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A BIBLIOGRAPHY OF TASMANITE

WITH

AN INTRODUCTION AND ANNOTATIONS

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ABSTRACT

Since the discovery of tasmanite in 1851, scientific interest in this oil shale has shown much variation. The recent resurgence of research activity on tasmanite has been occasioned by the availability of new techniques which now permit the organic matter to be examined in considerable detail.

This paper presents a summary of the history, nature and chemistry of tasmanite, followed by a comprehensive bibliography. The survey was prompted by a recent catalogue of *Tasmanites* from the palynological viewpoint, and the lack of a similar publication on tasmanite itself. The references are given in alphabetical order, together with an abstract. Additional annotations are made, if pertinent.

INTRODUCTION

Any reader of research papers on oil shale cannot fail to notice the irregular frequency of publication in this field. It must be confessed that past research has been largely a reflection of technological interest in these rocks as a source of fuel. On the contrary, the recent upsurge in geochemical investigations has been motivated by agencies interested in the composition of traces of organic matter; the interest being directly connected with the bioassay of extra-terrestrial materials; such as the lunar rocks. Because of the extreme resistance of spores and exines to biochemical and geochemical decay, it seems likely that, if life had existed elsewhere, spore-like bodies might be found in rock samples from space sources. This speculation has stimulated research into the chemistry of particulate organic matter in terrestrial rocks, including tasmanite.

Intense interest was shown in tasmanite after its discovery, and its display at the Tasmanian Court of the International Exhibition in London in 1862. However, for nearly half a century thereafter, there was indifference to the substance, followed by renewed research in the 1910's and 1930's. Later, studies of tasmanite again became negligible but revived in the 1960's following the recognition of very rich deposits in Northern Alaska. Very comprehensive literature surveys have recently been completed on the world's oil shales (Prien 1966, Neto 1971) but there are unexpected gaps in their coverage. These lacunae arise because important papers have been published in journals which do not have recognised international circulation, and thus miss the abstracting services. As tasmanite has suffered badly in this respect, the present contribution is put forward in an attempt to make good the lack of a comprehensive bibliography on this substance. This bibliography deliberately excludes those papers dealing with *Tasmanites* from the viewpoint of the taxonomist or palynologist, as an extremely comprehensive review of such aspects has recently been published by Muir and Sargeant (1971). A few selected palynological references are given only because they contain useful information on spore chemistry or provide data which assist in an understanding of the chemistry of tasmanite itself.

To distinguish between the genus *Tasmanites* and the plural form of the rock (tasmanites), the genus is written italicised and the rock in roman type with a lower case initial letter throughout this paper.

A Bibliography of Tasmanite with an Introduction and Annotations

THE NATURE AND OCCURRENCE OF TASMANITE

The first reference to tasmanite (dysodile) was published by Milligan (1852), although it was not until twelve years later than Church (1864) attempted to describe the nature of the rock. Church's paper was followed by a profusion of descriptive contributions by various authors, the result of which was considerable uncertainty as to the origin of the material and of the disc-shaped bodies found therein. Because of the existing name 'tasmanite', the disc-like disseminules were given the generic name *Tasmanites* by Newton (1875), who agreed with Ralph (1865) that the bodies were algal of uncertain affinity. During the next century, the taxonomic history of *Tasmanites* was one of nomenclatural change mixed with several reappraisals of genus, family and order. Although there is now general agreement that the disc bodies are algal microfossils, their exact classification is still doubtful. If we regard the fossil genus as equivalent to the extant *Pachysphaera* (Wall 1962), the microfossils can be regarded as cysts of a planktonic alga belonging to the class Prasinophyceae.

As mentioned above, Muir and Sargeant (1971) have published an annotated bibliography of tasmanids in which the genus *Tasmanites* is credited with 40 species but only two species are known to occur in local high concentrations. Although *Tasmanites* is scattered geographically and over a wide range of sediments from the Ordovician through the Permian to Recent, tasmanite on any reasonable scale occurs only in Alaska and Tasmania. Both deposits are marine and their genesis appears to be in prodigious blooms of a planktonic alga which grew fairly close to the ancient coast lines. It seems that the kerogen was laid down in a quiet ecosystem of shallow bays and inlets where the alga was free to multiply.

Alaskan tasmanite occurs as contorted outcrops along the northern slopes of the Brooks Range in Northern Alaska. The rock, in general appearance, is more like a low grade torbanite, nearly black in colour, more compact than that from Tasmania and considerably richer in organic matter. This oil shale has been known for a considerable time (Stoney 1900) but, only in the last few years, has it received any attention from geologists or geochemists. The species of *Tasmanites* in the Alaskan rock is a matter of doubt. Because of the terrain and climate, any commercial exploitation seems unlikely.

The Tasmanian deposit occurs in Permian sedimentary rocks and is found as a narrow belt along the Mersey Valley from Latrobe to Kimberley, continuing linearly through Deloraine to Quamby Bluff. There is another minor deposit at Beulah with which the Latrobe tasmanite is probably associated. The geology and general nature of this tasmanite are well documented, (see Twelvetrees 1911, Reid 1924 and Kurth 1934). Sporadic attempts to recover useful products have been made since 1901-2, when the Tasmanian Shale and Oil Coy. undertook preliminary work. Various retorts and processes were exploited during the ensuing years, but none was really successful. Over a dozen organisations have attempted the commercial exploitation of the Latrobe oil shale but all activity stopped in the middle 1930's.

