, begin by thanking the Members for electing me as their Chairman, because I am only occupying this position at the request of the Committee as *locum-tenens* for Mr. Carleton, your own elected Chairman, whose continued ill-health and inability to be present this evening we must all greatly deplore. Let us anxiously hope he will soon be with us again. I am afraid I have not the pleasure of a personal acquaintance with Mr. Carleton, and, in thinking over the fact, my memory has gone back to the days when I believe I knew every Engineer in Sydney in the employment of the Government. I well remember, at any rate, the inauguration, forty years ago, of the department of which Mr. Carleton is the head, and the original officers connected with it. Possibly none of you are aware (for I have never seen a record of the fact) that the iron trussing to the spans of the present Glebe Island Bridge (one of the first works of this department) was all made for Pyrmont Bridge, but never used there. The drawings for the cast iron struts—which were cast in Sydney—and the drawings for the tie rods and bridles—which were ordered from England—were made by myself.

As a memento of those days, I am able (through the courtesy of Mr. Hudson, who purchased all the plans formerly belonging to Messrs. P. N. Russell & Co.) to exhibit the general drawing of the Steam Dredge "Hunter," still working at Newcastle, which was made by me in the year 1859. I think I also made all the working drawings for the machinery of this work, except those for the engine, which was an imported one. The hull was built at Waterview Bay by Captain Rountree, with Mr. Anderson as foreman, who was, I believe, responsible for her lines. Mr. Anderson was afterwards, and until his death, a much respected Assistant Engineer under the late Chief Engineer, Mr. E. O. Moriarty, M. Inst. C.E. Perhaps the only value of this drawing now is the associations connected with it.

As the principal object of our meetings is the reading of papers on Engineering subjects, and the promotion of discussions thereon, it is certain that the present Session, to be a successful one, will not depend upon any efforts of mine, but upon the members generally entering warmly and loyally into the work. Members, however, may rest assured that my best efforts will be united with those of the other members of the Committee in the endeavour to make the Session a prosperous one. Let us hope that all will do their best towards providing an attractive programme for every meeting.

An opening address of this kind should hardly admit of discussion in the sense of inviting a contradiction of its propositions, but it may perhaps be fairly permitted to suggest subjects that await discussion, when they are of more or less importance to the Members as Engineers, and are of interest to the community at large.

I do not know if many of our Members have noticed how, with the ever increasing use of steam power, the smoke nuisance is becoming very pronounced in and around Sydney; or that they are aware that the Smoke Nuisance Act 29 Victoria No. 16 is in force. The only valid legal excuse under the act is said to be the proof that the owner of an offending furnace has actually tried all reasonable and available methods of preventing the smoke complained of. Some years ago this protected owners in the case of actions at law, because there were not then many schemes for them to try; but in these days of reliable automatic stokers, and more perfect combustion furnaces, it is probable that successful actions could now be brought against most offenders, but whether it would apply to Government Works and steamers is a legal question I am unable to answer.

I believe the much-debated subject of Land Boiler Inspection has never engaged the attention of this Section. The tendency of legislation in New South Wales appears to diverge somewhat from the direction it is taking in the Old Country, and the question of compulsory registration versus inspection affords a large field for discussion. As a matter of fact, the actual loss of life in the colony by boiler explosions has hitherto been very small, and practically insignificant when compared with that which happens from such causes as lift accidents, falls of unsecured earth, and the use of cheap and defective crane plant; to which latter class of causes a large and unnecessary waste of life has been attributable. It is held by many thinkers, that some system of registration, under which there would be always a record available, showing the history and condition of every boiler, and of the person responsible for such condition, would effect the same object with less vexatious interference. This, combined with a registration of the qualification of every person in charge of boilers, so as to be able to absolutely fix the liability if a proper and safe condition was not maintained; and the conferring of punitive powers on a Board of Enquiry, in the case of accidents, is thought by many to be preferable to an inquisitorial system of official inspection. Of course there are many things to be said about both systems, but may not one ask in the meantime :—Is it not a farce to call those explosions "accidents" which are shown to be the result of using cheap and second-hand boilers, without any previous examination by experts, or the employment of skilled supervision for periodical examination?

We have been very much indebted to the University in the past for original research in connection with the strength of materials, but I am not aware if any experiments have been made with regard to the relative amount of deterioration, by corrosion, which high and low grades of steel undergo, as compared with pure and common iron, when these metals are subjected to atmospheric influences, or to complete immersion in water. There is a prevailing opinion among many mechanical Engineers that high grade irons or steels corrode much more rapidly, and that cases occasionally occur where a greater weight of an inferior material would be more economical than the use of less metal with a greater tensile strength. I have strong reasons for believing that iron is better than steel for wire cables under certain conditions, and should be glad if in the course of the session some authoritative information were given on the subject.

Leaving such comparatively small subjects as have just been referred to, and our little local world, to look abroad over the universal Domain of Engineering at this *fin de siecle* period, we are struck with the fact, that with the termination of the century, now close at hand, we shall, from the indications already apparent, enter upon a new era of Science and the Arts, which bids fair to be markedly in advance of the last, when our fathers used flint and steel to obtain light, when semaphores were the only means of telegraphing, and the stage coach—supplanting the waggon and horses—reigned supreme as the means of rapid transport on land. Every hour almost in the present day brings us advances, some of them, perhaps, in a direction where we think they have already gone far enough. Among the latter may be placed the American architectural-engineering structures, towering towards the clouds—"Sky-scrapers" I believe they are called. It is not to such abnormal developments that I would refer, although even they have added largely to our knowledge of combinations of steel and concrete for foundations.

Of all departments of modern science, those connected with the application of electricity are, undoubtedly, surrounded with the greatest halo of mystery and attractiveness, as they appeal to scientists, to capitalists, and to the masses. Perhaps the latest triumph in their developments is the practical application of Hertzian waves by Signor Marconi, and their successful utilisation for signalling without wires. The claim that a

Swedish engineer has succeeded in applying waves of energy in another form, to direct the course of a torpedo from a distance, has hardly yet been proved to have such useful practical advantages; but all such advances as these open up boundless vistas of future possibilities.

When considered by comparison with the intangible mysteries connected with the explored and unexplored possibilities of electrical energy, the use of compressed air is to many persons only as poor prose to heavenly poetry, and its use has to be extended without any halo; but notwithstanding the want of this help, it is getting along all the time, as our American friends say. The range of the application of compressed air is daily increasing, and it would be very interesting if we could get reliable records of the working of the Popp-Conti tramways in Paris.

In the practical operation of Heat Engines there are signs that some of the heat, which is generally looked upon as irretrievably wasted, may be further utilized.

With every successful step in the reduction of temperature towards absolute zero, new possibilities are opened up. If Mr. Tripler's claims (as set forth in recent magazines) could possibly be substantiated, then the foundation, on which our present theories of Heat Engines rest, would, of course, be overthrown. Doubtless, in the desire for sensation, and to please the public, the writers have over-stated the case. Mr. Chas. E. Tripler is an American gentleman who is following in the footsteps of Professors Dewar and Dr. Hampson in England, and Professors Linde and Pictet in Germany; but he produces liquid air on a much larger scale than his predecessors, and then employs it as a medium for the production of motive power.

Mr. Tripler, as reported, is said to have obtained sufficient power from the evaporation of one pound of liquid air, to enable him to liquefy four pounds. Photographs of the machinery employed are published, but the claim that is made as to such results is not supported by any data or authority which carries weight, and, therefore, may be dismissed as absurd. Many persons, however, in criticising this claim in the scientific journals, have fallen into errors themselves, and others would, probably, say, " It is impossible, because it would be perpetual motion, or the production of energy from nothing." A little consideration of the latter proposition, however, will show us that such critics might be wrong as to their reasons, even if they were correct as to their view of the facts, because the operation might come under one of these classes of perpetual motion which are improperly so called. Perhaps it may be worth while here to devote a few minutes to the consideration of the almost tabooed subject of perpetual motion.

Every one present has, no doubt, in his time been brought face to face with one or more of those absurd and impossible projects for producing perpetual motion, or "gaining power," examples of which are continually being patented, or brought into notice, in Sydney, just as in other parts of the world.

In these types something is intended to be obtained for nothing, and they should not be confounded with other projects which only seek—in a novel way—to utilise natural energy. In the former types it is often "wonderful mechanism," which always wants the one little finishing touch to make it go, that is employed in the futile attempt to make the descent of a lesser weight lift a greater one to the same height. Sometimes the inventor does not believe in the weight of the atmosphere, or the effect of gravity, or something else of the sort, and thousands of such machines appear to have been actually constructed. I have had at least a score of such projects brought under my notice at different times by as many would-be inventors; of course, the missing link necessary to make them go is never forthcoming.

Then there are the Perpetual Motion Frauds, which really do go; but go only by means of a concealed storage of power. Of such was the celebrated Keeley Motor, on which hundreds of thousands of pounds were sunk, and which was operated by highly compressed air supplied through apparent wires that were really tubes. Some forty years ago I was the possessor of a small machine in which a concealed magnetic needle was rotated by means of clock work under a thin hollow stand. This magnet caused the actual revolution of a light conical pendulum, the motion of which was ostensibly produced by a circle of permanent magnets in sight of the on-looker. Such things are interesting as toys, and dangerous as frauds; but they have no scientific importance. In the second class before referred to, and to which Tripler's case (if it were not otherwise impossible) belongs, the so-called perpetual motion is produced either by the direct utilisation of the heat of the sun's rays, by storing up heat during the day time, as in Ericson's Solar Engine, to be given out when the temperature is lower at night; or by some other system of utilising natural heat energy, just as it is employed in any other heat engine. Instead, however, of the temperature range being limited at the cold end by about 100 degrees Fah., as in the steam engine, it may possibly be limited by the lowest temperature attained by the atmosphere.

If, however, the effective work of the heat engine can be increased, and its lower range be economically extended to condensing temperatures produced artificially (as claims which have been made on behalf of the use of liquid air would lead the general public to believe), then the application of the laws of thermo-dynamics must be modified.

It would be a most fascinating subject for contemplation if we could assume that, through the instrumentality of liquid air instead of water as the medium for our motive power, we could construct a heat engine in which the range of temperature would be altogether below the ordinary temperature of the atmosphere, on the grounds that it is a liquid which boils at atmospheric pressure 312 degrees below Fahrenheit's zero, and as a vapour or gas occupies 800 times its liquid volume. Having a supply of liquid air, it is certainly quite possible to drive an engine with high-pressure air as a vapour or gas, and for the heat necessary to produce such evaporation to be abstracted from its surroundings, finally exhausting the expanded medium so cold as to be still below the freezing point of water. Numbers of estimates have already been made as to the amount of external heat which would have to be supplied (or the number of thermal units that would be required) at a temperature above that of the atmosphere, before an equal weight of air could be liquefied, but I have seen none which appear to exhaust the possibilities. It will, perhaps, show why this subject is so attractive to so many minds, if for a short time we leave the substantial for the visionary.

In the steam engine we know that the useful work performed generally lies between, say, 100 degrees and 300 degrees Fah. One of the most useful contributions that has ever been made towards a simple comprehension of the thermal efficiency of the steam engine, is the report and accompanying diagrams, from the specially appointed Committee, which appears in the last volume of "The Proceedings of the Institution of Civil Engineers."

From these papers we see it graphically demonstrated, how with a range of temperature of 259 degrees (between 100 and 359 degrees) the Leavitt pumping engine* (one of the highest type for efficiency yet constructed) leaves in round numbers four times as much of its heat energy in the condensing water, as it converts into mechanical work. This efficiency is 67 per cent. of that possible with an ideally perfect steam engine.

Looked at in another way, this unused heat means that the engines of a mail steamer which indicate 10,000 horse-power will pump overboard every hour sufficient heated circulating water to warm 2,300 tons of the ocean 20 degrees, four-fifths of the calorific effect of the coals burnt being thus wasted.

Now, suppose it was possible to find a medium which would not only evaporate under pressure while below 32 degrees (as many substances in common use actually do), but which would also re-liquefy below 32 degrees when it gave up heat by expanding against a piston, and doing mechanical work. What would be then possible?

---

* At Louisville, Ky., U.S.A., described in the transactions of the American Society of Mechanical Engineers.

In the first place, the water of the ocean at 62 degrees might be used as fuel if it were pumped through an evaporator and discharged at 32 degrees, because then 30 degrees of its temperature could be communicated to evaporate such medium, and make the necessary gas or vapour for the engine, instead of requiring the heat to be obtained from the combustion of coal. In the second place, only one-fourth part of the quantity of water at present required for condensing, would be necessary as such fuel; and the coal would be altogether unnecessary.

With all the substances at present known which are capable of being used as the medium in a heat engine, their pressure as a gas or vapour diminishes under expansion in such a different ratio to their reduction of temperature (the range of pressures approaching relatively so much closer to the practical zero of pressure than the range of temperatures does to absolute thermal zero) that, when fully expanded, they still retain so much heat as to require cooling or condensing water to take it away. In the case of air, or so called caloric engines, simply to reduce the volume; in the case of other engines in a lesser way to produce liquefaction of the medium, and in a greater way to reduce the volume.

It is the simplest thing in the world to bring a pound of water at 212 degrees into intimate contact with another pound at 32 degrees, and produce two pounds at say 122 degrees, but it is quite another matter to attempt to separate the commingled waters into two separate pounds at their original temperatures. Will that problem ever be solved? Will a medium ever be found that will enable a heat engine to be run entirely below normal temperatures, as recent statements would imply?

It is no doubt true that the bare suggestion of such propositions, in the light of established theories, lays one open to ridicule. The mere idea, almost but yesterday, would not have been considered worth a second thought; yet, in the light of recent events, it will not be wise to dogmatise as to what improvements are possible in the heat motor of the future. Chemical action, as we understand it, seems to cease at low temperatures, and it may be possible yet to store power by indirect means involving latent chemical action, as well as directly by the use of liquid air.

I hope that both the Sydney University and the Technical College will soon be equipped with appliances in their laboratories to carry out a series of experiments at very low temperatures. That for the Technical College should be made on the College premises, instead of being imported.

It is possible that these aspects of engineering, out of the usual course, may not possess the attraction for members generally which more material and ordinary subjects have, and if I have been rather wearisome in this hasty attempt to indicate possible material for future papers I trust I shall be pardoned.

THE NORTH SYDNEY AND DOUBLE BAY SEWERAGE SCHEMES.

By J. Davis, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, June 21st, 1899.*]

THE NORTH SYDNEY SEWERAGE SYSTEM.

In the year 1882, the sanitary condition of what was then known as North Shore, comprising the old Boroughs of St. Leonards, East St. Leonards, and Victoria, had become so defective that the Minister for Public Works authorised the preparation of a sewerage scheme, and accordingly the late Mr. W. C. Bennett, M. Inst. C.E., who was Engineer-in-Chief for Sewerage at the time, instructed Mr. Bowyer-Smijth, M. Inst. C.E., to deal with the question comprehensively.

The area under consideration being hilly, sloping to the shores of Long Bay (Middle Harbour) on the North, and Sydney Harbour on the South, has ideal facilities for drainage by gravitation to one or the other of its tidal frontages.

Mr. Bowyer-Smijth recommended that provision should be made for collecting and conveying the sewage by gravitation through the hill between Sydney Harbour and Willoughby Bay, to disposal works at the latter place. The total area provided for in the proposal was 350 acres, the length of sewers contemplated 9½ miles. It was suggested that the sewage should be precipitated and filtered before being discharged into the waters of Middle Harbour, and it was estimated the works would cost £60,000.

The surroundings of North Sydney are such that a sufficient area of suitable land, within any reasonable distance, could not be found for broad irrigation, and it was therefore decided that no more satisfactory method could be adopted than precipitation and intermittent filtration.

For this purpose it is certain that a better site could not have been chosen than that at Willoughby Bay, for while not so remote as to entail an expensive length of outfall sewer, the immediate surroundings are so precipitous that the neighbourhood of many buildings is a remote possibility. Moreover there is facility for allowing the sewage to gravitate through every stage of its treatment, thus saving the expense, entailed in many similar works, of pumping.

The necessity of Sewerage works even at that date could not be questioned, as the natural watercourses had become so polluted with sewage, that they were little better than foul open sewers, most dangerous to the health of the people residing along their course, and more especially so where discharging into tidal waters. These evils were worst at Careening Cove and Neutral Bay on the South, and Willoughby Falls Creek on the North.

