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THE OIL SHALES OF TASMANIA

INTRODUCTION

It was the original purpose of the writer to deal with the two types of shale, namely; tasmanite and the so-called torbanite or kerosene shales, but as the subject assumed such large proportions it was decided to confine attention to tasmanite only. Much research is still necessary to decipher the problems unsolved relating to the actual nature of the oil-producing organic matter and also to the nature of the oils produced in the processes of distillation. The information contained herein whilst adding to our general knowledge of the subject should prove an incentive to further investigation.

HISTORY OF DISCOVERY & DEVELOPMENT

The name of the discoverer of oil shale in Tasmania was not recorded in the annals of that time. The earliest account appears in the "Papers and Proceedings of the Royal Society of Van Dieman's Land" in a paper read by Milligan in the year 1851. Since its discovery so many years ago the deposits have continued to excite the attention of scientists as evinced by the large number of contributions to our knowledge from the pens of many investigators; but until recent years it has proved of passing interest only to investors as its exploitation was not considered a commercial possibility. In the early nineties a local company was formed to explore the seam and determine the value of the shale as a source of oil. The early history of the industry is essentially the history of the operations of that company. After an expenditure of many thousands of pounds without return the present members of this Company remain hopeful and expect soon to receive the reward of their patient industry. A number of companies hold shale interests in Tasmania to-day, one of which, the Australian Shale Oil Company, has erected a very large plant and has opened another area for mining. It is expected that the plant will be put into operation this month. If crude oil can be produced from the great shale deposits of Tasmania by the utilisation of the Bronder process as cheap as the average cost of production of drilled wells, then the operation on a large scale of the shale deposits must prove a very attractive proposition and one which must command attention in the very near future.

GEOGRAPHY

There is, as will be shown later, a genetical association between the two important types of oil-producing shale in Tasmania; therefore one is regarded as an indication of the near presence of the other, yet the two are never found superimposed. Investigation shows that the shales are found in disconnected basins situated in the north and north-central parts of Tasmania, associated with kerogenite and humic-kerogenite coals. The most important is that extending from Latrobe to Quamby Bluff and Chudleigh. From Latrobe the seam has been traced to Railton, Nook, Paramatta, Kimberley, Deloraine, Osmaston, Beaulah, Cheshunt, and Chudleigh. Outcrops are found in each area named. From Latrobe the seam has been traced without serious interruption under the broad flood-plain and valley sides of Mersey River to a point three miles south-east of Kimberley. Between Kimberley and Deloraine the shale series of rocks are covered with basalt lava and ash, but they reappear again a mile south of Deloraine and are well-exposed at Osmaston. Remote from these are the Cam River bed of tasmanite, exposed near Henrietta and Oonah, and the so called torbanites of Preolenna and Mt. Pelion. The Henrietta tasmanite and Preolenna torbanite (Kerogenite and humic Kerogenite coals) are directly connected, but the Mt. Pelion sea, is far distant and apparently lies at a slightly higher horizon in the formation than the others.

GEOLOGICAL HORIZON

The tasmanite shale seam and the associated bed of coal lie at the same horizon in the Permo-Carboniferous formation. In the coal portion of the basins land and freshwater beds are intercolated between Lower Marine and Upper Marine mudstones; but in the tasmanite portion the Lower Marine and Upper Marine form a continuous series uninterrupted by land or freshwater deposits. Long it was doubtful whether the shale and coal seams were homologous, but recent investigation sets all doubt aside. Early observers noted that in the marine beds above the coal seam fossils are found similar to those in the beds above the shale (tasmanite), and below the shale pebbly mudstone passing down a basal conglomerate prevails just as happens below the coal seam. The fossils above and below the bed of shale and coal are identical and all are marine or open estuarine. In boring for oil shale near Latrobe it was found that there is an intergraduation from shale to coal. At Nook the bed of shale abuts against the coal seam on two sides. In the bed of Don River below Bott Gorge is a thick seam of black coaly shale which differs in many important particulars from tasmanite and apparently marks the transition between it and the humic Kerogenite coal of the region, for, in addition to sporingia of tasmanite, it contains black coaly matter derived probably from another order of plants.

The Don Valley black shale cannot be lighted as readily as tasmanite, but the characteristic odour of the latter is given off in burning. Even with the aid of the microscope the structure of this material cannot be perceived. It is interesting to note that the shale layers are separated here as elsewhere by a band of almost barren mudstone.