There have been vague reports of small low grade deposits of tasmanite in Brazil and in the Sahara area of Africa.

TASMANITE KEROGEN

The kerogen of tasmanite is composed of the walls of *Tasmanites* and the earliest work on its chemical composition was by Church (1864) who postulated that this kerogen might be a sulphur analog of retinite ($C_{40}H_{64}O_4$). Later Zetzsche, Vicari and Scharer (1931) considered that tasmanin (their name for tasmanite kerogen) was a type of sporopollenin and allocated the formula $C_{90}H_{134}O_{15}(OH)_2$, but work by Kurth (1934) at the University of Tasmania cast considerable doubt on Zetzsche's findings. Brooks and Shaw (1969) also asserted that tasmanin was allied to sporopollenin and could be considered as an oxidative polymer of carotenoids but their hypothesis cannot be regarded as satisfactory. Kjellstrom (1968) examined the cell wall by microspectroscopy and considered it to be a complex lipoid substance containing hydroxy, alkyl, and carboxylic groupings. Work by the present writer substantiates Kjellstrom's opinion, and also that of Wall

(1962), the consensus now being that tasmanin is essentially a complex carboxylic lipoid-derived polymer. Nevertheless, no structural composition can be put forward with confidence and the exact nature of tasmanite kerogen must be considered as still undefined.

Tasmanite contains a small amount of soluble organic matter and Kurth and Rogers (1938) stated that the extractives have a resin-like composition. Hoering (private communication - 1968) of the Geophysical Laboratory of the Carnegie Institution of Washington has demonstrated that Alaskan tasmanite extractives contain a normal spectrum of alkanes, whereas Tasmanian extractives have an unusual composition with only a few major components. The main hydrocarbon is a tricyclic alkyl substituted alkane ($C_{19}H_{34}$). Hoering's molecular formula corresponds to that of fichtelite, a hydrocarbon associated with retene and connected, chemistry-wise, with rosin.

Burlingame *et al.* (1969) has examined the structure of the acidic extractives from tasmanites and found a simple range of alkanoic acids between C_8 and C_{16}, peaking at n-C_{11} for Alaskan, and somewhat higher for Tasmanian, tasmanite. The extractives are unusual as there is little or no component of branched or isoprenoid acids. In addition, there are present polycyclic condensed aromatic acids and other members corresponding to alkyl benzene and to naphthalene carboxylic acids.

BIBLIOGRAPHY

The bibliography has been compiled, with two exceptions, from first hand study of the cited references. As mentioned earlier, papers dealing exclusively with the botanical, taxonomic or palynological aspects of *Tasmanites* have been omitted, likewise references to Tasmanian shales other than tasmanite. In many general articles, a casual 'single sentence' reference to tasmanite might be encountered. This type of reference has also been excluded.

The bibliography appears in this paper as a supplement. As a general rule, the verbal tense of the abstract is that which best suits the tense of the original publication.

ACKNOWLEDGEMENT

The writer acknowledges the assistance of his daughter (Hilary V. Cane) who checked some of the obscure references in the archives of the Library of the University of Tasmania.

REFERENCES

Brooks, J., and Shaw, G., 1969: Evidence of Extraterrestrial Life. Identity of Sporopollenin with the Insoluble Organic Matter present in the Orgueil and Murray Meteorites and also with some Terrestrial Microfossils. *Nature*, 223, 5207, 756.

Burlingame, A.L., Wszolek, P.C., and Simoneit, B.R., 1969: Fatty Acid Content of Tasmanites in *Advances in Organic Geochemistry*, 1968, Ed. Schenck and Havenaar, pp. 131-156. Pergamon (London).

Church, A.H., 1854: On Tasmanite: A New Mineral of Organic Origin. *Phil. Mag.*, 28, 465-470.

Kjellstrom, G., 1968: Remarks on the Chemistry and Ultrastructure of the Cell Wall of some Palaeozoic Leiospheres. *Geol. Foren. Stock. Borband.*, 90, 221-228.

Kurth, E.E., 1934: *The Oil Shales of Tasmania and New South Wales*. Thesis for D. Sc. degree of the University of Tasmania (Hobart).

Kurth, E.E. & Rogers, L.J., 1938: The Oil Shales of Australia *in Oil Shale and Cannel Coal*. pp. 193-209. *Institute of Petroleum* (London).

Milligan, J., 1852: Report on the Coal said to be found in the Don River and upon the west bank of the Tamar River in Tasmania. *Pap. Proc. R. Soc. Van Diemen's Land*, 2 (1), 90-106.

Muir, M.D., and Sargeant, W.A., 1971: An annotated Bibliography of the Tasmanaceae and related forms *from* Les Acritarches. Vol. 3 of *Microfossiles Organiques du Paleozoique*. Editions du Centre national de la researche scientifique (Paris).

Neto, C.C., 1971: Bibliografia do Xisto. pp. 531. *Instituto Brasileiro de Bibliografia* (Rio de Janeiro).

Newton, E.T., 1875: On "tasmanite" and "Australian" white coal. *Geol. Mag.*, New Ser. 2, (8). 12, 337-342.

Prien, C.H., 1966: *Literature Survey on the Fundamental Aspects of Oil Shale*. pp. 183. University of Denver (Denver).

Ralph, T.S., 1865: Observations on the microscopical characters presented by a mineral (Dysodile) from Tasmania. *Trans. and Proc. R. Soc. Vict.*, 6, 7.

Reid, A. McI., 1924: The Oil Shale Resources of Tasmania. *Miner. Resour. Tasm.*, 8, (Vol. 1), pp. 119. Government Printer (Hobart).