The question, however, was allowed to remain in abeyance until 1886, when the pressing necessity for immediate action again appears to have asserted itself upon the authorities. By this time, although only four years had elapsed, the population had doubled itself. At the end of the year, at the instance of Mr. Bennett, a further comprehensive and independent investigation was made by Mr. G. H. Stayton, M. Inst. C.E., of the Sewerage Department, and on the data collected a scheme of sewerage was submitted by that gentleman. This scheme though differing in extent and detail from the original proposal, embodied the same principles.

At the suggestion of the Engineer-in-Chief for Sewerage, the Secretary for Public Works moved Parliament to submit this amended scheme to the Parliamentary Standing Committee on Public Works. The evidence taken by the Committee resulted in the recommendation to Parliament that the scheme be carried out by the Government.

The drainage area of the amended proposal was 888 acres, with an existing population of 12,000, and an ultimate maximum population of 30,225, and included 24 miles of main, sub-main and subsidiary sewers.

Mr. Stayton proposed that the sewers should be calculated to discharge the following :—

Sewage, or Dry Weather Flow—50 gallons per head per day.

Rainfall—40 per cent. of 1¼ inches during 24 hours, or 1·26 cubic ft. per minute per acre.

half the daily sewage flow to pass off in four hours.

The growth of the locality has been so rapid, however, that it has been found necessary to extend the scope of the system to the adjacent suburbs of South Willoughby and Mosman, and the outfall works are now designed to treat the sewage from an area of 2,328 acres, divided as follows .—

North Sydney	608 acres.
Mosman (North)	720 ,,
Mosman (South)	727 ,,
South Willoughby	273 ,,
Total	2328 acres.

The altered circumstances permitted the discharge of the sewers to be calculated on the following basis :—

Sewage Flow—·57 cubic ft. per minute per acre.

Rainfall allowance per minute per acre—North Sydney: 1·26 cubic ft.; North Mosman and South Willoughby: ·63 cubic ft.; South Mosman: ·94 cubic ft.,

half the daily sewage flowing off in six hours.

The outfall sewer is therefore designed for a maximum sewage flow of 1,327 cubic ft. per minute, and a maximum combined flow of 3,402 cubic ft. per minute.

The present flow treated at the outfall is about 750,000 gallons per day.

DESCRIPTION OF SEWERS.

The scheme was practically initiated in 1891 by the construction of the main outfall sewer from Milson's Point to Willoughby Bay. This is the principal artery of the system, and has a length of nearly two miles, its highest level at Milson's Point being

40 ft., and its outlet 19½ ft. above the datum, which latter is 1·125 feet above mean high water. The sewer is oval in section, built in concrete, with brick arching round the upper half, and ranges in size from 4 ft. 6 in. by 3 ft. 6 in. to 3 ft. 3 in. by 2 ft. 2 in. The grades vary from 1 in 540 to 1 in 750. The level at the outlet is kept high enough above high water to allow of the sewage passing through its various stages of treatment by gravitation before being discharged into the harbour.

Passing under the high land along Alfred Street, the tunnel in places is 260 ft. deep. The sub-mains, however, are at a lesser depth, their contents reaching the main sewer through drop-pipes built in the sides of segmental shafts. There are twelve of these deep shafts on the main line, substantially built of brick and concrete, which are provided with wrought iron ladders and all appliances necessary to facilitate inspection, flushing, and ventilation.

The sub-mains are either brick and concrete oval sewers or stoneware pipes, varied with the requirements of the area drained. The chief sub-mains in North Sydney are those from Blue's Point and Lavender Bay, and, like the main sewers, these are oval sewers in tunnel through rock.

To intercept the drainage of the southern half of Mosman, a branch sewer, 185½ chains long, is now in course of construction. It will rise near Little Sirius Cove, and, after traversing the harbour slopes as an oviform sewer in tunnel, finally discharges into the main sewer in Alfred Street.

On this sewer a length of 85 chains will be built of pipes constructed on the "Monier" system. The object of this system of construction is to increase the strength of structures by the judicious insertion of iron rods in cement; the effect is to admit of lightness and economical proportion in arches, floors, or other works, as the case may be. On the Mosman sewer, oval pipes 3 ft. 1 in. in length and of 2 ft. 5 in. by 1 ft. 9 in. cross sectional dimensions are to be built on this principle; a lattice of wrought iron is inserted in the cement of which the pipes are formed. The joint is effected by placing neat cement into grooves round each end, and so forming a dowel or tongue.

Under some circumstances the cheapness and speed with which such work can be done renders a great saving of money and time possible, as against the ordinary brick and concrete sewer. In the South Mosman branch the discharging capacity of the sewer did not require it to be over 2 ft. 5 in. by 1 ft. 9 in., and the "Monier" construction enabled the sewer to be built that size, whereas if the ordinary section had been adopted—concrete and brickwork—the smallest size which could be constructed with advantage is 3 ft. 3 in. by 2 ft. 2 in.

A steel arch will carry the sewer, which is in the form of a rivetted steel tube over the head of Mosman's Bay, and other aqueducts are to be built where depressions have to be crossed.

Another branch sewer, the first section of which tenders will be called for in the course of a few weeks, will be constructed to drain the northern or Middle Harbour side of Mosman. This will join the main sewer near its outfall.

The South Willoughby branch, 70 chains in length, is now being constructed, and, like the Mosman branch, will be an oval sewer in tunnel through rock. Here, also, a "Monier" pipe 2 ft. 5 in. by 1 ft. 9 in. is being used, and the remarks made as to the South Mosman branch apply in this case.

The work of reticulation, which has in the main been constructed by the Metropolitan Water and Sewerage Board, has now been finished over a portion of North Sydney, and a large population is already served by the system in that borough. With the completion of the branches to the other suburbs the whole of the area will be similarly connected.

TREATMENT WORKS.

The original method and site of sewage disposal has been practically adhered to, and briefly the process in operation is as follows. After the sewage has passed through screens, to remove the larger floating solids (which are afterwards burnt), it is treated with lime to facilitate precipitation of the suspended matters in the settling tanks. After settlement has taken place, the clearer top liquid flows over a weir situated at and forming the end of the tanks, into an effluent channel which conveys it to filter beds, where it is purified by oxidation and bacterial agencies, and eventually finds its way to the tidal waters as a harmless effluent.

The solids, on the other hand, are deposited in the tanks as sludge, which is drawn off and reduced to sludge cake by forcing the liquid sludge through filter presses. The cake is then burnt in destructor furnaces.

Sufficient land was resumed to enable the tanks and other works to be erected (a plan of which is attached hereto). This, with the portion reclaimed for filtration area, amounts to about 13 acres. The reclaimed portion, about eight acres, was filled in with sand to an average depth of about six feet, and formed into eight filter beds. At the southern end of the resumption, and at the outfall end of the main sewer, the treatment works are situated, comfusing the straining chamber, air compressor engine, filter presses, sludge receivers, and lime mixing apparatus. Adjoining the outlet of the sewer and the building are five large open *settling tanks*, built of concrete with brick lining, of such an aggregate capacity that four will cope with the average daily sewage flow, leaving the fifth as a reserve for an emergency.

Abutting on the settling tanks, and so placed as to receive the deposited solids from them when required, is a *sludge reservoir*, which is a long covered concrete chamber of about 8,100 cubic feet capacity. An open conduit of concrete superposed on the sludge reservoir conveys the sewage to the tanks from the straining chamber in the building. The open *effluent channel*, also of concrete, conveying the effluent floated off from the tanks, runs round two sides of the latter and then passes along the sides of the filter beds. From this the effluent is distributed through offlet valves, and troughing over each bed as required. Willoughby Falls Creek formerly discharged into the head of the bay, and when this was filled in for the filter beds it was necessary to build a stormwater channel to conduct the stream through the reclamation to the tidal waters. This channel is also available as an overflow for the main sewage conduit near the tanks, and relieves the works of any exceptional flow of stormwater during continuous heavy weather. The filter beds are protected on the harbour frontage by a rubble dyke, and a jetty has been provided for the purposes of the works.

Two contracts were let for the construction of the outfall works. One included the preparation of the site for the treatment works, and the formation of the filtering areas and the construction of stormwater and effluent channels. The second contract comprised the erection of the tanks and buildings, as well as the supply and installation of the air compressing machinery and fittings.

The air compressing plant consists of a Tangye horizontal steam engine, type H, which drives a horizontal double-acting air compressor. The air compressing cylinder is 11 in. diameter and 18 in. stroke, with water jacket and all necessary fittings. The inlet valves are opened and the outlet valves closed automatically.

The sewage upon reaching the treatment works first passes through the screening chambers, which are in duplicate. The screens are of wrought iron bars, and can be lifted alternately and cleaned of the floating solids retained, which are burnt in the destructors. The sewage, after screening, flows along a winding channel, where a concentrated solution of lime, prepared in a mixer in the adjoining room, is admitted into the stream. The supply of lime can be regulated according to the flow of sewage. The quantity to be used, which is at the rate of 1 ton for every 1,000,000 gallons of sewage, is shown by a dial indicating the flow of sewage passing into the works from the main sewer.

The sewage next passes through a cast iron rotatory agitator, or churn, embedded in the conduit, and the lime is thereby thoroughly incorporated with the sewage. The agitator and lime mixer are driven by shafting and belting from the engine in the basement adjoining.

The sewage passes from the agitator into an open concrete channel, 5 ft. 3 in. by 3 ft. 3 in., which runs along the whole extent of one side of the five settling tanks at a higher level than the latter. There is an off-let pipe from the conduit into each of the tanks, so that by opening the valves attached, the sewage may be admitted into any of the tanks as required.

Each settling tank has a capacity of 93,750 gallons. All of them are so arranged that one or more can be used continuously, or each may be filled, allowed to rest, and emptied in rotation. It is preferable generally to adopt what is called the "continuous flow" system, that is two or more tanks are used continuously at one time. The present maximum dry weather flow, 750,000 gallons, can be treated in this way by two tanks, the liquid at the surface being floated off continuously over a weir at the end of the tanks. Even during the six hours of maximum flow each day the capacity of two tanks is such that they would be emptied twice only in that time, or once every three hours, a rate quite sufficient to allow of complete precipitation of the grosser solids. Of course during the time of lesser flow, or 18 hours of the day, one tank would be ample for the present discharge, as it would take 4½ hours for the sewage to pass through it.

Four tanks working together in this way would be able to cope with the greatest daily flow. Ultimately, however, when the population increases, additional tanks will have to be provided, and for these ample space has been left.

When, after a few days, the tank becomes foul, it is necessary to empty it into the effluent channel. To ensure that in this process only the liquid portion of the contents of the tanks is removed, a floating arm controlled by a valve has been adopted.

The liquid sludge which remains in the tank passes down the dished and sloped bottom by gravitation into the sludge reservoir adjoining.

The sludge is allowed to gravitate from the reservoir through a 12-in. pipe into two close-rivetted steel cylinders, each of 900 gallons capacity, which are situated immediately under the presses. Lime is again supplied in a suitable proportion to facilitate the pressing of the cake.

Near the sludge receivers, and of similar construction and capacity, is a third cylinder for compressed air, which is supplied from the air compressor at a pressure which for all ordinary requirements averages about 80 lbs. per square inch.

When the sludge receiver is filled, the sludge supply is closed and an inlet valve from the air cylinder is opened. The compressed air exerts a downward pressure on the surface of the sludge, forcing it through a deep pipe which passes up to one or other of the filter presses on the upper floor of the building.

The filter presses were manufactured by Messrs. Manlove, Alliott & Co., of Nottingham, and specially designed for these works. Each press consists of a series of rectangular cast iron plates, each 3 ft. 2 in. square, vertically hanging between and bearing upon the sides of a strong frame in such a way that they can be moved together or apart. Each plate is cast with a 4 in. diameter hole in the centre. At one end of the frame a strong cast iron cylinder is attached into which compressed air can be admitted with the effect of actuating the headstock that bears against the series of plates. To prepare the plates for use each is tightly sewn up in filter cloth, leaving the hole in the centre open.

A small quantity of slack coal is used to start the combustion in the destructors. After a fair start, owing to the greasy nature of the cake (with the coke breeze mixed with it after leaving the press), it burns quite freely, producing a hard clinker quite devoid of the slightest odour.

Steam injectors fed from the boiler are provided to increase the draught in the destructors. The fumes pass round the boiler and over the fire grate before finding their way to a chimney stack 80 ft. in height.

The amount of sludge produced by precipitation, with the present population, would, if the area were all sewered, be about

15 tons a day. At present, however, the quantity is not more than three or four tons.

This amount is greatly reduced by pressing, five tons of wet sludge from the tanks producing only one ton of sludge cake; the difference represents the liquid portion which is extracted by the presses. Fully 90 per cent. of bulk of the wet sludge is water, but the percentage in the cake after pressing is only 55.

The value of the cake as manure is not as well-known or appreciated as in countries where intense cultivation is practised, and it was deemed inadvisable to rely solely for any demand for the product as a means of disposal. On the other hand burning was a method readily available, and, after all, the most *efficacious*.

After the sewage has passed through the filter beds it is collected in its purified state by the underdrains, which are of perforated pipes laid in coke breeze. These converge into an outfall pipe 21 in. in diameter, which discharges into Willoughby Bay slightly above mean spring tide level.

When drain pipes in sand filters have been made sufficiently porous to admit of the effluent passing freely into them, difficulty has been experienced in keeping the sand out.

As the success of the filter beds depended upon both the effluent getting into the pipes and the sand being kept out, before finally deciding the mode to be adopted at Willoughby Bay it was deemed advisable to carry out experiments.

Three tanks were constructed, each 4 ft. deep, and having a combined area of 0·9 of a yard. At the bottom of each tank a glazed perforated pipe was placed, and surrounded with 6 in. of fine breeze coke, the perforations being $\frac{1}{8}$ in., $\frac{3}{16}$ in., and $\frac{1}{4}$ in. diameter respectively. The boxes were then filled with sand to within a few inches of the top. Each tank formed a miniature sand filter, and as no sewage was available, the city water was laid on to them.

The water, which was measured by meter, was turned on at 3.30 p.m. on Friday, 10th December, 1897, and at 11.12 a.m. on Saturday the meter recorded 2,245 gallons as having been used. The rate of flow would therefore be 120 gallons per square yard per hour, or say 13,939,200 gallons per acre, when it was found a very small quantity of sand passed through the coke into the pipes. The $\frac{1}{8}$ in. and $\frac{3}{16}$ in. had given slightly the best results.

The experiments were continued to 28th December, 1897, and quantities varying at the rate of from 4,250,000 gallons per acre per day, to 14,907,200 gallons, when practically no sand was carried into the pipes.

As, therefore, not more than one-tenth of the smaller quantity, 4,250,000 gallons per acre per day, would ever be put into the filter beds at Willoughby, it was, the Author thinks, safely assumed that *(a)* the perforations and coke surrounding the pipes would permit of the effluent entering the pipes faster than required, and *(b)* that with the maximum flow of sewage at the rate of say 400,000 gallons per acre per day, no sand would be carried into the effluent pipe.

The Author finally decided to adopt the $\frac{3}{16}$ in. perforations, as no more sand passed through these than the $\frac{1}{8}$ in. perforations. It is also thought that the presence of the coke round the pipes will have the effect of preventing the growth of fungi in the perforations.

The principles which underlie the purification of sewage by intermittent downward filtration need no justification on the part of the Author. The highest scientific and practical evidence has firmly established the efficiency of this method based, as it is, on natural processes.

It is only, therefore, necessary to mention that in the North Shore works the main features of the most modern system of filtration have been adopted.

Each filter bed is in reality a bacterial hot bed, where, through chemical changes, brought about by micro-organisms, the organic impurities of the sewage, which constitute its chief danger, are broken up into harmless forms.

About two-thirds of the suspended solids, organic and otherwise, are left behind as sludge in the settling tanks, and the surface of the filter beds retains most of the remainder, and thus the first function of the bed is to some extent a mechanical one, but it is the organic matter in solution, and the finer particles in suspension, particularly which are chemically and biologically dealt with and rendered inocuous in the bed itself.

The sewage as it sinks through the sand clings in a thin film over every particle, exposing an enormous surface to oxidation.

Air is drawn into the beds during each period of æration by the sinking of the sewage itself, and by that means the action of the nitrifying micro-organisms is facilitated.