At Chudleigh not far from the Cheshunt bed of tasmanite coaly matter similarly charged with sporangia has been found. In further confirmation the writer has found thin bands of coal, brittle and of pitch-like lustre, encased in or attached to tasmanite shale at Latrobe. It is noteworthy that the relative proportions of volatile hydrocarbons to fixed carbon is 1 to 1 in this coal as in the main body of coal in the fields of Spreyton, Carleton, and Dulverton. It is remarkable that where tasmanite is nearby torbanite is not found in direct association with humic-kerogenite (cannel) coal. Yet torbanite, like shales, are found below Bott Gorge and at Chudleigh replete with the sporangia of tasmanite. The inference is that sporangia of the marine deposit tasmanite is one of the chief components of torbanite with perhaps a far larger proportion of pollen. There is also an intergraduation of torbanite to cannel (humic kerogenite) coal as there is from tasmanite to cannel coal. The gradations may be expressed in the following degrees:- tasmanite, black carbonaceous shale of Don Valley class, torbanite or kerosen shale, cannel or humic kerogenite coal.

THE SHALE BED

The tasmanite seam is 5 to 7 feet thick and lies at or about the horizon of the coal bed in contiguous areas. Only one seam of tasmanite and only one seam of coal is known where the two are closely connected. There is no evidence to show that tasmanite and coal are anywhere mutually superimposed; on the contrary it is known that where coal is found it is futile to search for tasmanite and where tasmanite is found for coal. This knowledge facilitates exploration considerably by the elimination of all coal areas from examination. It has been established that the seam of tasmanite fringes the shore-line of the Permo-Carboniferous sea from which it follows that where the upper marine mustones abut early Palaeozoic and Proterozoic rocks the presence of tasmanite may be anticipated.

A rather striking feature is that there is no noticeable thinning of the seam as the shore line is approached. This is due in part to the steep slope of the shore rock and to the fact that the materials of which the shale is composed were deposited in waters not less than 10 feet deept. The arenaceous muds and sporangia forming the bed of shale were deposited in shallow waters along the shores of islands or in estuaries. It is noteworthy that the shale bed in every locality consists of twomain layers separated by a band of mudstone, one to two feet thick, similar to that in which the shale is encased thus indicating similar conditions of formation and direct association. The separating mudstone band contains tasmanite sporangia, butthe roof and floor mudstone are almost devoid of them. Embedded in the shale are numerous well-rounded pebbles and boulders of quartzite, conglomerate, chert, schist, and quartz, many very pyritic. These large inclusions vary in size from marbles to boulders two feet in diameter. The large boulders are subangular and evidently were precipitated into the sea from nearby shore hills. Where the shale enwraps the pebbles and boulders it appears more compressed and closely laminated. In may places the calcite of the marine fossil has been completely replaced by pyrite. Secondary pyrite is abundant also in the rock pebbles and nodules and veinlets are not uncommon in the body of the shale. The nature of the discs in the shale.was discovered by R.M. Johnston and was first recorded by him in "Field Memoranda for Tasmanian Botanists published in 1874. Johnston states that "tasmanite is the product of the spores and sporangia of certain cryptogams allied to the clubmosses and that the sporangia were washed down by an ancient muddy river and deposited in the quiet bottom of an inlet of the Upper Palaeozoic sea and among the sediments thus deposited marine organisms lived and died".

The following is an incomplete list of the marine fossils that have been found in the shale:-

Spirifera tasmaniensis (Morris)
Cardiamorpha gryphoides (De Kon)
Pachydomus hobartensis (Johnston)
Pleurotomaria Morrisiana (McCoy)
Pleurotomaria Woodsii (Johnston)
pteronites latus (De Kon)
Aviculopecten latrobensis (Johnston)
Aviculopecten subquinquelineatus (McCoy)
Aviculopectin fittoni (Morris)
Aviculopecten sprentii (Johnston)
Eurydesma hobartense (Johnston)
Keeneia Twelvetreesi (Dun)
Arthitutes (Fischer)