Stoney, G.M., 1900: Naval Explorations in Alaska. *Naval Inst. Publ.* Annapolis, pp. 105 (U.S.A.).

Twelvetrees, W.H., 1911: The Tasmanian Shale Fields of the Mersey District. *Bull. Geol. Surv. Tasm.*, 11, pp. 123. Government Printer (Hobart).

Wall, D., 1962: Evidence from Recent Plankton regarding the Biological Affinities of Tasmanites and Leiosphaeridia. *Geol. Mag.*, 99 (4), 352-362.

Zetzsche, F., Vicari, H., and Scharer, G., 1931: Palaeobotanical Study of Membranes of Spores and Pollens. *Helv. Chem. Acta.*, 14, 67-78.

Supplement

A BIBLIOGRAPHY OF TASMANITE

from 1852 to 1972

containing abstracts of papers and occasional notes

Anderson, V.C., 1922: Oil Shale - A Review for 1921. *Petroleum Times*, 7, 259-263.

A resume of world operations including a brief mention of Tasmanian deposits and their workings.

Anon., 1862: On Dysodile - A Combustible Matter from the Banks of River Mersey. *Intellectual Observer*, September, 1862, p. 144. London.

A combustible rock has been exhibited in the London Geological Museum, the same as that shown at the recent International Exhibition. The combustible matter is believed identical with the rare mineral dysodile. Mention made that the organic matter consists of brownish yellow discs which are easily separated from the matrix. Its properties and pyrolysis behaviour are discussed.

Anon., 1853: Occurrence of Tasmanite. *Proc. R. Soc. Van Diemen's Land*, 2, 2, 315.

A two line record that a sample of combustible schist (dysodile?) from the Mersey River was exhibited.

Anon., 1931: "Shale Oil in Tasmania" *in "Cyclopedia of Tasmania"*, p. 386. Service Publishing Co., Hobart.

A general review of attempts at the commercial exploitation of tasmanite. The surveys of the Tasmanian Shale Oil Co. are discussed as well as their use of the Crozier retort to produce various grades of fuel oil and road bitumen.

Archer, W., 1854: On a fine pulverulent substance, washed from the conbustible schist of the Mersey River, Tasmania. *Proc. R. Soc. Van Diemen's Land*, 2, 3, 509-511.

The organic matter of tasmanite is described. The author concludes it is a resin of "smooth flattened grains" from the leaf or bark of a tree or plant. Further samples were submitted for inspection.

Ball, L.C., 1915: Oil Shale Industry. An Introduction to a Report on the Oil Shales of Lowmead now being prepared. *Q'd Govt. Min. Jl*, 16, 608-616.

Casual mention of tasmanite in world oil shale survey.

Banks, M.R., 1962: "Permian" *in* "Geology of Tasmania". Ed. A.H. Spry & M.R. Banks. *Jl Geol. Soc. Aust.*, 9, 2, 189.

Tasmanite is stated to be found in the Quamby Group of the Permian, with the opinion expressed that it is not a facies varient of the Mersey Coal Measures. Banks has clarified the stratigraphic anomalies. The matrix is a poorly fossiliferous dark siltstone.

Brooks, J., and Shaw, G., 1969: Evidence of Extraterrestrial Life. Identity of Sporopollenin with the insoluble organic matter present in the Orgueil and Murray Meteorites and also with some Terrestrial Microfossils. *Nature*, 223, 5207, 756.

Sporopollenin is believed to be an oxidative polymer of carotenoids and carotenoid esters. The infra-red spectrum of *Tasmanites* is similar to those of Lycopod spores and of extant carotenoids. *Tasmanites punctatus* pyrochromatograms are illustrated.

Burlingame, A.L., Wszolek, P.C., and Simoneit, B.R., 1969: "Fatty Acid Content of Tasmanites" in *Advances in Organic Geo-chemistry, 1968*, ed. Schenck and Havenaar, 131-156. Pergamon (London).

The soluble acids of tasmanite are of simple composition and consist of straight chain acids between C_8 and C_{16}, peaking at n-C_{11} for Alaskan, and somewhat higher for Tasmanian oil shale. Polycyclic acids occur in both deposits and are probably condensed tricyclic systems. Tasmanite acids are peculiar in that there are little or no branched chain or isoprenoid acids.

Cane, R.F., 1939: *The Chemical Composition of Tasmanite Shale Oil.* Theses for M.Sc. degree, University of Tasmania, Hobart.

The contents of this thesis are covered in Cane (1940) and Cane (1941), which see.

_____., 1940: Studies in Tasmanite Shale Oil. *Pap. Proc. R. Soc. Tasm.*, 74, 23-32.

The properties of crude tasmanite oil and distillation fractions are given. m-Cresol has been isolated from the tar acids. The sulphur distribution over a limited boiling range shows a gradual increase and aromatic sulphur compounds were shown to occur. Alkyl thiophenes have also been detected. Higher sulphur compounds were present but not identified.

_____., 1941: The Nitrogen Bases in Tasmanite Shale Oil. *Pap. Proc. R. Soc. Tasm.*, 75, 55-62.

An investigation of the heterocyclic nitrogen bases in tasmanite oil including methods of isolation and identification. Trimethylpyridine and alkyl quinolines are present. A peculiar physiologically active nitrogen base is to be found in the higher fractions and this is possibly alkaloidal in nature.