Sand, though not primarily as rich in such organisms as a good garden soil, soon becomes an excellent filter capable of cleansing the sewage, which has previously been subjected to precipitation, of as many as 8,000 persons per acre, if intermittently applied and the bed is sufficiently rested. On that basis the present filtration area, 8 acres, will provide for a maximum population of over 60,000 persons.

The treatment works having only recently been put into operation there has hardly been time to procure an analysis of the effluent, but it is hoped one will be available for the information of the section at the next monthly meeting.

TEST OF EFFICIENCY OF PLANT.

On the 6th and 7th June, 1899, tests were made of the machinery.

On the first day the boiler only was being fired, and ½ ton of slack coal was consumed in 10 hours. During this time the sludge presses were running, and the engine, therefore, was driving compressor and lime and sewage mixers. On the second test, again for a period of 10 hours, the boiler and one destructor furnace were being fired, consuming together ¾ of a ton of slack coal. The sludge presses were also in operation, and the engine was driving compressor and lime and sewage mixers. The coal used for each day included that used for lighting up. The extra coal used on the second day was required to start the destructor furnace.

Indicator diagrams were taken of the compressor and engine under varying conditions, viz. : (1) Full load driving compressor and lime mixer. (2) Light load, engine driving lime mixers and shafting only.

In each case a constant pressure of 80 lbs. per square inch was maintained in the receiver, and a steam pressure of 80 lbs. per square inch on the boiler.

DOUBLE BAY LOW LEVEL SEWERAGE.

Obviously the object to be attained in the construction of the sewerage of Sydney and suburbs has been to provide means of carrying the sewage off quickly and conveniently, and prevent it flowing into the Harbour on the North, and Cook's River on the South.

A small portion of the country to be drained is below the level of the gravitation sewers which discharge at Ben Buckler, Cook's River, and Arncliffe, and has, therefore, to be lifted by pumping or other means to the higher level.

Double Bay being one of these low lying areas, the sewage is raised by means of Shone's Hydro-pneumatic Ejectors through delivery mains into the Darling Point branch of the Bondi main sewer.

These works have just been completed under the supervision of the Author, and they form the subject of this portion of his paper.

The Double Bay low level zone, which comprises 77·4 acres after roads, reserves, etc., have been deducted, affords facilities for the adoption of the Shone system, as it is flat and sufficiently large to warrant a separate air compressing plant being erected.

It is 6 or 7 feet above mean high water, and the sub soil is peat and sand heavily water charged.

It may, therefore, be seen that many difficulties were met with in sinking the ejector chambers, and laying the sewers and mains, but such difficulties would have been magnified had a pumping scheme been adopted. In such a scheme a proper self-cleansing grade in the sewer would only have been obtained at the expense of a deep pump well and a correspondingly high lift to the gravitation sewer, and the cost of constructing the sewers would have been thereby greatly increased.

The Shone system, on the other hand, with shorter and smaller sewers laid at lesser depths and fair gradients, and dealing with the sewerage by independent ejector stations had everything to recommend it.

The system was designed upon the following basis :—

1. Drainage area, 77·4 acres (nett).
2. Population, 30 persons per acre.
3. Total prospective population, 2,323.
4. Sewage allowance per head per day, 50 gallons.
5. Proportion of rainfall admitted to the sewers, 2 in. per 24 hours, on an area of 200 square ft. per head.
6. The average daily dry weather flow, therefore, would amount to 80·62 gallons per minute.
7. The sewers are designed to carry off half the dry weather flow in four hours, together with the rain water.
8. The maximum combined flow would be 577·8 gallons per minute.

The following table gives in convenient form the data upon which the sewers, rising mains, ejector and air compressing machinery were designed.

The estimated maximum H.P. required is 8·83, and assuming the efficiency of the whole system as 35 per cent. the indicating H.P. at the Generating Station would be 25½.

For the purposes of the scheme the area was divided into four sub areas, each having an ejector station and collecting well into which the gravitation sewers discharge.

The total length of the sewers laid is 8,117 ft., comprising 7,829 ft. of 6 in. and 288 ft. of 9 in. pipes. The grades vary from 1 in 200 on the level ground to 1 in 20 on the slopes bounding the area, while the velocities range from 1½ to 2 ft. per second with the sewage flow. Automatic flushing stations are provided in suitable positions which will have the effect of increasing the velocities to about 5 ft. per second, a sufficient rate to cause thorough flushing.

TABLE I.

From Ejector Station	To Ejector Station.	Number of Acres.	Estimated Prospective Population Connected with each Ejector Station.	Gallons per minute			Ejectors.		Size of Sewage Sub-Main, to Delivery Main, in Inches.	Size of Delivery Main, in Inches.	Size of Air Main, in Inches.	Length of Sewage Main, to Delivery Main, in Yards.	Length of Delivery Main, in Yards.	Length of Air Main, in Yards.	Approximate Velocity in Sewage and Delivery Main (Feet per Second).	Dead Lift, in Feet.	Friction in Sewage Main, to Delivery Main, in Feet.	Friction in Delivery Main, in Feet.	Friction in Air Main, in Feet.	Total Lift, including Friction in Air and Sewage Mains, in Feet.	H.P. Corresponding to Maximum Lift.
				Maximum Dry Weather Flow.	Volume of Rainfall.	Combined Maximum Discharge.	Number.	Capacity of Each.													
1	2	11	330	34·37	47·75	82·12	2	50	4	—	3	273	—	273	3	38·96	7·40	—	0·89	55·02	1·37
2	3	42·25	1,268	132	183·37	315·37	2	150	6	8	3	5	119	154	3	38·67	0·48	2·36	0·61	47·53	4·54
3	4	12	360	37·50	52·06	89·56	2	50	4	9	3	336	185	119 336	3	38·96	10·83	3·06	1·61	56·81	1·54
4	Outfall	12·16	365	38	52·75	90 75	2	50	4	9	3	220	101	405	3	38·96	7·28	2·35	1·72	50·31	1·38
Total		77·41	2,323	241·87	335·93	577·8															8·83

Ejector station No. 1 is at the intersection of Pelham and Cross Streets; No. 2 at the corner of Cross and Bay Streets; No. 3 in William Street, near Double Bay; and No. 4 on the Marine Parade, near Ocean Street.

At each station the Shone's Hydro-pneumatic Ejectors are in duplicate, one ejector being ample to deal with the maximum sewage flow, while the pair working together are capable of discharging the maximum combined flow of rainfall and sewage.

At stations Nos. 1, 3, and 4 the ejectors are each 50 gallons capacity, and at station No. 2, 150 gallons.

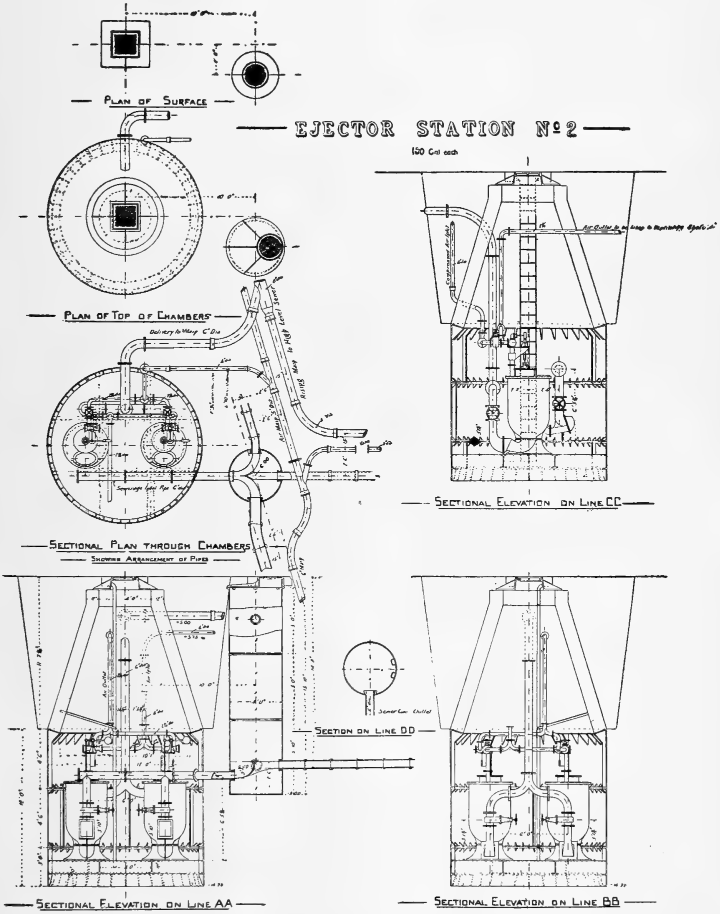
The ejector stations and collecting wells alongside are of cast iron. The collecting wells are 4 ft. diameter, of $\frac{3}{4}$ in. metal, and receive the sewage from the different collecting sewers. The ejector chambers are 10 ft. diameter, except No. 2, which is 12 ft. They are constructed of cast iron segmental plates 1 in. thick, bolted together through vertical and horizontal flanges, strengthened by gussets. The bottom section is strengthened by cross girders of H section bolted to a wider flange running round the cylinder 12 in. from the bottom.

After the cylinders were sunk to the required depth, the bottom was filled in with concrete between the H girders. To these the ejectors are secured.

The upper portion of the chamber, being above the water level. is composed of concrete which sits on the top flange of the cylinder. It is built with a decreasing diameter finishing at 4 ft. 6 in. at the surface. This allows sufficient room to remove the ejectors if required for repairs. The opening is closed with a cast iron manhole door.

Ventilating shafts are provided near each collecting well to carry off the sewer gas. The ventilation at these shafts is materially assisted by the discharge of the exhaust air from the ejectors through a nozzle into the shafts.

The air and delivery mains are of cast iron, the Normandy joint being used in the air mains, and ordinary spigot and faucet in the delivery mains. The Normandy joints have proved to be highly satisfactory, no leaks were discovered when these mains were tested. Both the air and delivery mains are in sections, so that any branch can be cut out in case of an accident. Means are provided for emptying the delivery mains into the sewers when repairs have to be effected.



The air compressing station is situated off Bay Street, near Swamp Street, and is a one storey building of brick with sandstone facings, and roofed with tiles. The engine room is 39 ft. by 23 ft. 9 in., and the accumulator room 23 ft. by 21 ft. There is also an office 9 ft. by 7 ft. 6 in.

MACHINERY.

At present the air compressing plant consists of two Parker continuous current shunt wound motors actuating two air compressors. Space has been left for the duplication of this machinery when an extension of the sewerage system requires it.

The motors are each capable of developing 25 H.P. at a speed of 470 to 500 revs. per minute, when supplied with a current pressure of 500 volts. One motor is, therefore, when running at full speed, capable of performing the whole work.

By arrangement with the Railway Commissioners, the electrical energy is supplied through a 19/16 in. cable from the power house at Rushcutter's Bay at a cost of 1⅓d. per B.T. unit.

The air compressors are similar in every respect to that at Willoughby Bay.

The air receivers are of mild steel, with segmental ends, 4 ft. 6 in. internal diameter, and 9 ft. high. They are fitted with manholes and dead weight safety valves, regulated to blow off at 35 lbs. pressure.

The inlet and outlet pipes are 6 ft. diameter, the former extending upward in the centre of the vessel about 5 ft., and the latter has its mouth protected by a cast iron baffle. The spray water by these means is separated from the air and discharged by a trapped drain pipe in the usual way.

The motors and compressors, by working in parallel or series, can be run at half or full speed. To accomplish this, and also to ensure the safe starting of the motors against a maximum load, a series-parallel controller has been designed, which allows the current at starting to pass through a series of resistances, which are cut out step by step.

As the work to be performed is so variable, necessitating the air compressor being run to suit the flow of sewage, it was considered prudent to introduce means by which, when the pressure had either risen or fallen between certain fixed limits, the machinery would be automatically stopped or started.

The maximum pressure decided on was 30 lbs., and the minimum 22 lbs , the latter being the smallest pressure which would lift the sewage from the ejector stations to the gravitation main, and the former being as high as the pressure could be economically used. Moreover, when the pressure rises above 30 lbs. per square inch, it seriously affects the working of the valve gear in the ejectors. It became necessary, therefore, that the series-parallel controller should be automatically governed, so that the pressure should be maintained between these two limits. In order to effect this the air pressure is admitted to either end of a small cylinder, the prolongation of the piston rod of which is a toothed rack, which engages a pinion on the head of the controller spindle. Immediately above this rack there are a series of stops cut on the bar to which the rack is fixed. These stops correspond exactly with the different positions the series-parallel controller must stop at when cutting the resistances out step by step. The bar carrying these stops passes round a die plate, so arranged that only one stop can pass through the plate, the next being unable to do so until the die plate has moved either up or down, as the case may be. The motion is given to the die plate by means of two small hydraulic cylinders, which allow it to slowly travel up or down. The effect is that while the die plate is slowly travelling up or down, as the case may be, immediately the stops referred to coincide with the opening in the die plate the pressure of air in the cylinder forces the stop through the plate, and thereby the rack actuates the controller. The pauses necessary for cutting out the resistances are thus secured.

This mechanism is regulated by a valve which is constructed to rise at the 22 lbs. pressure, and fall at the 30 lbs., and admit the air pressure on either end of the air cylinder, and simultaneously the water pressure on one hydraulic cylinder, and exhaust from the other.

There is one other detail to be thought of in stopping and starting the machinery, namely, the circulating and spray water. A small air cylinder, which is regulated by the valve referred to above, works an equilibrium valve placed in the water service.

By this means the water is turned off or on when the machinery stops or starts.

STORAGE BATTERY.

A storage battery has been installed, consisting of 230 Epstein cells. The primary duty of this is to provide power to run the plant at night when the tramway plant is not available, and, in the second place, during ordinary running to reduce the drop in the line between Rushcutter's Bay and Double Bay.

The battery is always switched on, so that when the machinery is running the motors obtain their energy partly from that and partly from the line. As soon as the motors are stopped the batteries start charging, making up for what has been used whilst running. In addition to the advantages derived in this way from the battery, it was possible to materially reduce the area of the cable.

SWITCH BOARD.

A switch board is provided with all the necessary fittings, including recording ammeter, voltmeter with connection to line or battery, ammeter to each motor, polarised battery ammeter, and all the necessary quick break switches, polarised battery, cut out plug fuses, and electric light circuit connections.

QUANTITY TO BE PUMPED.

Taking the average annual rainfall at 51·522 inches, the quantity of sewage and rainfall to be pumped would amount to 54,846,137 gallons per annum, and the h.p. hours expended, taking the efficiency of the whole plant as 34·8 per cent., would be 35,371. The cost of electrical energy would therefore be £147 7s. 6d. per annum, and the cost (including energy, wages, and 6 per cent. per annum on capital cost for repairs and renewals) of lifting 1,000 gallons would amount to 5·688 pence with present population, and 3·991 pence with future population.

EFFICIENCY TESTS OF PLANTS.

In order to obtain efficiencies of the plant, tests were made under ordinary working conditions on February 13th, 14th, 15th and 16th, with one air compressor and all the ejector stations working.

TABLE II.

DOUBLE BAY LOW LEVEL SEWERAGE.

Result of Test of Efficiency of Plant taken over a period of 2 hours 20 minutes, February 16th, 1899.

EJECTORS.									COMPRESSORS.							LINE.			EFFICIENCIES.						
Station.	Capacity in Gallons.	No. of times discharged.	No. of Gallons each Station discharged.	Dead lift in feet.	No. of Foot-pounds of Work done per Station—omitting Friction.	Total No. of Gallons lifted.	Total No. of Foot-pounds of Work done.	Total Horse-power hours of Ejectors.	No. of Compressors.	Dia. of Piston in inches.	Dia. of Piston Rod in inches.	Revs. per minute.	Pressure in Receiver.	Mean total I.H.P.	Total Horse-power hours of Compressor.	Total No. of B.T. Units used =	Total No. Horse-power hours.	Loss on Line.	Efficiency on Line.	Efficiency of Motors and Shafting.	Efficiency of Compressor.	Efficiency loss through drop in temperature.	Nett results efficiency of Motors and Compressor.	Loss of efficiency in Ejectors and through friction in air and Delivery Mains.	Resultant Efficiency.
No. 1	50	127	6,350	38.96	2,845,054	26,050	11,734,423	5·85	1	11	1·5	50	20 lbs. per sq. ins.	5·65	13·18	12·6	16·8	4·6%	95·4%	87%*	90%	96%	79%	54%	34·8%
No. 2	150	74	11,100	38.67	4,936,225																				
No. 3	50	98	4,900	38.96	2,195,396																				
No. 4	50	74	3,700	38.96	1,657,748																				

* NOTE.—This figure was obtained at Full Load, and would be reduced during test, while Efficiency of Compressor would be relatively increased.