NATURE OF TASMANITE

Tasmanite, like Kerogenite and humic Kerogenite coals (the so-called kerosene shale and cannel), is not an oil-bearing but an oil-producing substance, that is to say there is no free oil in the material. That marks the distinction between oil shale and oil sands. In oil sands the oil is contained in the sands as oil. In shale there is no oil as such, but the substance is in it from which oil can be generated. Oils cannot be extracted from it by solvents nor by subjecting the material to high pressure but oils can be formed from it by the application of heat under suitable conditions. The source of the oil is an organic substance called "kerogen" with which the shale is impregnated. This organic material is of vegetable origin and may be regarded as a concrete fixed oil. Yet, it does not follow that there is any direct relation between natural petroleums and the kerogenous materials of oil shale. In fact, it is generally believed that natural petroleums are not of vegetable origin. Shale is essentially a mineral product consisting largely of hardened arenaceous muds in which are embedded certain fossil hydrocarbons not uncommonly found in the Perm-Carboniferous formation. Kerogenous shales are found in the PermoCarboniferous of many countries, and also in later formations. They differ considerably, the difference being due largely to the variation in the conditions under which they were laid down and preserved and to variation in the nature of the plant remains of which they were formed. Some are marine deposits, others are terrestrial; some consist largely of the waxy covering of spore cases, some of pollen and other plant remains in addition. The Kerogenous material of tasmanite so adapted to the generation of artificial petroleum by distillation consists of the waxy covering of minute disc-shaped spore cases which are set in a fine-grained arenaceous sediment. The amber-coloured discs or sacs are about half a millimetre in diameter and, if not deformed, are nearly circular in outline. They appear as flattened bodies pressed together in overlapping layers, and can be separated easily by the insertion of a sharp instrument between them. Under the microscope they appear contorniate the harder rim part being marked in most cases by carbonaceous material. Twelvetrees presents the following description:-

> "In transmitted light they are transparent, with a peripheral external wall crowded with rod-like wedge or gash-shaped cavities of minute size, disposed for the most part, subradically within each sac or spore case, and suggestive of the presence of some cellular structure, faint traces of which are occasionally revealed."

The spore cases have been preserved by a decay-resistant waxy or resinous substance forming the outer skin, but the spore cases have decayed, and their remains are generally almost indistinguishable, except for a little black carbonaceous material marking the division between the cutaneous waxy covering. However, the nature of the spore sac is clearly revealed in the less deformed specimens. The sporangetes or wax like spore exines (walls) compose the bulk of the oil-producing material, and represent the protective covering of the spores of a plant probably of lycopod relation and allied to present day club-mosses. It is pointed out by John that the spores, evidently, had been discharged, as almost every sac appeared to be fractured as if rent asunder by internal force. These waxy or resinous products of the plant are hydrogen-rich and oxygen-poor substances. The kerogen of these shales, then, consists of the sporangia or spore cases of a supposed lycopodiaceous plant termed by Professor Newton of the British Museum "tasmanite punctatus". The structure of modern clubmosses (lycopods) furnished a feasible explanation of the origin and nature of the fossil remains. Stewart a Scottish investigator, obtained a substance similar to shale oil by the distillation of a mixture of 25 per cent. lycopodium spore dust and 75 per cent. of Fuller's Earth.

PHYSICAL PROPERTIES OF TASMANITE

Colour - light yellow or amber when fresh; dark brown on exposed surfaces, grey on weathered surfaces. Lustre - resinous to pearly. Texture - finely laminated fossils, weathered shale splits into thin flexible paper-like sheets. Fracture - the material is tough and sectile. It breaks unevenly and with great difficulty across the plane of bedding. Weathering - the shale withstands weathering remarkably, and exposures stand out prominently from the encasing mudstone. The effect of weathering on the oil yield is inappreciable. Specific Gravity - the specific gravity varies from 1.2 to 1.6, the richer layers having the lower value. Hardness - this property varies according to the degree of richness, the average being 1. Flexibility - in thin sheets the shale is capable of being bent through a large arc without breaking. This property is increased by submersion in boiling water, Solubility - almost, if not quite, insoluble in ether, pyridine, benzine, and carbon bisulphide; unlike ordinary resins and waxes it is only slightly soluble in alcohol. It is not acted on by HCl, slowly oxidized by $H N O_3$, readily carbonised by H_2SO_4 with evolution of H_2S.

Fusibility - the shale ignites readily with a match, and continues to burn freely when removed from the external source of heat. In burning at that temperature it produces a large volume of black sooty smoke, and gives off a strong unpleasant odour.

CHEMICAL COMPOSITION OF TASMANITE

When the shale is placed in a retort and subjected to heat the organic component is progressively decomposed into permanent gases and oil vapors of various kinds, the latter of which can be easily condensed into crude shale oil. The richness of the shale is in proportion to the amount of kerogen it contains or in proportion to the number of sporangia. It is remarkable that although the richness of the shale varies from the top to the bottom of the seam the variation is similar in every shale area and the average oil content remains constant. The upper part of the seam is richer than the lower in every area, yet the average content of oil in the material as a whole remains between 40 and 45 gallons per ton of shale.