_____., 1968: The Nature of Tasmanian Oil Shale. *Pap. Proc. R. Soc. Tasm.*, 102, 2, 65-68.

The occurrence and nature of tasmanite is discussed together with an analysis of the mineral matter. The probable nature of tasmanite is considered in relation to other oil shale kerogens. Its pyrolysis behaviour differs from other oil shales and appears to arise because of the resinous nature of the kerogen. The oil is high in sulphur and appears to contain some bioactive compounds.

Carey, S.W., and Ahmad, N., 1961: "Glacial Marine Sedimentation" *in* "Geology of the Artic". *Proc. First International Symposium in Arctic Geology.*, 2, 865-894. University of Toronto Press, Toronto.

This paper discussed the ecosystem in which tasmanite was deposited. Tasmanite must have been laid down while icebergs were still in vicinity as the sediments contain occasional erratics. Many marine fossils are to be found in the sediment, as well as pyrites, glendonites and calcareous concretions. Probably reserves are more than 30 million tons.

Carne, J.E., 1903: The Kerosene Shale Deposits of N.S.W. *Mem. Geol. Surv. N.S.W.*, 3, pp. 333. Govt. Printer, Sydney.

The author compares tasmanite with the torbanites of N.S.W. He also refers to

Tasmanites discs in parrot coal from Scotland. A special section is devoted to tasmanite itself, and a full account is presented of early investigations and reports. Elemental analyses are included. The book quotes extensively from earlier papers but does not attempt to interpret previous findings.

Church, A.H., 1864: On Tasmanite: a new mineral of organic origin. *Phil. Mag.*, 28, 465-470, and also *Geol. Mag.*, 2, 237.

The Geol. Mag. reference is an account of the tasmanite exhibit in the International Exhibition of 1863. Church states that tasmanite is not dysodile and that it is resistant to chemical attack. He gives the elemental formula as $C_{40}H_{62}O_2S$ and compares it to retinite ($C_{20}H_{31}O_2H$). In the Phil. Mag. paper, the formula is given as $C_{40}H_{64}O_2S$. The ash is mainly silica and alumina with a little ferric oxide. When heated, tasmanite fuses and yields oily and solid products. The sulphur is in organic combination and tasmanite is the first carbonaceous mineral with such a large amount of combined sulphur.

Combaz, A., 1970: Microspherules muriformes dans les roches-meres du petrole. *C.R. Acad. Paris*, 270, 2240-2243.

Electron micrographs of Tasmanian and Saharan *Tasmanites* are presented and a comparison made between them. The paper includes tasmanite in a consideration of source rocks for petroleum. The author discusses mineral composition and presents trace metal analyses. Tasmanite kerogen contains not only *Tasmanites*, but amorphous brownish organic matter associated with the "spores" as well as small spherical reticulated bodies and algal mycelia. The small granules are associated with pyrites and appear to have a bacterial origin. Excellent electron scan micrographs are presented.

Conder, H., 1902: On oil shales in Tasmania. *Australian Mining Standard*, 21, 597, No. 703

A general geological description of the Mersey Valley with mention of an oil bearing shale associated with sandstones. Tasmanite outcrops on the edge of the river but better grades are to be found in the mining shafts. The paper discusses the appearance and spore content of the rock and expresses doubt as to the profitability of working the seam. Tasmanite contains oil-bearing spores which appear to have been derived from club mosses.

David, T.W.E., 1950: (Edited and Supplemented by W.R. Browne): *The Geology of the Commonwealth of Australia*. Edward Arnold and Co., 2, p. 500-502. London.

A chapter is devoted to a discussion of Australian oil shales including tasmanite. Tasmanite is a light yellow to dark brown rock, finely laminated and fissile. Its general properties are given, together with a description of the Latrobe deposit. Tasmanite lies along a belt about 7 miles wide and 27 miles long, running from Latrobe towards Quamby. Coal and tasmanite are not found in association and tasmanite usually encloses marine fossils. It seems that the oil shale was laid down along a coastline, concurrently with the deposition of coal in the inland freshwater swamps. Reserves are of the order of 20 million tons.

Dawson, J.W., 1871: On Sporecases in Coals. *Amer. J. Sci.*, 1, 4, 246-263.

A survey of certain "spore cases" in coal and clays. Reference to *Tasmanites* found in the Devonian series at Kettle Point, Lake Huron.

Donnell, J.R., Tailleur, I.L., and Tourtelot, H.A., 1967: Alaskan Oil Shale. *Colo. Sch. Mines Qtly.*, 62, 3, 39-43.

A general review of oil shales in Alaska containing a paragraph devoted to tasmanite. The tasmanite seam is up to 5 feet thick and oil yields of up to 150 gals/tons have been recorded. The mineral matter contains diagenetic silica and barite.

Down, A.L. and Himus, G.M., 1940: The Classification of Oil Shales and Cannel Coals. *Jour. Inst. Pet.*, 26, 329-335.

A suggested classification of oil shale and torbanite based on concentration and type of organic matter. Tasmanite is classed as a spore shale within the general group "Kerogen Rocks".

Dulhunty, J.R. and Dulhunty, R., 1949: Notes on Microspore Types in Tasmanian Permian Coals. *Proc. Linn. Soc. N.S.W.*, 74, 3-4, 132-139.

Microspores in Tasmanian Permian Coal were surveyed in order to compare the Tasmanian and N.S.W. deposits. Generally the types of microspores were common to both. Only casual mention of tasmanite itself.