Each day before starting a man was placed at each ejector station to count and keep tally of the number of times the ejector discharged, from the time of starting to the finish of each trial; and, the capacity of ejectors being known, the number of gallons of sewage discharged by each station could be readily computed. From this and the total left, the work performed was obtained.

The compressor was kept going at a uniform speed of 50 revolutions per minute, which maintained an average air pressure of 20 lbs. per square inch in the receivers.

Indicator diagrams were taken off the compressor at intervals, in order to obtain the average indicated horse power developed.

On starting the plant each day the reading of the Watt meter at Double Bay station was taken when the air pressure had risen to 15 lbs. per square inch, and simultaneously a reading was taken of the Watt meter at Rushcutter's Bay generating station. Readings were also taken of both Watt meters at the end of the day's trial. By this means a record was obtained of (*a*) the electrical energy which left the generating station at Rushcutter's Bay (*b*), the loss of energy in the line, and (*c*) the energy used by the motors at the Double Bay power station.

The loss of efficiency, due to drop in temperature, was obtained under normal working conditions by taking the temperature of air leaving the compressor and at each ejector station.

On the first day the trial was taken for a period of two hours, on the second day two hours, and on the third day one hour twenty-five minutes.

On each of these days it was found that Nos. 3 and 4 stations were pumped out shortly after starting, as there was not sufficient sewage flowing into them to keep them working continuously for the same period as the other ejectors.

On the following day the flushing stations and a couple of hydrants were turned into the sewers, and by that means a constant flow was maintained, enabling all the ejectors to work continuously during two hours and twenty minutes. The conditions, therefore, under which the latter test was made were more satisfactory than the first three, and the efficiencies which are given in the above table were based upon this day's results.

It may be mentioned that when taking these tests with one compressor at 50 revolutions per minute, the plant was practically developing only one-quarter of its full power.

With the maximum quantity of sewage to be lifted, necessitating both compressors running full speed, the efficiencies would be higher.

In conclusion, the Author desires to acknowledge the very able assistance and loyal support he has invariably received in the preparation of the designs and construction of the works dealt with in this paper, from Messrs. Millner, Assoc. M. Inst. C.E., and Cutler, Assistant Engineers of the Sewerage Construction Branch of the Department of Public Works.

For a general plan of outfall works see PLATE I.

THE MANUFACTURE OF MONIER PIPES.

By F. M. Gummow.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, June 21, 1899.*]

The development of the combination of concrete and iron for the purpose of obtaining the maximum strength with a minimum of material, and at the same time manufacturing an article light, easily handled, and cheap, has led to the establishment of a factory in Sydney for the purpose of making concrete-iron pipes.

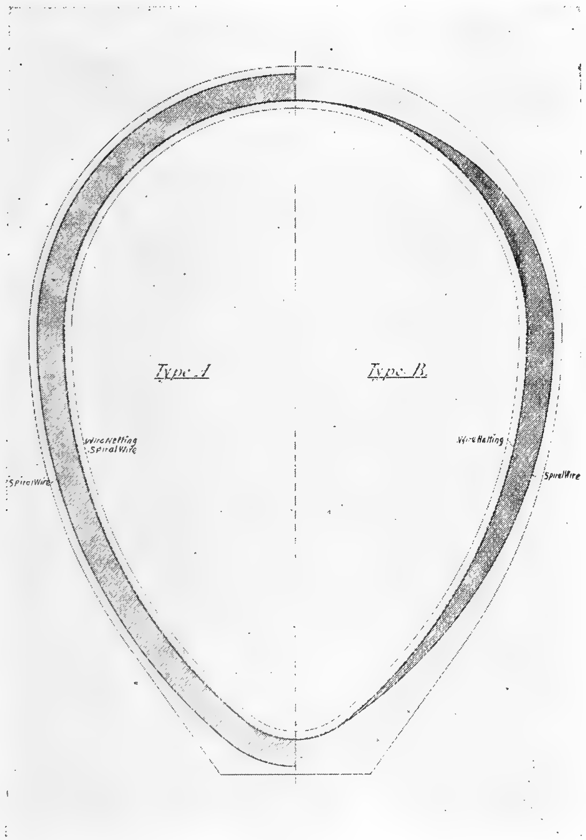
These are of varying dimensions and shapes, and are used for sewerage work, stormwater-drains, as sheathing for piles, cylinders for bridges, etc.

It is a well-known fact that pipes under pressure are subjected to tensile strains on the inner and outer surfaces alternately. In order to take up these strains, and at the same time produce a pipe with the minimum of thickness and a maximum of strength, it is necessary to augment the tensile strength of the cement-mortar by the use of iron, which in this case takes the shape of a spiral wire. The spiral wire is either concentric—and, in case two of them being used, one is placed near the inner and the other near the outer surface (Type A)—or eccentric, in which case one spiral wire is sufficient, passing alternately from the inner to the outer surface of the pipes, as shown on the diagram (Type B).

The pipes are made with a flat bottom, to ensure better packing when laid, and also to make sure that the pipe is placed in the proper position as designed.

A *resumé* of the process of pipe manufacture may be briefly stated thus:—

The pipe machine consists of a framework of iron or timber, with the necessary appliances for revolving the iron sockets, into which a spindle and drum are horizontally placed, allowing of a rotary motion, fast or slow, and maintaining them in any position required.



The drum is of light steel, collapsible, and closed at the ends by wooden discs, which serve—

Firstly,—To support the steel drum, and give the same the required shape.

Secondly,—As a connection between the drum and the spindle.

Thirdly,—As a gauge for the thickness, and as faceboards for the pipe.

The drum, after being oiled to prevent the cement adhering to it, is coated with a thin cement grouting, over which is spread a layer of cement-mortar. This layer is well consolidated with wooden floats, and roughened to receive the next layer.

A netting is next strained round the cement-mortar and fastened off, over which is wound a spiral wire (Type A). The whole surface is then grouted, and a second layer of cement-mortar is put on and worked as previously described to about $\frac{3}{8}''$ from the full thickness of the completed pipe, and then a second spiral wire is wound round as before.

This surface is then grouted, and a third and final layer of cement-mortar is put on, well consolidated, and the pipe finished off to its required thickness.

In the manufacture of pipes with only one spiral wire (Type B), the operation is slightly different, in so far that after placing the netting round the first coating the surface is grouted and the second layer is put on, but in such a way as to form an eccentric shape, around which the spiral wire is wound, and the third and final layer is then put on, and the pipe finished off.

Immediately upon completion the pipe, drum, and spindle are lifted out of the sockets and placed in a vertical position on a truck, and removed to any convenient place; a second drum is then placed in position, and the process repeated. The finished pipe is left for about three days on the drum, then taken off the truck, the ends of the drum removed, and the steel lining, which is collapsible, extracted without difficulty.

The inner surface of the pipe is then rubbed, and if considered necessary, "bagged" over with cement and left ready for sale.

A number of tests have been made by the Sewerage Department of New South Wales demonstrating the great strength and elasticity of the pipes. Even when badly fractured under a heavy load during testing, they still were able to sustain the load placed on them without collapsing, and after removing the load they partially recovered their original shape, thus showing the elastic nature of such a construction.

The pipes are made in convenient lengths, from 1′ 9″ to 5′ 0″ in diameter, with thicknesses varying from 1⅜″ to 2⅜″ respectively. In comparing their weight with those of earthenware pipes, it is found that they are slightly lighter, an earthenware pipe of 2″ diameter weighing 2cwt. 1qr. 21lb., while a pipe of the former description, of similar length and diameter, weighs only 2cwt. 1qr. The simplest form of jointing is made by butting the pipes, and placing outside a bandage netting embedded in cement-mortar ; other joints are also used to suit circumstances.

Large numbers of these pipes have already been used in New South Wales.

"LE PONT VIERENDEEL."

A NEW TYPE OF BRIDGE,

By J. I. HAYCROFT, M.I.C.

[*Read before the Engineering Section of the Royal Society of N.S. Wales, September 20, 1899.*]

PROFESSOR VIERENDEEL, of the University of Louvain, who is also Engineer-in-Chief and Director of Technical Service in Western Flanders, has recently written a work called "Longitudinals with trellis, and Longitudinals with arcades," which presents some novelties in Bridge design.

The writer proposes to extract from that work sufficient to explain the method of calculation and peculiar properties of a bridge, shown by Fig. 1, which, to all intents at first sight, is a plate girder with portions of the web removed between the vertical stiffeners.

Prof. Vierendeel, hereafter referred to as the Professor, states that the metal trellis owes its origin to the American wooden truss, and that, whilst the Americans have preserved the articulation which existed in these trusses in their present practice with pin connections, European engineers have abandoned the articulation in favour of rigid rivetted connections.

Whilst the bad effect of rivetting lattice bars is great, still the Professor says the bad effect of pin connections is greater still. It is in the nature of things that there should be rigidity in metal structures and articulation in wooden ones. Originally trellis girders had multiple systems, but during the last 25 years the systems have been reduced by only employing the bars, actually necessary, and so the triangular trellis has eventuated.

Such bridges are calculated on the hypothesis that the intersections of the latticing, and the flange are articulated. Now, whilst this is allowable in the case of a pin-connected bridge, it is not only incorrect in the case of a rivetted structure, thereby leading to an erroneous conclusion, but through it no account is taken of the secondary stresses due to the bending which arises from the rigid connections.

A method of arriving at the value of these secondary stresses has been devised by Mauderla in 1880*, who bases his system on the hypothesis of the perfect fitting of the lattice bars with the flanges, or, in other words, the invariability of the angles, under different conditions of loading, of the lattice bars between themselves. In order to reduce these secondary stresses to a minimum, Continental engineers have advocated and designed trellis girders with redundant members ; such have been erected on the Rotterdam-Amsterdam Line, of 323 feet span.

French Government engineers have investigated the question during the years 1893-94, and as a result advocate the use of multiple trellis, approaching as near as possible a plate girder.

The Professor, however, states that these solutions are not the proper ones for the purpose of getting over the difficulty due to secondary stresses, and believes that the true solution will be found, not in the complication, but the simplification of the trellis, that is by doing away with all diagonals and reverting to a type which he calls rectangular. The Professor states that in a triangular trellis the diagonal is indispensable if the intersections are articulated, but are redundant, and therefore useless if they are rigid.

The Professor claims three advantages for his type over all other types, as follows :—

1st. Theoretic advantage, in that all calculations can be made without recourse to any hypothesis, and, further, that the calculation is incomparably more simple than that based on the theory of Manderla.

---

*H. Manderla, Die Berechnung der Sekundärspannungen. Allgemeine Bauzeitung, 1880.

2nd. Technical advantage, that the longitudinals are stronger, less sensible to dynamic effects, less exposed to the action of rust, and less subject to dislocations than trellis girders; all these tend to greater durability.

3rd. Commercial advantage, which the Professor states may reach 25% reduction of cost over a trellis Bridge equally strong.

Some of the disadvantages which the Professor states pin-connected trusses suffer under, and from which his design of Bridge is free, are as follows:—

Complications in carrying out the articulations, the adjusting and arrangement of the pieces, at least 4, at each intersection; complications connected with the cross-girders and wind bracing, due to the fact that they should be fixed on the vertical central line of the articulations in a rigid manner, and so as not to interfere with the articulations; the insecurity which results from the use of forged pieces (an operation which always debases the metal), or from welded joints, which even the most experienced operator can neither verify or guarantee the results of; the wear, which after a lapse of time, is produced in the articulation, and the resulting mobility in the entire framework, by which the dynamic effects of the line load is greatly increased.

The writer, whilst endorsing the Professor's criticisims of rivetted trusses, does not agree with his strictures on American trusses, as though such strictures may have been justifiable in former years, nowadays such objections are only theoretic.

The writer is also surprised at the practice of Continental engineers using redundant members in Bridge trusses, though aware such were employed in other structures, notably the Eiffel Tower.

Let Fig. 1 represent the side elevation of portion of a girder with parallel flanges. Throughout the description H is taken as the vertical distance between the centres of gravity of the flanges, and D is the distance between the axes of the verticals.

Cross girders are fixed on the centre line of each vertical, either on top or bottom.

Fig 1

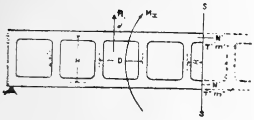


Fig 2

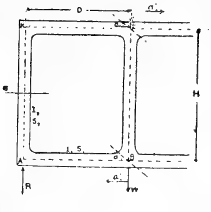


Fig 3

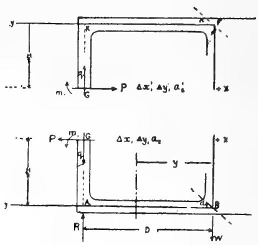


Fig 4

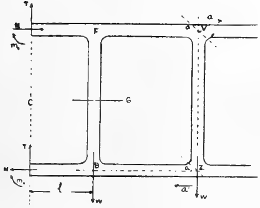


Fig 5

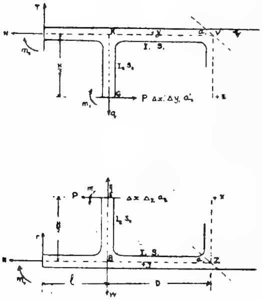
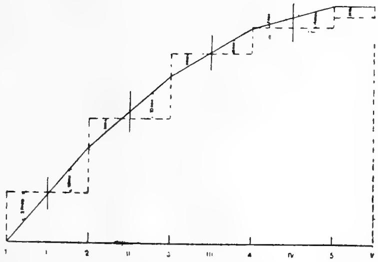


Fig 6



Scale for Longitudinal 0m01 per mètre
Moments 0m001 per 2000 kgmètres

Fig 7

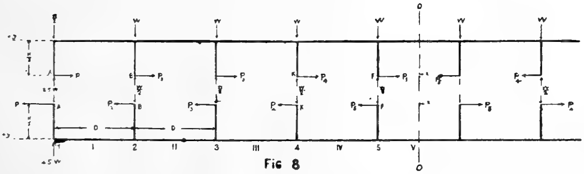
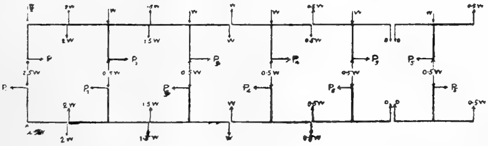


Fig 8



Let any panel be cut by a vertical section S at a distance x from the nearest left-hand vertical; the external forces applied at this section can then be represented by their resultant R, and their moment Mx; the internal forces in each flange can be represented by their horizontal and vertical components applied at the centre of gravity of each flange, and their moment in reference to the same point. Thus, in the upper flange there is a horizontal force N', a vertical force T', and a moment m'. Similar quantities referred to the lower flange are respectively N'', T'', m''.

The several forces at this section being in equilibrium, the following relations exist:—

(1) $N' + N'' = 0.$

(2) $R + T' + T'' = 0.$

(3) $Mx + N'' H + m' + m'' = 0.$

Equation (1) shows that the horizontal components are equal, but of opposite signs; either of them may be designated N.

Equation (1) is also true when the section S is not vertical, so long as its trace does not intersect the axis of a vertical within the boundary lines of the girder; thus N is constant throughout the length of either flange included between the axes of any two adjoining verticals.

The above equations can be replaced by the following:—

(2) $R + T' + T'' = 0$

(3) $M'x + N H + m' + m'' = 0.$

There are here two equations and five unknowns; the three equations wanted are furnished from the conditions of deformation.

Take the first panel, A K F B, Fig. 2, and consider the loading on the lower flange, *i.e.*, the cross girders are fixed to the lower end of the verticals; the reaction of the support is taken as R.

Let I_1 S_1 be respectively the moment of Inertia and area of cross section of the flanges, and I_2 S_2 corresponding quantities for the verticals.

It should be observed that no hypothesis is made as to the invariability or articulation of the corners of the panel, which is taken as constructed, continuous at the angles.

The axis of the vertical B F, before deformation, is taken as a reference line (during the following investigation, where co-ordinate axes are required, the vertical axes cf the verticals are taken as the axis of x, and the horizontal lines through the centre of gravity of the flanges as the axis of Y.