Dun, W.S., 1912; Marine fossils from the Tasmanite Spore Beds of the Mersey River. *Rec. Geol. Surv. Tasm.*, 1.

The paper gives results of a survey of the marine invertebrates associated with tasmanite beds. Twelve species are now identified.

Evitt, W.R., 1963: A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritachs. *Proc. Natl. Acad. Sci. U.S.*, 49, 2, 158-164. *Ibid.*, No. 3, 298-302.

Because of the confusion about the identity of certain micro-fossils, a decision was made to place *Tasmanites* into a group termed "Acritachs".

Gould, C., 1861: Report on the Resinous Shales of the Mersey River, Tasmania. *Report of the Mines Dept.*, pp. 3. House of Assembly Paper No. 8. Legislative Council, Paper No. 8. Tasmanian Parliament, Hobart.

The report gives a brief description of the outcrops and general appearance of "dysodile". Gould believes the deposit to be marine because of the nature of the fossils therein.

There is a further reference to tasmanite at Caroline Creek in Assembly Paper No. 35 (29/10/1861) in the note "Report upon the Mersey Coalfields".

Herapath, W., 1856: Copy of analysis of "White Coal or Bituminous Sand" from Australia. *Trans. N. England Inst. Mining Engineers*, 4, 191.

This reference could not be located in Australian libraries.

Hey, M.H., 1962, (2nd ed.): *An index of mineral species and varieties arranged chemically.* Condon, Printed by order of Trustees of the British Museum.

Tasmanite is classified under the category "Hydrocarbons, Resins, etc,": Sub Group 33.10 Sulphur Bearing Resins, Sub Type 33.10.4. It is a sulphur rich resin. C, 79.3% H, 10.4% O, 4.9% S, 5.3%. Ref: Dana 1010.

Hills, C.L., 1921: Oil Shale at Quamby Bluff. *Dep. Min. Tasm, Unpubl. Rep.*

Unpublished report of general features of deposit and economic aspects.

Himus, G.W., and Rudrakanchana, S., 1941: The composition of the ash of Tasmanian spore shale. *J. Inst. Petroleum*, 27, 446-447.

Ash analyses were made to determine the likelihood of *Tasmanites* being connected with Lycopods because the *Lycopodineae* are remarkable for their high aluminium content. However, the authors state that the analyses are not suitable for the differentiation of lycopods. The amount of Al_2O_3 in the ash was 11.8%.

James, C.E., 1933: Report of Tasmanian Shale Oil Investigation Committee. *Miner. Resour. Tasm*, 8, II, pp. 214. Tas. Dept. of Mines. Government Printer. Hobart.

A detailed description of the geology, extent, nature of organic matter and analyses of the Latrobe oil shale field. A section of the report is devoted to factors affecting the retorting of shale and conditions necessary to obtain maximum oil yield. A summary of research into the refining of shale oil is also given. Data are present on the economics of utilization and recovery of various distillation fractions. Five Appendixes give further information on the sampling, analyses and distillation of oil shale. Costing information is also included, including much information on the operations of the Tasmanian Shale Oil Company.

Jennings, I.B., Noldart, A.J., and Williams, E., 1967: Geology and Mineral Resources of Tasmania. *Bull. Geol. Surv. Tasm.*, 50.

Mention of the occurrence of tasmanite and the production of oil therefrom.

Johnson, J.H., 1967: Bibliography of fossil algae, algal limestones and the geological work of algae. *Colo. Sch. Mines Qtly.*, 62, 4, 1-148.

A review of the period 1956-1965. Mention is made of the papers of Wall, Eisenack, Sommer and Van Boekel on the palynology of *Tasmanites*. Represents an extension of an earlier paper *(Colo. Sch. Mines Qtly.*, 53, No. 2, 1-84), which is a review of fossil Devonian algae. Little application to tasmanite, but contains useful auxiliary information.

Johnston, R.M., 1877: Tasmanite or Mersey "Yellow Coal". 8vo, p. 8. Hobart. Also see Science Corner "Tasmanian Weekly Mail" for 25/8/1872, which is reprinted in *Geology of Tasmania*, 1888, p. 136-140 under "Tasmanite, Dysodile or Yellow Coal".

The author sees little connection between tasmanite and coal. He notes that tasmanite burns easily, leaving a white residue retaining the original shape of the sample. The organic matter is composed of disc-shaped amber-coloured bodies "welded together like grains of meal in an oat cake. The discs resemble diminutive flattened flabby gooseberry skins rent or fractured on one side as by sporadic emission of contents."

_____., 1879: *Field Memoranda for Tasmanian Botanists*. Published August, 1874. Hobart.

A description of tasmanite sacs is given as well as some general information.

_____., 1888: *Systematic Account of the Geology of Tasmania*. 4to, pp. 408 & 131 plates. Govt. Printer, Hobart.

The occurrence, nature, and stratigraphy of the tasmanite beds are discussed including a list of fossils found therein. Johnston presents a long discussion on the likely origin of the disc shaped bodies, comparing them to the sporangia of club mosses. The Mersey deposit is marine, probably estuarine, but the organic matter has been washed down by rivers, mixed with muddy sediment and deposited in a quiet Palaeozoic sea. Johnson claimed priority as to his observations on the nature and peculiar markings of the discs.

Kjellstrom, G., 1968: Remarks on the Chemistry and Ultrastructure of the Cell Wall of some Palaezoic Leiospheres. *Geol. Foren. Stock. Borband.*, 90, 221-228.

Studies show that the cell wall is a high molecular weight organic substance with a lipoid character. Ultra thin sections of the leiospheres were examined by infrared microspectroscopy and showed to contain methylene, methyl and carboxylic groups. The essential chemistry is believed to be long chain alkanes with some carboxylic functions. The ultrastructure, as revealed by electron microscopy, shows differences between species. The walls of *Tasmanites punctatus* are penetrated by pores of various sizes in a radial arrangement.

Kurth, E.E., 1934: *The Oil Shales of Tasmania and New South Wales.* Thesis for D. Sc. degree, pp. 389. The University of Tasmania. Hobart.

A comprehensive monograph on the technological aspects of tasmanite shale, largely devoted to factors affecting the yield and the quality of oil. The examination includes the effect of particle size, time, temperature, and the presence of steam upon oil yield and composition of oil. The thesis also includes a study of the composition of tasmanite organic matter and the nitrogen and sulphur distributions in the oil. Considerable detail is presented on mass balances and thermal profiles during retorting. Consideration of refining the oil is also included.

_____., and Rogers, L.J., 1938: "The Oil Shales of Australia" *in* "Oil Shale and Cannel Coal", pp. 193-209. *Institute of Petroleum, London.*

A general review of knowledge as at 1938. Discusses the general nature of tasmanite, origin, geology, history and commercial utilization. Gives data on shale oil and analyses of the mineral matter associated with the kerogen.

MacNaughton, T., 1855: Concerning the Mersey Shale. (Together with a sample of oil presented by Dr. Lee). *Pap. Proc. R. Soc. Van Diemen's Land*, 3, 1, 187-188.

A description of the resinous discs of tasmanite, as seen under the microscope, together with a brief description of the mineral.

McKee, R.H., 1925: Shale Oil. *American Chemical Society Monograph 25.* 8vo, pp. 326. Chemical Catalog Co., New York.

Mention made of tasmanite and its mining operations. Erroneously classifies tasmanite as a torbanitic deposit.

Mansfield, H.W., 1916: Oil Shales. *J. Inst. Pet. Tech.*, 2, 162-190. Casual mention in world survey.

Milligan, J., 1852: Report on the Coal said to be found on the Don River and upon the West Bank of the Tamar River in Tasmania. *Pap. Proc. R. Soc. Van Diemen's Land*, 2, 1, 90-106.

First record of "a brown schist of a nature highly combustible: its surface is usually finely punctated - it is semi soft, sectile, fissile, flexible and slightly elastic". When burning, it gives out "a peculiar and highly diffusive odour". A general description of tasmanite and its properties are given. The structure of the rock indicates a very tranquil aqueous environment for the deposition of the spores and a continuous repetition of the occurrence of deposition. The author believes that tasmanite is a bed of coal in the process of formation.

Moore, T., 1855: On Experiments Testing the Comparative Value of the Mersey Schist and the Coals from Schouten Island and Douglas River for Gas Making Purposes.

Proc. R. Soc. Van Diemen's Land, 3, 1, 177-178.

The use of tasmanite for gas production was discussed and its possible use exemplified by experimental data on destructive distillation and gas yields. A record of a talk given to the Society on 14/6/1854.

Newton, E.T., 1875: On "Tasmanite" and Australian "White Coal". *Geol. Mag.* N.S. 2, 12, 8, 337-342.

The first paper to give any scientific detail, containing the original suggestion to name the spores *T. punctatus*. Newton believed that the peculiar discs were not algae but sporangia of lycopods which go to make up the entire organic matter of the deposit. By treating tasmanite with HCl and HF, he was able to isolate individual discs and to show they were thick walled sacs with perforated walls. The occurrence and nature of tasmanite is treated in some detail.

_____., 1876: Remarks on tasmanite or Mersey Shale. *Proc. R. Soc. Tasm.* 5, 4.

This reference appears to be the record of a verbal presentation of Newton's (1875) paper at the 14/3/76 meeting of the Society, as some portions are repeated verbatim.

Nye, P.B., and Blake, F., 1938: The Geology and Mineral Deposits of Tasmania. *Bull. Geol. Surv. Tasm.*, 44.

Brief mention on p. 103 with estimated size of deposits.

Orton, E., 1850: A Source of the Bitumenous Matter of the Black Shales of Ohio. *Proc. Amer. Assoc. Adv. Sci.*, 3, 2, 373-384.

Discussion of *Tasmanites* found in the Huron shales of Ohio. It is believed the bitumenous nature of the shale is caused by the spores. Other fossils are found in the shale beds.

Penny, P., 1855: Report on the Chemical Qualities and analysis of a Combustible Mineral substance from the Mersey River, Tasmania. *Pap. Proc. R. Soc. Van Diemen's Land*, 3, 1, 108-114.

The shale is a mixture of clay and sand together with a combustible substance allied to resin. The resins in tasmanite are much less soluble than most but burn giving off much smoke. The analysis shows ash 71.2%, sulphur 0.73%. When distilled, tasmanite yeilds an oil, a strong acid and tarry matter but does not produce much gas. An ash analysis is given.

_____., 1859: Report on the Chemical Qualities and Analysis of a Chemical Substance from Van Diemen's Land. *Trans. Phil. Soc. N.S.W., Sydney Mag. of Science and Art*, 2, 213-215.

An examination was made to determine the gas making qualities, but the author states that it may be difficult to make a satisfactory gas. Gives analyses of the organic matter. The resinous matter renders the mineral highly combustible and produces much smoke when distilled in a closed vessel. Penny states it is different from coal and cannot be considered as a bitumen because of insolubility. He concludes that it is not a good gas maker.