The lower flange is inclined to the horizontal at B by an angle a_1, due to the deformation of the longitudinal under the influence of loading between the right-hand support and the vertical B F. As the flanges are supposed to be identical, the upper flange is also inclined at angle a_1. Further, the point B, that is, the intersection of the axis of B F with the axis of the lower flange, advances through a distance a', to the left due to the lengthening of the lower flange, and the corresponding F recedes to the right by a similar amount, due to the compression of the upper flange. Now, suppose the end vertical A K cut horizontally at its middle point and the two semi-panels slightly separated, as shown at G, Fig. 3.

The interior forces at the section G are q vertical, P horizontal and a moment m. Now refer the panel to co-ordinate axes and let Δx_1, Δy_1 be the linear displacements of the centre of gravity of G, and a_2 its angular variation as belonging to the lower semi-panel. Δx_1^1, Δy_1^1, a_2^1 are the corresponding quantities for the upper semi-panel.

These six quantities give three equations, thus :—

(4) $\Delta x_1 = - \Delta x_1^1$

(5) $a_2 = - a_2^1$

(6) $\Delta y_1 = \Delta y_1^1$

With the aid of these equations the values of P q and m can be found, thus :—

$$\Delta x_1 = + a_1^1 D + \int_A^G \frac{Q\,dx}{S\,E} + \int_B^G (D-y)\,\frac{M\,ds}{E\,I}$$

E = coefficient of elasticity

Q = direct stress acting on each section of the members

For the lower flange $dx = 0$

$$\therefore \int_A^G \frac{Q\,dx}{S\,E} = \int_B^G \frac{q\,dx}{S_2\,E} = -\frac{q\,H}{2\,S_2\,E}$$

The factor $(D - y)$, where y is the distance from the second vertical, is zero on the line A G, thus to evaluate the effect of M the section B A need only be considered, for which

$$M=(R-q)\,(D-y)-P\frac{H}{2}-m$$

$$\therefore \int_B^G (D-y)\frac{M\,ds}{E\,I} = \frac{1}{E\,I_1}\int_0^D (D-y)\,M\,dy$$

$$=\frac{1}{E\,I_1}\left(\frac{(R-q)\,D^3}{3}-\frac{P\,H\,D^2}{4}-m\frac{D^2}{2}\right)$$

$$\therefore \Delta\,x_1 = a_1^1\,D - \frac{qH}{2\,S_2\,E}+\frac{1}{E\,I_1}\left(\frac{R-q)\,D^3}{3}-\frac{P\,H\,D^2}{4}-\frac{mD^2}{2}\right)$$

The value of $\Delta\,x_1^1$ for the upper semi-panel is similarly found, thus—

$$\Delta\,x_1^1 = -\,a_1^1\,D - \frac{qH}{2\,S_2\,E}+\frac{1}{E\,I_1}\left(\frac{-\,qD^3}{3}+\frac{P\,H\,D^2}{4}-\frac{mD^2}{2}\right)$$

and since $\Delta\,x_1 + \Delta\,x_1^1 = 0$

$$\therefore 2\,qD\left(1+\frac{3\,I_1\,H}{2\,S_2\,D^3}\right)+3\,m-R\,D=0$$

neglecting $\frac{3\,I_1\,H}{2\,S_2\,D^3}$ as being small compared to unity

$$\therefore 2\,qD + 3\,m - R\,D = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

As regards the angular variations

$$a_2 = -\,a_1 + \int_B^G \frac{M\,ds}{E\,I}$$

for the length B A

$$M = -(R - q)(D - y) + \frac{PH}{2} + m$$

and for A G, $M = +P\left(\frac{H}{2} - x\right) + m$

$$\therefore a_2 = -a_1 + \frac{1}{EI_1}\left(-(R - q)\frac{D^2}{2} + \frac{PHD}{2} + mD\right)$$
$$+ \frac{1}{EI_2}\left(\frac{PH^2}{8} + \frac{mH}{2}\right)$$

In the same way

$$a_2^1 = +a_1 + \frac{1}{EI_1}\left(\frac{qD^2}{2} - \frac{PDH}{2} + mD\right) + \frac{1}{EI_2}\left(-\frac{PH^2}{8} + \frac{mH}{2}\right)$$

Since $a_2 + a_2^1 = 0$

$$\therefore \frac{D}{2I_1}(2qD + 4m - RD) + \frac{mH}{I_2} = 0 \ldots\ldots\ldots\ldots(8)$$

Equations (7) and (8) give

$$m = 0 \qquad q = \frac{R}{2}$$

From this we see that at the mid-height of the vertical there is a point of inflexion, and the direct compression equals one half the re-action of the support.

In considering the second panel B F V Z, Fig. 4, let the first panel be cut by a vertical section C at a distance l from the second vertical. Owing to previous investigation it is known that at this section of the flanges there is, as shown, a horizontal force N a vertical force T, and a moment m_1. These are the internal forces resisting the effect of the external forces from C to the left end of the girder.

At B there is a vertical load W due to the cross girder fixed at that point. The line of reference is taken as V Z before deformation.

Divide the vertical B F at its middle point, and slightly separate the two sections as before, Fig. 5, taking the same notation as before

$$\Delta x_1 = a_1^1 D + \int_Z^G \frac{Q\,dx}{SE} + \int_Z^G (D - y)\frac{M\,ds}{EI}$$

$$\int_{Z}^{G} \frac{Q\,dx}{S\,E} = \int_{B}^{G} \frac{q\,dx}{S_2\,E} = + \frac{q\,H}{2\,S_2\,E}$$

$$\int_{Z}^{G} (D - y) \frac{M\,ds}{E\,I} = \frac{1}{E\,I_1} \int_{0}^{D} (D - y) \Big(T\,(l + D - y) + m_1 - (W - q)\,(D - y) - \frac{P\,H}{2} - m \Big)\, dy$$

$$\therefore \Delta x_1 = a_1^1 D + \frac{q\,H}{2\,S_2\,E} + \frac{T\,D^2}{6\,E\,I_1}(3l + 2\,D) + (q - W)\frac{D^3}{3\,E\,I_1} + \left(m_1 - \frac{P\,H}{2} - m\right)\frac{D^2}{2\,E\,I_1}$$

also

$$\Delta x_1^1 = -a_1^1 D + \frac{q\,H}{2\,S_2\,E} + \frac{T\,D^2}{6\,E\,I_1}(-3l - 2D) + \frac{qD^3}{3\,E\,I_1} + \left(-m_1 + \frac{P\,H}{2} - m\right)\frac{D^2}{2\,E\,I_1}$$

Since $\Delta x_1 + \Delta x_1^1 = 0$

$$\therefore \frac{q\,H}{S_2\,E} + \frac{2\,q\,D^3}{3\,E\,I_1} - \frac{m\,D^2}{E\,I_1} - \frac{W\,D^3}{3\,E\,I_1} = 0$$

The displacement $\frac{q\,H}{S_2\,E}$, due to the extension or compression of the vertical B F can be omitted in presence of the double displacement $\frac{2\,q\,D^3}{3\,E\,I_1}$, due to moments of bending, induced by the force q on each of the flanges.

Thus $2\,q\,D - 3\,m - W\,D = 0$...............................(9)

$$a_2 = -a_1 + \int_{Z}^{G} \frac{M\,d\,s}{E\,I}$$

for the line B Z we have

$$\int_{Z}^{B} \frac{M\,d\,s}{E\,I} = \frac{1}{E\,I_1} \int_{0}^{D} \Big(-T\,(l + D - y) - m_1 + (W - q)\,(D - y) + \frac{P\,H}{2} + m \Big)\, dy$$

$$= \frac{1}{E I_1}\left(- T\left(ld + \frac{D^2}{2}\right) + (W - q)\frac{D^2}{2} + \left(- m_1 + \frac{P H}{2} + m\right) D \right)$$

for the line B G

$$\int_B^G \frac{M\, ds}{E I} = \frac{1}{E I_2}\int_0^{\frac{H}{2}} \left(P\left(\frac{H}{2} - x\right) + m \right) dx$$

$$= \frac{1}{E I_2}\left(\frac{P H^2}{8} + \frac{m H}{2} \right)$$

$$\therefore a_2 = - a_1 + \frac{1}{E I_1}\left(- T D\left(l + \frac{D}{2}\right) + (W - q)\frac{D^2}{2} + \left(- m_1 + \frac{P H}{2} + m\right) D + \frac{H}{2 E I_2}\left(\frac{P H}{4} + m\right) \right)$$

Similarly

$$a_2^1 = + a_1 + \frac{1}{E I_1}\left(T D\left(l + \frac{D}{2}\right) - q\frac{D^2}{2} + \left(m_1 - \frac{P H}{2} + m\right) D\right) + \frac{H}{2 E I_2}\left(- \frac{P H}{4} + m \right)$$

Since $a_2 + a_2^1 = 0$

$$\therefore \frac{D}{2 E I_1}(- 2 qD + 4m + W D) + \frac{m H}{E I_2} = 0$$

Inserting the value of equation (9)

$$m = 0 \quad q = \frac{W}{2}$$

There is no necessity to solve for these values in connection with any other vertical, as on investigation similar values would result.

Thus, in every vertical, there is at mid-height a point of inflexion. The stress in the end verticals is always compressive, and equals half the reaction, whilst the stress in all other verticals is tensile, and equal to half the load supposed to act at the end of the cross girder fixed to the vertical.

On investigating the stresses, due to the load being on the top flange, or, rather, to the cross girders being fixed at the top of each vertical, the point of inflexion at mid-height of all verticals will be found still to exist, and the compression in the end verticals will be found equal to half the sum of the reaction of the support added to the weight, due to the cross girder attached on top, whilst the stress in the intermediate verticals will in this case be compressive, but of same value as when the load is on the lower flange.

These results show that the verticals are not affected by the vertical shearing stresses, properly so called.

It now remains to find the several values of P applied at the centre of each vertical in a horizontal direction : Let Fig. 7 represent the semi-longitudinal with its centre at the section o o : divide the longitudinal by a horizontal plane through the centre lines of the verticals and separate the two portions as shown: the condition of stress as far as has been investigated is shown on the figure: all is symmetrical with regard to the centre section o o : that section has experienced neither linear or angular displacement: it is taken as the line of reference, and the half of the longitudinal to the left is referred to the rectangular axis o x and o y as shown. Note: The value of Δy_1 of the section at A, considered as belonging to the lower portion of the longitudinal, is equal and of the same sign as $\Delta y'_1$ of the same section considered as belonging to the upper portion of the longitudinal, a similar equality exists in the sections of the other verticals.

$$\text{Let } W_1 = \frac{W}{2} \text{ and let } P = P_1 + P_2 + P_3 + P_4 + P_5$$

$$\Delta y_1 = \int \frac{Q\,dy}{S\,E} + \int \left(\frac{H}{2} - x\right) \frac{M\,ds}{E\,I}$$

$$E\,\Delta y_1 = \frac{1}{S} \int Q\,dy + \frac{1}{I} \int \left(\frac{H}{2} - x\right) M\,ds$$

The section at F considered as belonging to lower half section is displaced an amount = E d, due to the deformation of the lower flange proceeding from the origin O towards the vertical at F, thus $E\,d = \frac{P\,D}{2\,S_1} - 10\ W_1 \frac{H\,D^2}{4\,I_1} + P \frac{H^2\,D}{8\,I_1}$

Note.—This displacement also effects the other verticals to the same extent. The same section at F is also displaced by an amount $E\,d_1$ due to the deformation of the upper half of the vertical, thus $E\,d_1 = + \dfrac{P_5\,H}{24\,I_2}$

$$\therefore E\,\Delta y_1 = E\,d + E\,d_1$$

$$= \frac{P\,D}{2\,S_1} - 10\,W_1\,\frac{H\,D^2}{4\,I_1} + P\,\frac{H^2\,D}{8\,I_1} + P_5\,\frac{H^3}{24\,I_2}$$

$$= F \text{ say}$$

The displacement of the next vertical to the left

$$= \left(F - P_5\,\frac{H^3}{24\,I_2}\right) + 2\,(P - P_5)\,\frac{D}{2\,S} - 9{\cdot}5\,W_1$$

$$\frac{H^2\,D}{8\,I_1} + 2\,(P - P_5)\,\frac{H^2\,D}{8\,I_1} + P_4\,\frac{H^3}{24\,I_2}$$

$$= K \text{ say}$$

The following is a table of these displacements :—

HORIZONTAL DISPLACEMENT OF CENTRAL POINT OF EACH VERTICAL.

F

$$\frac{P\,D}{2\,S_1} + 10\,W_1\,\frac{H\,D^2}{4\,I_1} + \frac{P\,H^2\,D}{8\,I_1} + P^5\,\frac{H^3}{24\,I_2}$$

$$= P\left(\frac{D}{2\,S_1} + \frac{H^2\,D}{8\,I_1}\right)$$

$$+ 10\,W_1\,\frac{H\,D^2}{4\,I_1}$$

$$+ P_5\,\frac{H^3}{24\,I_2}$$

K

$$F + \frac{H^3}{24\,I_2}\,(P_4 - P_5)$$

$$- 9{\cdot}5\,W_1\,\frac{H\,D^2}{2\,I_1}$$

$$+ 2\,(P - P_5)\left(\frac{D}{2\,S_1} + \frac{H^2\,D}{8\,I_1}\right)$$

C

$$F + K + \frac{H^3}{24\ I_2}\ (P_3 - P_4 - P_5)$$

$$- 22{\cdot}5\ \frac{H\ D^2}{2\ I_1}$$

$$+ 2\ (P_1 + P_2 + P_3)\ \left(\frac{D}{2\ S_1} + \frac{H^2\ D}{8\ I_1}\right)$$

$$+ 3\ (P_1 - 2\ P_5)\ \left(\frac{H^2\ D}{8\ I_1} + \frac{D}{2\ S_1}\right)$$

$$= F + K + \frac{H^3}{24\ I_2}\ (P_3 - P_4 - P_5)$$

$$- 22{\cdot}5\ \frac{H\ D^2}{2\ I_1}$$

$$+ \left(\frac{D}{2\ S_1} + \frac{H^2\ D}{8\ I_1}\right) \left(5\ (P_1 + P_2 + P_3) + P_4 + P_5\right)$$

B

$$F + K + C$$

$$+ \frac{H^3}{24\ I_2}\ (P_2 - P_3 - P_4 - P_5)$$

$$- 28\ W_1\ \frac{H\ D^2}{2\ I_1}$$

$$+ \left(\frac{D}{2\ S_1} + \frac{H^2\ D}{8\ I_1}\right) (7\ P_1 + 7\ P_2 + 5\ P_3 + 3\ P_4 + P_5)$$

A

$$F + K + C + B$$

$$+ \frac{H^3}{24\ I_2}\ (P_1 - P_2 - P^3 - P^4 - P_5)$$

$$- 30\ W_1\ \frac{H\ D^2}{2\ I_1}$$

$$+ \left(\frac{D}{2\ S_1} + \frac{H^2\ D}{8\ I_1}\right)\ 2\ (9\ P_1 + 7\ P_2 + 5\ P_3 + 3\ P_2 + P_5)$$

The values of Δy_1^1 of these sections have the same values, but with contrary signs, hence the equality $\Delta y_1 = \Delta y_1^1$ or $\Delta y_1 - \Delta y_1^1 = 0$ becomes $2 \Delta y_1 = 0$

Then by equating each of the five columns in the table to zero, the following five equations are arrived at :—

$$\left(\frac{H^2 D}{8} + \frac{D I_1}{2 S_1}\right)(P_1 + P_2 + P_3 + P_4 + P_5) + P_5 \frac{H^3 I_1}{24 I_2} = 5 W_1 \frac{H D}{2}$$

$$\left(\frac{H^2 D}{8} + \frac{D I_1}{2 S_1}\right)(3 P_1 + 3 P_2 + 3 P_3 + 3 P_4 + P_5) + P_4 \frac{H^3 I_1}{24 I_2} = 14{\cdot}5 W_1 \frac{H D^2}{2}$$

$$\left(\frac{H^2 D}{8} + \frac{D I_1}{2 S_1}\right)(5 P_1 + 5 P_2 + 5 P_3 + 3 P_4 + P_5) + P_3 \frac{H^3 I_1}{24 I_2} = 22{\cdot}5 W_1 \frac{H D^2}{2}$$

$$\left(\frac{H^2 D}{8} + \frac{D I_1}{2 S_1}\right)(7 P_1 + 7 P_2 + 5 P_3 + 3 P_4 + P_5) + P_2 \frac{H^3 I_1}{24 I_2} = 28 W_1 \frac{H D^2}{2}$$

$$\left(\frac{H^2 D}{8} + \frac{D I_1}{2 S_1}\right)(9 P_1 + 7 P_2 + 5 P_3 + 3 P_4 + P_5) + P_1 \frac{H^3 I_1}{24 I_2} = 30 W_1 \frac{H D^2}{2}$$

From these equations the several values of P_1 P_2 P_3 P_4 and P_5 can be ascertained.