Radforth, N.W., and Rouse, G.E., 1956: Floral Transgressions of Major Geological Time Zones. *Trans. R. Soc. Canada*, 50, 17-26.

Discusses the time distribution of *Tasmanites* from the Devonian to Tertiary eras.

Ralph, T.S., 1865: Observations on the microscopical characters presented by a mineral (Dysodile) from Tasmania. *Trans. Proc. R. Soc. of Vic.*, 6, 7.

Paper read on 27/5/1861, but only an abstract published. The author showed that "the mineral was a kind of shale containing, besides a bitumenous substance, a large amount of algae, of a spherical form which were preserved by their being coated by a resinous substance."

Reid, A.M., 1926: The Oil Shale of Tasmania. *Pap. Proc. R. Soc. Tasm., 42-51.*

A review article, covering the history and geology of tasmanite, the article depending largely on extracts from previous papers. It contains a general description of occurrence and lists marine fossils associated with the deposit. Tasmanite kerogen consists of "the waxy covering of minute disc-shaped spore cases", the cases having been preserved by the waxy or resinous substance of the outer skin (exines), although the spores themselves have decayed. A useful summary of the physical properties of tasmanite is given. Remarks on the constancy of composition over the whole area. The quantity of shale and possible utilisation is also discussed.

_____., 1924: The Oil Shale Resources of Tasmania. *Miner. Resour. Tasm.*, 8. 1, pp. 119, Tas. Dept. of Mines. Govt. Printer, Hobart.

A review of knowledge up to 1922. A detailed account of the geography and geology of the deposit, including a description of the nature and microstructure of tasmanite kerogen as well as some chemical features. Tasmanite is a marine deposit which has been laid down in shallow seas close to the Permian coastline or in marine estuaries. Consideration is given as to the best mining methods and handling of the rock. Part III is devoted to a detailed study of the shale field containing logs of bore holes and an estimation of the amount of shale in various areas.

Selwyn, A.R.C., 1855: Coal Seams of Van Dieman's Land. *Pap. R. Soc. Van Diemen's Land*, 3, 116-141.

Casual mention of tasmanite on p. 140.

Selwyn-Brown, A., 1916: Fuel Oil from Shale. *Eng. Mag.*, 50, 913-920.

Discusses the profitability of the recovery of oil from world shales; tasmanite yields 40-60 g/ton. Quotes mining and retorting costs. The paper states that spent shale is a useful fertilizer and gives ash analyses.

Singh, T.C.N., 1932: Notes on the Fossil Spores of an Oil Shale from Tasmania. *Pap. Proc. R. Soc. Tasm.*, 66, 32-36.

A reappraisal of the nature of tasmanite spores and an amplification of doubt regarding their lycopod origin. No evidence of Newton's observation of punctation on the surface of the spore wall.

Smith, P.S., and Mertie, J.B., 1930: Mineral Resources of N.W. Alaska. *U.S. Geol. Surv. Bull.* 815, p. 344. U.S. Dept. of Interior, Washington.

The tasmanite-like rock found in North Alaska is made up of large spores. The paper contains some notes on occurrence and geology.

Sommer, F.W., and Boekel, N.M. Van, 1967: Brazilian palaeozoic Algomycetes & Tasmanaceae. *Palaeontology*, 10, 4, 640-646.

A review of the work on Brazilian *Tasmanites*. Describes the plant microfossils found in Devonian marine strata. Eleven species of *Tasmanites* have been recorded, some of which are also in the Devonian shale of east Bolivia.

Stephens, T., 1876: Remarks on Tasmanite or Dysodile. *Proc. R. Soc. Tasm.* 5, 4-5.

Verbal remarks loc cit p. 5. Stephens was the chairman of the meeting at which Newton's paper was read - see Newton (1876).

Stoney, G.M. 1900: Naval Explorations in Alaska. *Naval Inst. Publ. Annapolis, U.S.A.*, 105 p. Annapolis.

A brief description of the "wood" used by Alaskan natives as fuel, with a general description of the oil shale.

Tailleur, I.L., 1964: Rich oil shale from Northern Alaska. *U.S. Geol. Surv. Prof. Paper* 475-D. pp. D131-D133. Washington.

A general description of Alaskan tasmanite with Fischer assays on various samples. Some information is given on occurrence and locations, together with a brief history of early observations.

Thiessen, R., 1921: Origin and Composition of Certain Oil Shales. *Econ. Geol.*, 16, 289-300, and *Bull. Geol. Soc. Amer.*, 32, 72-84.

A review of U.S. Devonian shales and an attempt to correlate the results of pyrolysis with the microscopic characteristics. The paper states that all the organic matter is derived from plants, and that animal remains do not occur. Discusses some U.S. shales with particular reference to the chocolate shales of the Devonian of Illinois which were first discovered in 1866. *Tasmanites* occur freely in the Devonian shales of Lake Huron and also in Ohio. Micrographs of bodies in typical poor grade tasmanite are shown. Thiessen regards them as spores and believed that the chemical composition is largely esters of higher fatty acids.

Thureau, G., 1883: Report on the Mersey Coal Deposits. *House of Assembly, Paper No. 52, and Legislative Council Paper No. 61.* (May, 1883). Hobart.

A report on tasmanite and dysodile outcrops along the Mersey River. Paper states that tasmanite "belongs to the bitumenous schists and, so far, it does not appear to have any special value at present".