As a particular case the Professor has taken a bridge of 31·5 metres span, as shown on Fig. 7. It is for a single line of railway and the live load is taken as 4,700 kgs. per lineal metre = 1·41 tons per foot; there are nine bays in the girder, the verticals being placed 3·5 m. apart; the cross girders are fixed to the top of the verticals; the weight of the bridge supported by the bearings is given as 62,703 kgs.; the length of each main girder is 32·1 metres and they are spaced 3 metres apart, thus the dead weight at each vertical $= \frac{62703 \times 3{\cdot}5}{32{\cdot}1 \times 2} = 3418$ kgs. and the live load at each vertical $= \frac{4700 \times 3{\cdot}5}{2} = 8225$ kgs., making a total load of say 11600 kgs. = W. The height of each girder between centres of gravity of the flanges is 3 metres, and from what has already been proved the vertical stress on the end diagonals $= 2{\cdot}5\ W = 29$ tons say and on the intermediate verticals $= \frac{W}{2} = 5{\cdot}7$ tons.

The mean values of the moments of Inertia and areas of cross section are taken to apply in the above equations, as they vary but little, but still, if great exactness is required, the actual values can be taken : the mean values in function of a metre are as follows :

$I_1 = 0{\cdot}00158$
$I_2 = 0{\cdot}00134$
$S_1 = 0{\cdot}02350$
$S_2 = 0{\cdot}01890$

Note : The sections are nett.

Substituting these values in the equations we get

$P_1 = 28{,}563$ kgs
$P_2 = 42{,}525$,,
$P_3 = 36{,}827$,,
$P_4 = 15{,}186$,,
$P_5 = 6{,}074$,,

To complete the calculation of stress on this Bridge it is necessary to find the stresses in the flanges : these are got from a diagram of bending moments, Fig. 6. The full line gives the B.M., due to the external loads and internal vertical stresses at each vertical, the moments being taken round the point of inflexion of each vertical.

The dotted stepped line gives the moments of the horizontal reactions at the inflexion point of each vertical. These moments are calculated round either end of each vertical.

The effective Bending moment on each bay of the flanges is equal to the vertical ordinate included between the full line and dotted line : their values, at a distance of one metre on each side of the centre point of each bay of the flange, are written on the diagram.

It should be noted that there is a point of inflexion in each of the three outer panels, very near the centre point of each bay of the flange.

The complete stresses, due to total load wholly distributed, are given in the accompanying tables.

The Bending moments on the verticals, due to the horizontal stresses at their points of inflexion, are calculated about a point 0·75 metres from their point of inflexion, that being the point where the vertical commences to round off to meet the flange. A brief description of these tables may prove useful.

STRESSES ON THE VERTICALS AT A POINT 0·75 M. DISTANT FROM MID-HEIGHT.

	a	b	c	d	e	f	g	h	k
Vertical.	Direct Stress Comprs.	P.	Moment P x 0·75.	S_2 in millim.	$\frac{10^6 I_2}{V}$ in kgs. mtrs.	STRESSES in kgs. per sq. millim.			Stresses in Tons per sq. in.
						Direct.	From Bending	Total.	
1	29,000	28,563	21,450	19,650	4,700	1·5	4·6	6·1	3·9
2	5,800	42,525	31,875	19,650	4,700	0·3	6·8	7·1	4·5
3	5,800	36,827	27,600	19,000	4,400	0·3	6·3	6·6	4·2
4	5,800	15,186	11,400	18,250	4,300	0·3	2·7	3·0	1·9
5	5,800	6,074	4,552	18,250	4,300	0·3	1·1	1·4	0·9

STRESSES IN FLANGES AT POINTS ONE METRE DISTANCE FROM CENTRE LINES (VERTICAL) OF EACH PANEL.

Panel.		a	b	c	d	e	f	g	h
Panel.		Direct Stress from Horizontal Stress at Inflexion Point of Vertical.	S_1 in millim.	Bending Moment from Diagram.	$\frac{10^6 I_2}{V}$ in kgs. mtrs.	STRESSES.			
						Kilos per sq. millim.			Tons per sq. in.
1	Left	28,563	19,200	25,000	4,270	1·5	5·9	7·4	4·7
	Right	28,563	19,200	21,500	4,270	1·5	5·1	6·6	4·2
2	Left	71,088	19,200	12,500	4,270	3·7	3·0	6·7	4·2
	Right	71,088	22,840	23,000	6,200	3·1	3·7	6·8	4·3
3	Left	107,915	22,840	11,000	4,200	4·7	2·6	7·3	4·6
	Right	107,915	22,840	13,000	6,200	4·7	2·1	6·8	4·3
4	Left	123,101	22,840	3,000	6,200	5·4	0·5	5·9	3·7
	Right	123,101	22,840	14,000	6,200	5·4	2·2	7·6	4·8
5	Left	129,175	22,840	9,238	6,200	5·7	1·5	7·2	4·6
	Centre	129,175	22,400	9,238	5,600	5·8	1·7	7·5	4·7
	Right	129,175	22,840	9,238	6,200	5·7	1·5	7·2	4·6

VERTICALS.—Column a are the several values of q. Column e is the moment of resistance of the cross section S_2 in kg. metres for a unit stress of 1 kg. per □ millim. Column f is the direct stress divided by the sectional area $= \frac{a}{d}$ and column g is the bending moment divided by the moment of resistance $= \frac{c}{e} =$ stress in kilos per square millim. Column k is the English equivalent in tons per square inch of column h.

FLANGES.—Column a are the direct stresses, being cumulative from the outer end to the centre. Column d is equivalent to column e in table for verticals. Column $e = \frac{a}{b}$; column $f = \frac{c}{d}$.

Professor Vierendeel states that though this exact and complete calculation of the stresses, as just explained, is neither long nor complicated, there still exists a means of considerably simplifying it without unduly sacrificing practical exactitude in the results. This method is as follows :—

As the diagram of bending moments shows that in each panel (except those near the centre) there is a point of inflexion in each bay of the flanges near their centres, in order to simplify the calculation, as proposed, the Professor acts on the hypothesis that a point of inflection exists at the centre of *each* bay of the flanges. This certainly is practically the case for the end panels, where the secondary stresses have their greatest effect. The Professor points out that this hypothesis is not so grossly incorrect as that used in the case of rivetted lattice girders. By utilizing these hypothetical points of inflexion, and the points of intersection of the verticals and the flanges as the origin of the various moments, the abridged calculation is effected. Fig. 8 shows portion of the longtitudinal cut horizontally at centres of the verticals, and the two semi-portions slightly separated. The various vertical stresses in the verticals can be written on at once. The several values of P are got as follows :—Take, for instance the third panel from the left.

$$P_3\frac{H}{2} + (P_1+P_2)\frac{H}{2} + WD\,(-2{\cdot}5\times 2{\cdot}5 + {\cdot}5\times 1{\cdot}5 + {\cdot}5 + {\cdot}5) = O.$$

$$\therefore\ \ P_3\frac{H}{2} = 4WD - (P_1+P_2)\frac{H}{2}$$

$$\therefore\ \ P_3 = \frac{8WD}{H} - (P_1+P_2).$$

The values of P_1 and P_2 having been ascertained, by inserting their values in this equation ; also $W = 11{,}600$ kg., $D = 3{\cdot}5$ m., and $H = 3$ m.

$$P_3 = 33{,}830 \text{ kgs.}$$

The moments shown vertically at the points of inflexion of the flanges are arrived at by taking moments round the points of intersection of the flanges and the verticals, of all the forces acting to the left of such point. Thus, for the flange in the third panel

$$\pm x_3\frac{D}{2} - 2W\times 3D + \frac{W}{2}\times 2D + \frac{W}{2}D + (P_1+P_2+P_3)\frac{H}{2} = O.$$

$$\therefore\ \ \pm x_3\frac{D}{2} = 4{\cdot}5\,WD - (P_1+P_2+P_3)\frac{H}{2}$$

$$\text{but } (P_1\times P_2+P_3)\frac{H}{2} = 4WD.$$

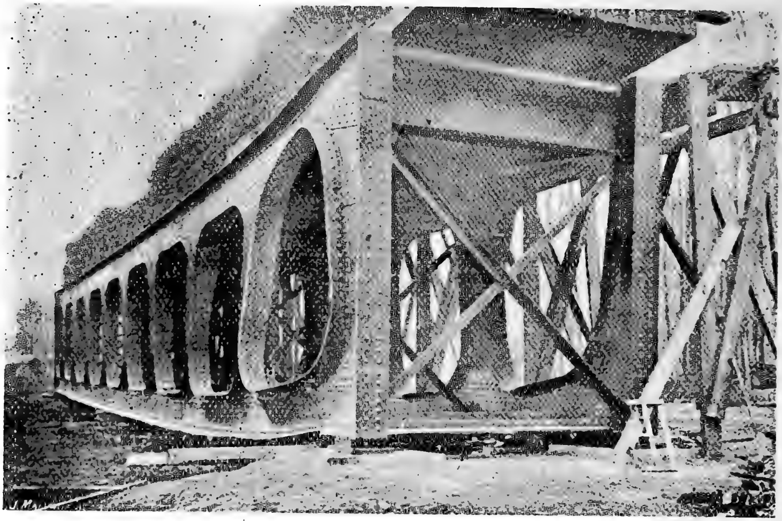
$$\therefore\ \ \pm x_3\frac{D}{2} = WD\,(4{\cdot}5-4) = {\cdot}5\,WD.$$

$$\therefore\ \ x_3 = \pm W.$$

The following are tables showing the results of the abridged method :—

STRESSES ON THE VERTICALS AT A POINT 0·75 M. FROM MID-HEIGHT.

Vertical.	Direct Stress Comprs.	P.	Moment P x 0·75.	S_2 in millim.	$\frac{10\ {}^6I_2}{V}$ in kgs. mtrs.	STRESSES. Kgs. per sq. millim. Direct.	Bending.	Total.	Tons per sq. in.
1	29,000	27,070	20,300	19,650	4,700	1·5	4·3	5·8	3·7
2	5,800	47,370	35,500	19,650	4,700	0·3	7·6	7·9	5·0
3	5,800	33,830	25,400	19,000	4,400	0·3	5·8	6·1	3·9
4	5,800	20,300	15,200	18,250	4,300	0·3	3·5	3·8	2·4
5	5,800	6,770	5,080	18,250	4,300	0·3	1·2	1·5	0·9



STRESSES IN THE FLANGES AT POINTS ONE METRE DISTANT FROM CENTRE LINES (VERTICAL) OF EACH PANEL.

Flange in Panel.	Direct Stress from Horizontal Stress at Inflexion Point of Vertical.	S_1 in millim.	Moment Calculated.	$\frac{10^6 I_1}{V}$ in kgs. mtrs.	STRESSES.			
					In kgs. per sq. millim.			Tons per sq. in.
					Direct.	Bending.	Total.	
1 Left	27,070	19,200	+23,200	4,270	1·4	5·4	6·8	4·3
Right	27,070	19,200	−23,200	4,270	1·4	5·4	6·8	4·3
2 Left	74,440	19,200	+17,400	4,270	3·9	4·1	8·0	5·1
Right	74,440	22,840	−17,400	6,200	3·3	2·8	6·1	3·9
3 Left	108,270	22,840	+11,600	4,200	4·8	2·8	7·6	4·8
Right	108,270	22,840	−11,600	6,200	4·8	1·9	6·7	4·2
4 Left	128,570	22,840	+ 5,800	4,200	5·7	1·4	7·1	4·5
Right	128,570	22,840	− 5,800	6,200	5·7	0·9	6·6	4·2
5 Left	135,340	22,840	0	4,200	5·9	0·0	5·9	3·7
Centre	135,340	22,400	0	5,600	6·1	0·0	6·1	3·9
Right	135,340	22,840	0	6,200	5·9	0·0	5·9	3·7

From a comparison of tables shewing the results according to rigorous and approximate methods, it will be seen that the only practical discrepancy is in the case of the flange stress at the centre of the longitudinal, where the difference amounts to 1·4 Kilos = 0·89 tons, but this could be considerably reduced by preserving the same flange area at that point as on either side of it.

On investigating the case of partial distribution of the live load, it will be found that the greatest increase of total stress due to partial loading on any vertical never exceeds 1 kg. per sq. millim = ·6 tons per square inch, so that by making verticals, 3 4 and 5 of similar cross sections, this difficulty can be surmounted, and the necessity for complete investigation of partial loading obviated.

This concludes the investigation of stresses in a girder with parallel flanges, but Professor Vierendeel applies his system to all shapes of truss. The bridge, with parallel flanges of 31·5 metres span, was erected in the Park of Terveureu, near Brussells, and tested to destruction under the supervision of two engineers from the Department of Roads and Bridges. It failed, as shown on the photograph, under a distributed load of 404 tons.

A short description of the tests may prove interesting. They were carried out during the latter part of 1897, and consisted of two series: During the first test, when 202 tons had been distributed, one of the supports collapsed, and the test load was entirely removed whilst repairs were effected. The second test consisted in placing a load of 150 tons on the bridge, proceeding gradually from one end to the other. This took eight hours, extended over three days, to put in place The second phase of the test consisted of placing 75 tons additional, but applying it equally from each end towards the centre; this took three hours ten minutes to put in place. A second additional load of 75 tons was then placed on the bridge in same manner as last load, taking nearly four hours to put in place; the load then on the bridge was 300 tons. A further loading of 150 tons was then commenced to be placed in position, proceeding equally from the ends. When 366 tons had been put in place, the first signs of rupture became evident. This took place when the bridge was loaded with the last test load, from the ends to the third vertical from each end. Rupture, as shown in the photograph, ultimately took place under a gross load of 404 tons, when the load was wholly distributed, with the exception of the fifth vertical from each end. The deflection which took place were as follows:—The bridge was erected without any camber, and deflected at the centre under its own weight, 13·55 m m. During the first test, under a distributed load of 152 tons, the deflection was increased by 35 m m, and under the 202 tons, when one of the supports failed, the increased deflection amounted to 40 m m.

During this test the load of 152 tons had rested continuously on the bridge for some two months, and when the whole load was removed for repairs to the support, a permanent deflection, due to the load, was observed of 15·5 m m = 0·6 inches.

During the second trial, under a load of 304 tons, the total deflection was 61·75 m m = 2·4 inches.

Professor Vierendeel concludes by saying that he does not pretend to believe that his type of bridge will please everybody, and will not be astonished at its being criticised, as such is the lot of all novelties, but hopes that critics, before giving their opinions, will take the trouble to thoroughly understand the arguments he uses, as, whilst art is difficult, good criticism is also difficult.

DISCUSSION.

During the discussion the following additional information was supplied by the author :—

The bridge, with which Professor Vierendeel compares his truss, is one of a series erected by the Dutch Government over the Meuse, near Nimègue. It was calculated for a range of stress of 4·11 tons per square inch, on nett section, but the Professor points out that this stress is only the primary stress, deduced in the ordinary way on the hypothesis that the intersections of the lattice bars and booms are articulated, whilst the engineer Van der Kolk has shown* that the actual stress arising from combined primary and secondary stresses may amount to from $6\frac{1}{3}$ to $7\frac{2}{3}$ tons per square inch ; yet in the case of the Vierendeel bridge, owing to the secondary stresses being taken account of in the calculation, the stress does not exceed 4·75 tons per square inch. Both bridges were constructed of iron, of what is known in Belgium as No. 3 iron of ordinary quality, the tests on the metal in the Professor's bridge resulting as follows :—Plates, longitudinally, 25·89 tons per square inch ; elongation, 23·5 per cent., and transversely 19·24 tons per square inch, with elongation of $3\frac{1}{3}$ per cent., the angle irons being 22·91 tons per square inch, with an elongation of 7·7 per cent.

Both bridges are single-line deck structures of 103 feet 4 inches span, with a live load of 1·41 tons per lineal foot. The depth of each truss is 9 feet 10 inches, and distance between centre of verticals is 11 feet $5\frac{3}{4}$ inches. The weight of the bridge over the Meuse is 0·64 tons per lineal foot, whilst the Professor's bridge weighs 0·58 tons per lineal foot, or a total weight of 6·81 tons in

---

* Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1889-90.

favour of the latter. It may, however, be noted that were the two bridges designed to withstand the same range of stress, primary and secondary, the comparison in favour of the Professor's bridge would be much more marked; also, that one girder as designed by the Professor would be 3¼ tons lighter than one of the girders in the other design as erected, the former containing 51 more rivets than the latter.

The engineers who superintended the test of the Vierendeel bridge report that the elastic limit was reached when the load (surcharge) was 358½ tons—thus the coefficient of security was 2·1—and that the stress at that moment was about 10 tons per square inch. Actual rupture took place under a surcharge of 396 tons. The Professor, however, taking into consideration the difference in the weights of the deck as constructed to receive the test load and the deck for which the truss was designed, arrives at a factor of 2·52, and the maximum stress at that moment was 9·56 tons per square inch.

As there can be no doubt that the statement of Professor Vierendeel to the effect that stresses arrived at, no matter by what means, which start on a false hypothesis must be incorrect, is absolutely true, perhaps it would be as well to ascertain what has been done by Continental engineers in this matter.

The Dutch Government tested three railway bridges on the Amsterdam-Rotterdam-Utrecht lines, of respective spans of 211 feet, 262 feet, and 324 feet, by means of the well-known apparatus of Manet-Rabut and Fraenkel, in order to arrive at the actual stress of various portions of these trusses under working conditions.

These trusses were of the same type, and may be roughly described as right line lower boom, polygonal upper boom, with counterbracing in each and every bay. The cross girders were not rivetted to the main girders, but so articulated that any bending in the former due to live load would have no influence on the stresses in trellis bars.

The principal results arrived at were as follows:—The recorded stress exceeded the calculated stress by as much as 110 per cent. in the case of the verticals, by 26 per cent. in the compression diagonals, and 52 per cent. in the tension diagonals.

The Dutch Administration have decided, as a result of these tests, that the erection of redundant trusses, such as those tested, was not the practical solution of providing for the secondary stresses, and have reverted to the simple triangular trusses calculated as articulated, but adding 100 per cent. to the calculated stresses in the lattice bars, in order to provide for the effect of the calculated primary and unknown secondary stresses.

French engineers have only investigated this question within the past six years, having tested a double line railway bridge over the Loire, of 14 independent spans, each 190 feet long, the trusses being N trellis, with the cross girders riveted to the verticals. The results were as follows:—An increase of 130 per cent. over calculated stress in the verticals due to secondary stresses, of 70 per cent. in the diagonals, of 93 per cent. in the upper flange.

The conclusion arrived at from these tests was that the best type was the close-lattice girder.

As regards Switzerland, it will be remembered that in June, 1891, the bridge at Mönchenstein, on the Jura-Simplon Line, collapsed, under ordinary working conditions, after a life of 16 years. The Swiss Government ordered an investigation to be made as to the cause of collapse by Professor Collignon and A. Hamer, Engineer-in-Chief of the Roads and Bridges in France. These experts reported, *inter alia*, that the defect was not due to any defect in design or execution, or to quality of the iron; the cause was, in fact, abnormal, and probably due to some hidden defect in the metal, which, however, when tested, showed no sign of fatigue, the results being as follows:—Breaking weight in 1874, 24 tons per square inch, whilst in 1891 it reached $24\frac{2}{3}$ tons per square inch, the elongation in 1874 being 7·46 per cent., whilst in 1891 it was 8 per cent.

Owing to the uncertain nature of this report, the Swiss Government determined to test to destruction a bridge of the same age as the one which collapsed, and the same type, viz., Warren or trellis in V, but of a somewhat stronger construction. This was the single line railway bridge over the Emme, at Wolhusen, of 157 feet span. During the test it was found that under a loading of one and a third times the load used in calculating the bridge stresses the limit of elasticity had been exceeded. The working stress used in the calculation was 4½ tons per square inch.

Ultimately, this bridge collapsed suddenly, through the rupture of the connection between a compression bar and the upper boom, when the test load was only twice that used in the calculation.

To sum up, if in the case of a riveted lattice truss, and one on the Vierendeel principle, the stresses be arrived at by the ordinary method of supposing the joints articulated, in the former the stresses will be at least 60 per cent. less than the actual stress; whilst in the latter, the calculated stress will equal or exceed by 5 per cent. the actual stress. This fact lends great weight to Professor Vierendeel's design, as, whether the latter be calculated on the false hypothesis of articulation or the exact method, certainty of result is attained, and thereby what an engineer should aim at, security for the structure.

Mr. J. Bowman gave results of an approximate comparison between an ordinary plate girder bridge with parallel flanges, and the test bridge mentioned in the paper, being altogether in favour of the plate girder. The weight of bridge under discussion (which failed under an external distributed load of 404 TONS), is given as 62,703 kilos = 61·14 TONS.

The weight of plate girder bridge for same span, and which will not be stressed beyond the elastic limit of 10 TONS per square inch under the ultimate load of 404 tons above, is only 40 TONS.

It is obvious that by developing the parabolic upper flange in place of the parallel flange assumed, the weight could be reduced even below 40 TONS. The depth of plate girder is great, in order to give stiffness; but, even so, it is only as deep as the Vierendeel bridge, and the flange area is greater than might be necessary, owing to the expediency (in construction) of putting three plates in the centre half, then two for the $\frac{1}{8}$-length outside that, and one plate at the ends of flanges.

WEIGHT OF PLATE GIRDER, 103·35′ SPAN.

	□′	Lbs.	Tons.
Web, $\frac{3}{8}''$ × 9·75′ × 105·32′	1026·87	15·3	7·00
Flange plates, 10″ × $\frac{1}{2}''$ × $({}^1/_{52}, {}^1/_{80}, {}^1/_{105\cdot32}$ $= {}^1/_{237\cdot32}$	237·32	17·0 × 2	= 3·60
Flange angles, 2/3$\frac{1}{2}''$ × 3$\frac{1}{2}''$ × $\frac{1}{2}''$ × 105·32′	210·64	11 0 × 2	= 2·00
Stiffeners (outside), 21/9′ × (5″ × 3$\frac{1}{2}''$ × $\frac{1}{2}''$ Tee)	205·80	13·6	1·25
Stiffeners (inside), 21/8·5 × (5″ × 3$\frac{1}{2}''$ × $\frac{1}{2}''$ Tee)	178·50	13·6	1·08
End Posts, 2 plates, 10″ × $\frac{1}{2}$ × 9·75′	19·50	17·0	0·14
,, 4 angles, 3$\frac{1}{2}''$ × 3$\frac{1}{2}''$ × $\frac{1}{2}''$ × 9·75′	39·00	11·0	0·19
Cross girders, 23/15″, I beams 9·8′ long	225·40	50·0 × $\frac{1}{2}$	= 2·50
Rail bearers, 2/105 32′ 15″ I beams	210·64	25·0 × $\frac{1}{2}$	= 1·18
			18·94
Add 5% for rivet heads	...	...	... 0·96
	Total tons	...	**19·90**

Say **20 tons.**

∴ Whole bridge = 20 × 2 = 40 tons.

Deflection under full load of 202 × 20 = 222 tons.

I = 160,600. E = 13,000 tons.

$$f'' = \frac{5 \times 222 \times (03\cdot35' \times 12)_3}{384 \times 13{,}000 \times 160{,}600} = \mathbf{2\cdot64''}$$

Sectional area of flange at centre—

Plates, 3 × 10″ × $\frac{1}{2}''$ = 15 sq. in.

Angles, 2 × (3$\frac{1}{2}''$ × 3$\frac{1}{2}''$ × $\frac{1}{2}''$) = 6·5 sq. in.

Add $\frac{1}{6}$ web area $\frac{1}{6}$ (117″ × $\frac{3}{8}''$) = 7·3 sq. in.

28·8 sq. in.

$$\text{Stress in flanges} = \frac{W\ L}{8\ D} = \frac{222 \times 103\ 35'}{8 \times 9\cdot75'} = \mathbf{294\cdot15}\ \text{tons}$$

Stress per sq. in. flanges $= \frac{294\cdot15}{28\cdot8} =$ **10·21 tons** per sq. in.

Shearing stress—

Area of Web $= 117'' \times \frac{3}{8}'' = 44\,\square''$

Shearing Force $= \frac{222}{2} = 111$ tons.

Shearing stress per sq. in. $= \frac{111}{44} =$ **2½ tons** per sq. in.

The Author in Reply.

Mr. Bowman's comparison of the plate girder, as designed by himself, and the bridge referred to in the paper by the Author, by which the former is shown to be equally strong, but some 50 per cent. lighter than the latter, is erroneous, as the following statement will prove.

The weight of the bridge as tested was 62,703 kgs. = 61·45 tons made up as follows :—

(1) 2 main girders ... ... = 31·75 tons.
(2) Cross girders, rail bearers, diaphragm stiffeners and wind bracing ... ... = 16·76 tons.
(3) Decking of corrugated iron, etc. = 9·80 tons.
(4) Oak planking on footpaths = 3·14 tons.

Total ... ... 61·45 tons.

Mr. Bowman does not include items (3) or (4) at all, and only portion of item (2), though, of course, his design is incomplete without the stiffeners and wind bracing.

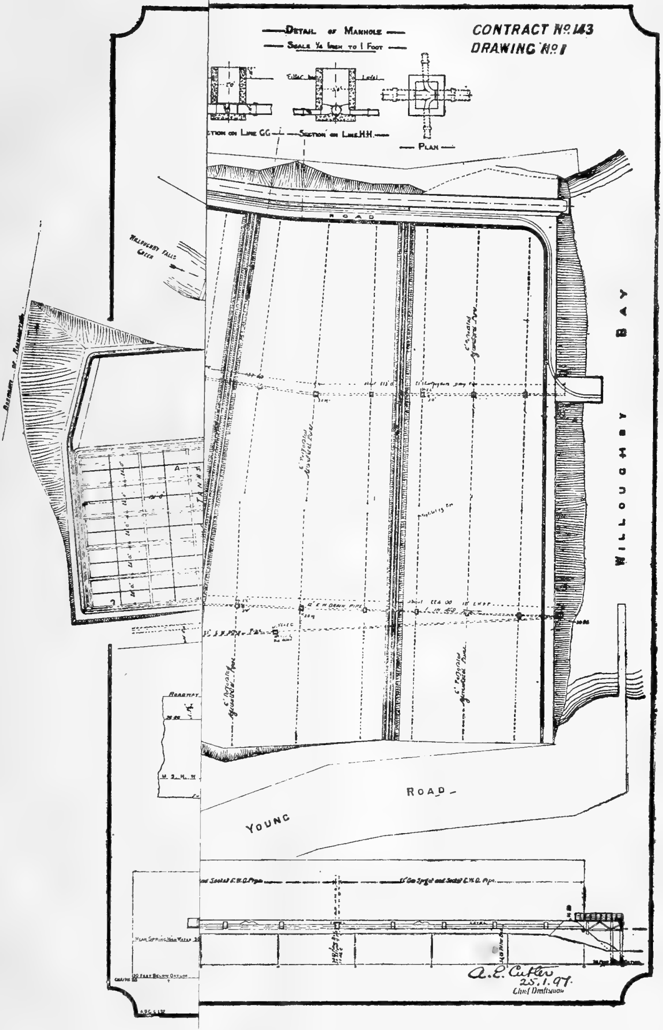
According to Mr. Bowman one of his main girders would weigh 15·26 tons, whilst the Vierendeel girder weighs 15·87 tons.

The latter bridge had flange plates 12·6 inches wide, whilst Mr. Bowman's were 10 inches, thereby necessitating, in the latter case, heavier diaphragm stiffeners, and owing to continuous web surface of Mr. Bowman's design, heavier windbracing than in the case of the Vierendeel girder. Had these facts been taken into consideration, it will be readily seen that Mr. Bowman's girder would be the heavier of the two when *properly* designed instead of, as stated, 50 per cent. lighter.

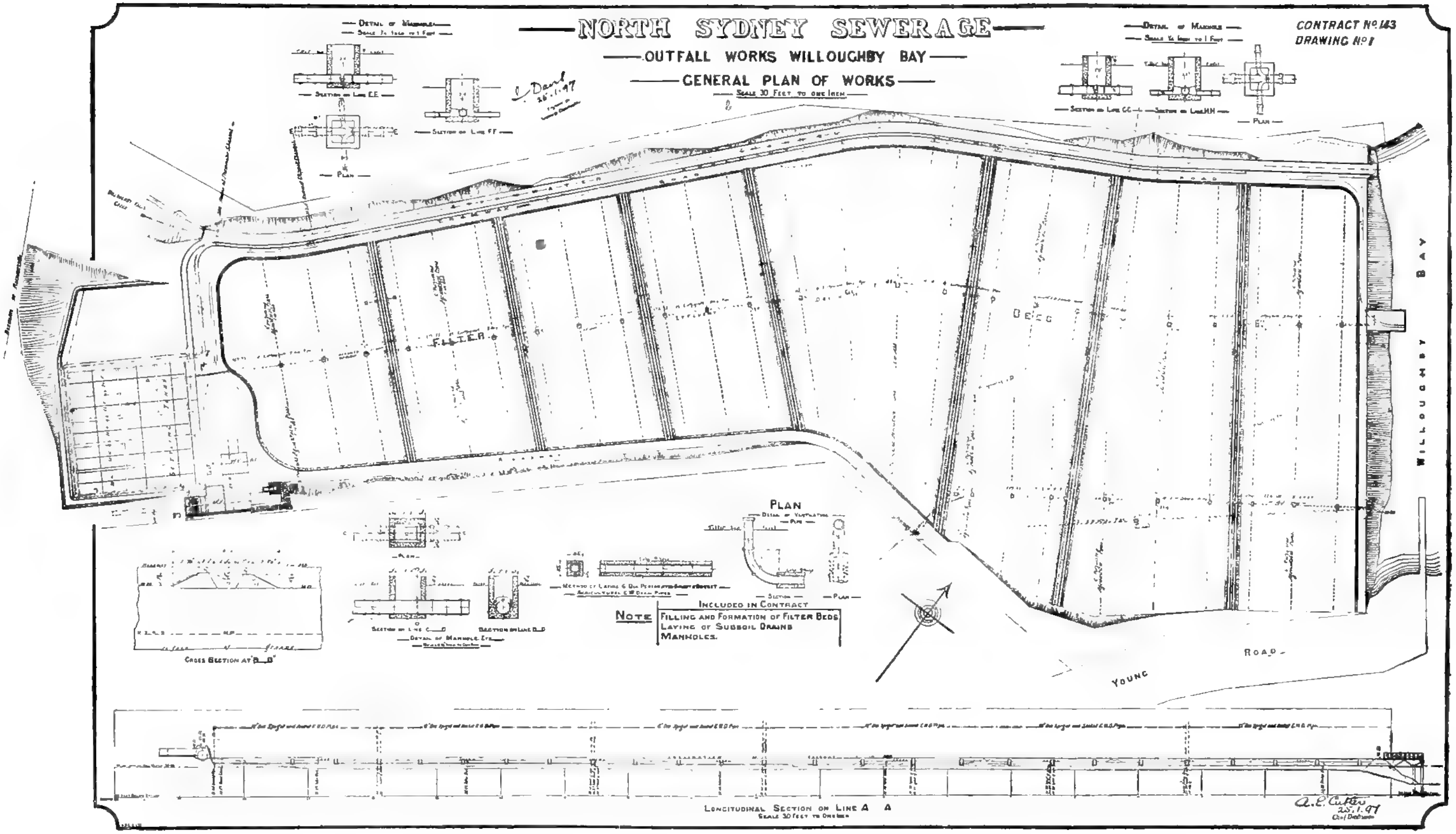
The *raison d'etre* of Professor Vierendeel's bridge has entirely escaped Mr. Bowman's notice. As shown by the author, the Professor's object was to prove the superiority of his design as regards correctness of ascertained stresses over rivetted lattice girders in ordinary practice. This, the Author considers, he has effectively done. Professor Vierendeel's truss does not compete with ordinary plate girders, which are rarely constructed of 100 feet span, but with lattice girders of that and greater spans. Had Mr. Bowman designed a rivetted lattice truss of same span as the Professor's, and been able to demonstrate its superiority in weight saved, under equal loadings and same range of stress, he would have accomplished something. As it is, he has done nothing beyond showing how unstable a truss may be designed.

ol. XXXIII., 1899. **PLATE I.**

ion.)