Tourtelot, H.A., Tailleur, I.L., and Donnell, J.R., 1967: Oil Yield and Chemical Composition of Shale from Alaska. *7th World Petroleum Congress (Mexico).* P.D. 14, 9, 75-80.

Tasmanite included in a description of organic rocks in N. Alaska. The paper presents oil assays, elemental and spectroscopic analyses of tasmanites from Alaska, Tasmania and Ohio. Alaskan tasmanite yields up to 144 gals/ton of oil.

Twelvetrees, W.H., 1909: Report on Shale Deposits in Tasmania. *Sec. of Mines Report for 1908.* Dept. of Mines Tas., Hobart.

An earlier and condensed version of Twelvetrees (1911), together with some assays from the Tasmanian Shale and Oil Sydndicate.

_____., 1911: The Tasmanite Shale Fields of the Mersey District. *Bull. Geol. Surv. Tasm.* 11, pp. 123. Dept. of Mines, Tasmania. Govt. Printer, Hobart.

A comprehensive report with a review of previous literature. Author discusses area, physiography, stratigraphic arrangement and geology of the deposit. Some information is provided on the physical characteristics of tasmanite and the possible origin of the "seed-like bodies" which, the author believes, may be derived from lycopods. The other consensus is that they were of algal origin associated with shallow seas of the Permian coastline. The report contains considerable data on the mining and retorting operations of the Tasmanian Shale & Oil Company, and other operators. Cost analyses are given.

_____., 1918: The Bangor Mineral District. *Bull. Geol. Surv. Tasm.*, pp. 20. Dept. of Mines, Tasmania. Hobart.

Some references are made to tasmanite as occurring in the Bangor district. The material is more of a carbonaceous shale, similar to a low grade cannel coal.

Voisey, A.H., 1938: The Upper Palaeozoic Rocks of Tasmania. *Proc. Linn. Soc. N.S.W.*, 63, 5-6, 309-333.

A description of a geological survey to compare the stratigraphy of the Kamilaroi Series in N.S.W. with corresponding deposits in Tasmania. Tasmanite is mentioned only in relation to the coal horizon of the Mersey district.

Walker, A., 1937: Investigations into the Manufacture of Asphalt from Tasmanite. *Rpt. Dept. of Mines, Tasm.* pp. 40. Hobart.

A discussion of the behaviour of tasmanite on heating and of the possibility of concentrating the organic matter by froth flotation. Tasmanite concentrate can be heated to yield a semi-liquid mass that has possibilities as a road bitumen. Heating the N.S.W. oil shales did not yield a similar resinous material but only a black residue.

Wall, D., 1962: Evidence from Recent Plankton regarding the Biological Affinities of Tasmanites (Newton, 1875) & Leiosphaeridia (Eisenack, 1958). *Geol. Mag.*, 99, 4, 353-362.

A review of existing literature on the taxonomy of *Tasmanites*, leading to the acceptance of *Tasmanites* as an alga of unknown affinity. Evidence is put forward showing the very close relationships between *Pachysphaera* and *Tasmanites*. Chemical tests shown that the wall membrane consists of a complex lipoid substance with little or no cellulose. In general features *Tasmanites* and *Pachysphaera* have close biological affinities and Wall suggests that *Pachyspaera* must be regarded as a living representation of the genus *Tasmanites*.

Wells, A.T., 1957: Geology of the Deloraine-Golden Valley Area, Tasmania. *Rec. Q. Vict. Mus. L'ton.* N.S. 8, pp. 13 & 2 maps.

A brief description of tasmanite in relation to the economic geology of the area. Oil shale originated as "a small shallow water-barred basin or estuarine deposit, separated structurally from the off-shore marine beds".

Wilson, L.R., and Skvarla, J.J., 1967: Electron Microscopy of the Wall structure of *Quisquilites* and *Tasmanites*. *Okla. Geol. Notes.* 27, 3, 54-63.

A discussion, supported by micrographs, of the relationship between *T. punctatus* and *Q. buckhornensis*.

Zetzsche, F., Vicari, H., and Scharer, G., 1931: Untersuchungen uber die Membran der Sporen und Pollen. Fossiles Sporopollenin aus dem Tasmanite und der Miskaurer Braunkohle. *Helv. Chem. Acta*, 14, 67-78.

Chemical analyses of tasmanite wall resembles those of recent spores. Tasmanite "spores" were treated with sulphuric and phosphoric acids, separated with carbon tetrachloride, then chemically treated and extracted to recover "pure" sporopollenin, which authors name "tasmanin". Tasmanin was given the formula $C_{90}H_{134}O_{15}(OH)_2$ and stated to be free from nitrogen and sulphur. Acetylation shows that tasmanin contains only two hydroxyl groups and the authors suggest that ion exchange accounts for the low hydroxyl content.

Zetzsche, F., Kalt, P., Liechi, J., & Ziegler, E., 1937: Zur Konstitution des Lycopodium Sporonins des Tasmanins und des Lange-Sporonins. *J. Prakt. Chem.*, 148, 267-286.

The paper discusses the group analysis of tasmanin in relation to the analyses of other sporopollenins. Experiments show that tasmanin is resistant to normal methods of organic analysis. Ozone oxidation of tasmanite kerogen produces a variety of dicarboxylic acids such as succinic, glutaric and adipic but no malonic acid. Oxidation with acid potassium permanganate gave no succinic acid. The tasmanin molecule appears to have three methyl groups and two hydroxyls. Research supports the earlier formula of $C_{90}H_{136}O_{17}$.