(Engineering Section)



INDEX.

A PAGE

Aboriginal Bora Ceremony xxvii.
—— tribes Queensland, divisions of ... ... 108, xxi.
Aborigines of Port Stephens, N.S. Wales, initiation ceremonies of 115
Abstract of Proceedings ... iii.
Address to Engineering Section I.
Analysis of Eudesmol 98
—— of topazes 203
Anchylostomum duodenale ... 225
Anniversary Address ... 1, ix.
Anopheles musivus, Skuse ... 62
Antarctic Exploration ... ... viii.
Anthropological and Ethnological Section xxvi., xxxi., xxxix.
Australian mosquito 48

B

Baker, R. T., F.L.S., on the *Darwinias* of Port Jackson and their essential oils 163, xliii., xliv.
Bancroft, Thos. L., M.B. *Edin.*, on the metamorphosis of of the young form of *Filaria Bancrofti*, Cobb, in the body of *Culex ciliaris,* Linn. 48, xiv.
Bastow, R. A., Key to tribes and genera of the Florideæ (Red or Purple Marine Algæ) ... ... 45, xiv.
" Belah " timber ... xli.
Books purchased in 1899 ...lxiv.
Boiler inspection ... ... III.
Bora ceremony ... ... xxvii.
Bridge, new type of ... XXXVIII.
Bubonic Plague in 1141 B.C. lxxii.
Building and Investment Fund iv.

C

Cineol 104
Clarke Memorial Fund... ... v.
Comet I. 1899 (Swift), orbit elements ... ... 177, xlv.
Consumption, sanitorium treatment of ... ... lxxiii.
Conversazione, informal ... xli.
Copper ores containing iodine 160
Corney, Hon. B. G., M.D., Note on the edible earth from Fiji 224, xlix.
Crystalline camphor of eucalyptus oil (eudesmol) and the natural formation of eucalyptol ... ... 86, xix.
Culex annulirostris, Skuse 61
—— *ciliaris,* Linn. ... 48, 49, 61
—— *hispidosus,* Skuse 61
—— *nigrithorax,* Macquart ... 62
—— *notoscriptus,* Skuse ... 61
—— *procax,* Skuse 62
—— *vigilax,* Skuse 61
Current Papers No. 4 ...145, xxxiii.

D

Dacite from Fiji 225
Darwinias of Port Jackson 163, xliii.
Darwinia fascicularis, A. Rudge 163, xliii., xliv.
—— *taxifolia,* A. Cunn .. 164, xliv.
Dasya villosa 47
David, Prof. T. W. E., B.A., F.G.S. Discovery of glaciated boulders at base of Permo-carboniferous system, Lochinvar, N.S. Wales ...154, xxxiii.
—— Records of rock temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain ... ... 207, xlvii.
—— Note on the edible earth from Fiji ... .. 224, xlix.
Davis, J., M. Inst. C.E., The North Sydney and Double Bay Sewerage Schemes XI., lxix.
Deane, H., M.A., M. Inst. C.E., Suggestions for depicting diagramatically the character of seasons as regards rainfall, and especially that of droughts ... ... 63. xvii.
Dermatitis exfoliativa neonatorum ... ... lxxii.
Dibromide of Eudesmol ... 99
Dick, J. Adam, B.A. *Syd.*, M.D. *Edin.*, on Bubonic Plague in 1141 B.C.... ... lxxii.

PAGE

Dieseldorff, Arthur, M.E., on N. S. Wales copper ores containing iodine .. 160, xliv.
Divisions of some Aboriginal tribes, Queensland 108, xxi.
Donations xi., xv., xviii., xxii., xxix., xxxv., xli., l.
Double Bay Low-level Sewerage XI., XXIII.
Drought-intensity, determination of ... ... 69, xx.

E

Edible earth from Fiji .. 224, xlix.
Engineering Section 3, vi., lxix.
Enright, W. J., B.A., The initiation ceremonies of the Aborigines of Port Stephens, N.S. Wales... ... ...115, xviii.
Essential oils of the *Darwinias* of Port Jackson 163
Eucalyptol ... ... 86, xix.
Eucalyptus amygdalina ... 90, 91
—— *camphora* 88, 95, 96
—— camphor ... ...86, 93, xix.
—— *citriodora* 170
—— *Dawsonii* 88
—— *dextropinea* 88
—— *dives*... ... ... 88, 91
—— *elæophora* 88
—— *eugenioides* 90, 91, 92, 94, 103
—— *globulus* ... 87, 94, 95, 102
—— *goniocalyx* 87, 94
—— *lævopinea* 88
—— *macrorhyncha* 88, 90, 92, 93, 94, 95, 96
—— *microcorys* 88
—— *piperita* ... 86, 90, 93, 94, 95
—— *radiata* 88
—— *Smithii* ... 87, 90, 94, 95
—— *stricta* 88
Eudesmol ... 86, 93, 95, xix.
Exchanges 4
Exhibits xiv., xviii., xxi., xxvii., xxviii., xxxiv., xxxv., xl., xli., xlix., l.

F

Fiji edible earth ... 224, xlix.
Filaria Bancrofti... ... 59, xiv.
—— *immitis* ... ... 55, xiv.
—— *nocturna*, Manson 48, 60, 61, xiv.
—— *sanguinis hominis*, Lewis 48, xiv.
Financial position ... 4, iii.

PAGE

Florideæ, Key to tribes and genera of ... ... 45, xiv.
Fluorine, estimation of 193, xlvi.

G

Gangamopteris spathulata, McCoy 157
Glaciated boulders at base of Permo-Carboniferous system, Lochinvar, N.S. Wales 154, xxxiii.
Gummow, F. M., on the manufacture of Monier pipes XXXIV., lxix.
Guthrie, F. B., F.C.S., Note on the edible earth from Fiji 224, lxix.

H

Hargrave, L., Sailing birds are dependent on wave-power... 125
Harker, G., B.Sc., on the composition of N.S. Wales Labradorite and topazes, with a comparison of methods for the estimation of fluorine 193, xlvi.
Haycroft, J. I., M.I.C.E.I., "Le Pont Vierendeel," a new type of bridge XXXVIII., lxx.
"House mosquito" of Australia 48

I

Iceberg in the Australian Bight 149
Initiation ceremonies of the Aborigines of Port Stephens N.S. Wales ... .. 115, xviii.
Iodine in N. S. Wales copper ores ... ... 160, xliv.

K

Kerry, Charles H., An Aboriginal Bora Ceremony illustrated by a series of photographs ... ... xxvii.
Key to tribes and genera of the Florideæ, "Red or Purple Marine Algæ" ... 45, xiv.
Kiddle, Hugh Charles, F.R.Met.Soc., on a remarkable increase of temperature after dark at Seven Oaks, Macleay River 204, xlvi.
Knibbs, G. H., F.R.A.S., Anniversary Address ... 1, ix.

PAGE

Knibbs, G. H., F.R.A.S., Observations on the determination of drought-intensity 69, xx.
—— Some applications and developments of the prismoidal formula ... 129, xxxvi., lxx.

L

Labradorite from N.S. Wales... 193
Land Boiler Inspection ... III.
“ Le Pont Vierendeel ” XXXIIIV., lxx.
Library 4
‘Liquid Air,’ ... ...xxxix., lxx.
Liversidge, Prof. M.A., LL.D., F.R.S., lecture on Liquid Air lxx.

M

Mathews, R. H., L.S., Divisions of some Aboriginal tribes, Queensland .. ... 108, xxi.
Marine Algæ, red or purple 45, xiv.
Medical Section... 3, xiii., lxxi.
Members, Corresponding (xxiii.)
—— Honorary .. ... (xxiii.)
—— Obituary 1899 ... (xxiii.)
—— Ordinary ... ... (xi.)
Merfield, C. J., F.R.A.S., Orbit elements Comet I. 1899, (Swift) ... ... 177, xlv.
Metamorphosis of the young form of *Filaria Bancrofti*, Cobb 48
Monier pipes, manufacture of XXXIV., lxix.
Mosquito, Australian 48

N

National Antarctic Expedition viii.
New Zealand and Antarctic Exploration... ... ... viii.
North Sydney Sewerage Scheme XI.
N.S. Wales copper ores containing iodine ... ... 160, xliv.
—— Labradorite ... 193, xlvi.
—— topazes ... ... 193, xlvi.

O

Obituary 1898 ... ... 1, 2
—— 1899 ... ... (xxiii.)
Observations on the determination of drought-intensity 69
Ocean currents 150
Orbit elements Comet I. 1899, (Swift) ... ... 177, xlv.
Original Researches 4

P PAGE

Papers read in 1898 ... ... 2, 3
Periodicals purchased in 1899 lxiii.
Pittman, E. F., Assoc. R.S.M., Records of rock temperatures at Sydney Harbour Colliery Birthday Shaft, Balmain 207, xlvii.
Prismoidal formula 127, xxvi., lxx.
Proceedings of the Engineering Section ... ...lxix.
—— Medical Section ... ...lxxi.
—— Society ... ... iii.

Q

Queensland, divisions of some Aboriginal tribes 108

R

Rae, J. L. C., Records of rock temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain ... 207, xlvii.
Rapid drift of current papers .. 146
“ Red Stringybark ” 88
Remarkable increase of temperature after dark ... 204, xlvi.
Retina of the ox’s eye ... ... xli.
Roberts, Sir Alfred, obituary notice... 2
Rock temperatures ... 207, xlvii.
—— in various places 223
Royal Geographical Society, London, letter from ... vii.
Rules, proposed alteration of xxxii., xxxix.
Russell, H. C., B.A., C.M.G., F.R.S., Current Papers No. 4 145, xxxiii.

S

Sailing birds dependent on wave-power .. .. 125, xxvi.
Sanitorium treatment of consumption ... ... lxxiii.
Science, influence of, upon civilisation ... ... 4, ix.
Sectional Meetings ... 3, vi., xiii.
Selfe, Norman, M. Inst. C.E., M.I. Mech.E., Annual Address to the Engineering Section ... I., lxix.
Sewerage system of Sydney lxxii.
—— schemes for North Sydney and Double Bay ... XI. lxix.
Shales with erratics 158
Smail, J. M., M. Inst. C.E., on the Water Supply and Sewerage Systems of Sydney... lxxii.

PAGE

Smith, Henry G., F.C.S., on the crystalline camphor of eucalyptus oil (eudesmol) and the natural formation of eucalyptol ... 86, xix.

—— on the *Darwinias* of Port Jackson and their essential oils ... ... 162, xliii., xliv.

Smoke nuisance in Sydney ... II.

Spencer, Walter, M.D., on an outbreak of Dermatitis exfoliativa neonatorum lxxii.

Steam Dredge "Hunter" ... I.

Stokes, Sir George Gabriel, Bart F.R.S., M.A., D.C.L., Jubilee xiii., xxvi.

Strata, Birthday Shaft, Sydney Harbour Colliery 211

Suggestions for depicting diagrammatically the character of seasons as regards rainfall, and especially that of droughts... ... 63, xvii.

PAGE

Sydney Harbour Colliery 207, xlvii.

T

Temperature, remarkable increase of ... ... 204, xlvi.

—— rock... 207

Thinnfeldia narrabeenensis 213, 216

—— *odontopteroides* ... 215, 216

Tick fever ... ... lxxii.

Tidswell, Frank, M.B. *Syd.*, D.P.H. *Camb.*, on Bubonic Plague in 1141 B.C. ... lxxii.

Topazes, N. S. Wales 193

W

Water supply system of Sydney lxxii.

Wave-power, sailing birds dependent on 125

Sydney:
F. W. White, Printer, 39 Market Street.
1900.

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

EDITED BY

THE HONORARY SECRETARIES.

FOUN. 1821. INC. 1881

PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 Warwick Square, Paternoster Row, London, E.C.
1900.

CONTENTS.

VOLUME XXXIII.

PAGE.

OFFICERS FOR 1899-1900 ... ... (vii.)

LIST OF MEMBERS, &c. ... ... (xi.)

ART. I.—PRESIDENT'S ADDRESS. By G. H. Knibbs, F.R.A.S. ... 1

ART. II.—Key to Tribes and Genera of the Florideæ (Red or Purple Marine Algæ). By Richard A. Bastow. (Communicated by J. H. Maiden, F.L.S.) (*Plates* i., ii.) 45

ART. III.—On the metamorphosis of the young form of *Filaria Bancrofti*, Cobb, [*Filaria sanguinis hominis*, Lewis; *Filaria nocturna*, Manson], in the body of *Culex ciliaris*, Linn., the "House mosquito of Australia" By T. L. Bancroft, M.B. 48

ART. IV.—Suggestions for depicting diagrammatically the character of Seasons as regards Rainfall, and especially that of Droughts. By H. Deane, M.A., M. Inst. C.E., &c. (*Plate* iii.) 63

ART. V.—Observations on the determination of Drought-intensity. By G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney 69

ART. VI.—On the crystalline camphor of Eucalyptus Oil (Eudesmol), and the natural formation of Eucalyptol. By Henry G. Smith, F.C.S., Technological Museum, Sydney 86

ART. VII.—Divisions of some Aboriginal Tribes, Queensland. By R. H. Mathews, L.S. 108

ART. VIII.—The Initiation Ceremonies of the Aborigines of Port Stephens, N. S. Wales. By W. J. Enright, B.A. (Communicated by R. H. Mathews, L.S. 115

ART. IX.—Sailing Birds are dependent on Wave-power. By L. Hargrave 125

ART. X.—Some applications and developments of the Prismoidal Formula. By G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney 129

ART. XI.—Current Papers, No. 4. By H. C. Russell, B.A., C.M.G., F.R.S. (*Plates* v., vi.) 145

ART. XII.—Discovery of Glaciated Boulders at base of Permo-Carboniferous System, Lochinvar, New South Wales. By Professor T. W. E. David, B.A., F.G.S. (*Plate* iv.) 154

ART. XIII.—On New South Wales Copper Ores Containing Iodine. By Arthur Dieseldorff, M.E., Freiberg, Baden, Germany. (Communicated by A. J. Bensusan, Assoc. R.S.M., F.C.S.) ... 160

CONTENTS.

PAGE

ART. XIV.—On the *Darwinias* of Port Jackson and their Essential Oils. By R. T. Baker, F.L.S., Curator, and H. G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney ... 163

ART. XV.—Orbit Elements Comet I., 1899 (Swift). By C. J. Merfield, F.R.A.S. 177

ART. XVI.—On the composition of N. S. Wales Labradorite and Topazes with a comparison of methods for the estimation of Fluorine. By G. Harker, B.Sc. (Communicated by Prof. Liversidge, M.A., LL.D., F.R.S.) ... 193

ART. XVII.—On a remarkable increase of temperature after dark at Seven Oaks, Macleay River. By Hugh Charles Kiddle, F.R. Met. Soc., Public School, Seven Oaks, Macleay River ... 204

ART. XVIII.—Records of rock temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain, Sydney, N.S. Wales. By J. L. C. Rae, E. F. Pittman, Assoc. R.S.M., and Professor T. W. E. David, B.A., F.G.S. 207

ART. XIX.—Note on Edible Earth from Fiji. By the Hon. B. G. Corney, M.D., Professor T. W. E. David, B.A., F.G.S., and F. B. Guthrie, F.C.S. 223

ART. XX.—Annual Address to the Engineering Section. By Norman Selfe, M. Inst. C.E. ... ... I.

ART. XXI.—The Sewerage Systems of North Sydney and Double Bay. By J. Davis, M. Inst. C.E. ... ... XI.

ART. XXII.—The manufacture of Monier Pipes. By F. M. Gummow XXXIV.

ART. XXIII.—"*Le Pont Vierendeel.*" By J. I. Haycroft, M.I.C.E.I. XXXVIII.

ABSTRACT OF PROCEEDINGS ... ... i.

PROCEEDINGS OF THE ENGINEERING SECTION ... ... lxix.

PROCEEDINGS OF THE MEDICAL SECTION ... ... lxxi.

INDEX TO VOLUME XXXIII. ... ... (xxvii.)