The following proximate analysis of shale from Latrobe area may be taken as a fair indication of the composition:-

Moisture	0.80	per cent
Volatile matter	30.84	" "
Fixed carbon	5.86	" "
Sulphur	2.56	" "
Ash	62.50	" "

The fixed carbon probably represents the black carbonaceous matter of the sac walls already referred to. A portion of the amount, however, may have been derived from the Kerogenous material owing to the insufficient distillation. It is possible for instance, that in the process of distillation and the formation of permanent gases and light gasolene surplus carbon was liberated. Tasmanite is distinguished from many similar plant remains by the high proportion of sulphur it contains in combination with its carbon and hydrogen. The distillate from these shales has the strong penetrating odour of sulphuretted hydrogen and alse of carbon-bisulphide. Evidently the greater part of the sulphur in that compound represents the amount originally contained in the body of the plant from which the pyrobituminous matter was derived. Extrinsic sulphur in combination with iron as pyrite and marcasite is a common accessory component of the shale, and in the process of conversion of Kerogen to oil some of it may have entered into combination with hydrogen and carbon. An ultimate analysis of the crude oil revealed its composition as follows:

Nitrogen	0.31	per cent
Hydrogen	10.41	" "
Oxygen	4.93	" "
Carbon	79.34	" "
Sulphur	4.93	" "

From a number of analyses Church arrived at the empirical formula C_{40}, H_{64}, O_2S, and suggested that the material may be a derivative of turpentine C_{20}, G_{32}, or the radicle he assumed them to contain may be a homologue of benzoyle $C_7H_5O + 13\ CH_2 = C_{20}H_{31}O$. It is doubtful whether the Kerogen of tasmanite can be expressed as a definite chemical compound the relative proportion of the constituents, however, can be expressed as a constant if sulphur is disregarded. The calorific value of the crude oil has been estimated at 21625 to 21336 B.T.U.; the flash point from 235° to 260°; and the specific gravity from 0.931 to 0.956. The crude oil remains fluid at the lowest natural temperature of the atmosphere. In the process of distillation the following products are obtained:-

Permanent gases and gasolene	10.00	per cent
Benzine	10.	" "
Fuel oil	80.	" "

By fractional distillation the fuel oil may be converted into:-

Lighting oils	25.	per cent
Lubricating oils	30.	" "
Tar	28	" "

The viscosity of the lubricating oil has not been determined but apparently it is not high, and the oil is not of standard quality. The fuel oil may be used to advantage in internal combustion engines or as a fuel for the generation of steam, or it may be "cracked" into benzine and residual tar. The oil derivable from tasmanite is of asphaltic base whereas that from the so-called torbanite and pelionite shales is of paraffin base. The nitrogen content of tasmanite is so small that it may be disregarded. However, it may prove of some value as a fertilising agent if discharged as a constituent of ammonium sulphate from the spent shale which contains other components of plant food. Tasmanite contains a small amount of potash and of soda, and a little phosphoric acid.

Applied as a poor fertiliser the spent shale may prove of some value also as a mechanical agent in breaking up the stiff basaltic oils of the neighbourhood. The following is an analysis of spent shale:-

Carbon	11.0	per	cent
Titania	0.40	"	"
Soda	1.57	"	"
Potash	1.93	"	"
Silica	64.80	"	"
Alumina	12.02	"	"
Ferric oxide	3.58	"	"
Lime	1.00		
Magnesia	1.74	"	"

QUANTITY OF SHALE AVAILABLE

In all the explored areas sufficient data are available for accurate calculation of the shale reserve. There are, however, certain untested areas in addition which are regarded as potential sources of shale, and, therefore deserve attention. The total tonnage of shale in the several areas is estimated as follows:

Actual Reserve	Probable Reserve
17,000,000	27,000,000

UTILISATION

The first question for consideration is whether it is advisable to market the fuel oil portion as such or whether it is advantageous to crack the fuel oil into benzine and tar. In this connection it will prove of interest to note the results of researches performed by Dr. Gustav Egloff of Chicago on antiknock motor fuels. To begin it may be stated that one of the most important problems in the oil industry today is the production of antiknock motor fuels. Normal straight-run gasolines produced from some oil fields develop the familiar knocking sound in an automative engine when labouring on hills, with wide-open throttle. For many years it has been believed that straight-run gasolines from paraffin base or semi-asphaltic base oils were superior motor fuels. Since, however, the advent of the commercial cracking of heavy oils into cracked gasolene this position is no longer tenable, for the cracking reaction can be so controlled that antiknock motor fuels can be produced of superior qualities to straight-run gasoline. Paraffin hydrocarbons vaporised with air detonate with an explosion velocity far beyond that of the normal burning wave. The high velocity of explosion gives a hammer-blow in the cylinder instead of propulsive force, and the high explosion wave gives rise to familiar sound of knocking in the motor engine when operating at low speed when the motor is on an ascending grade.

The napthene hydrocarbons in gasoline have antiknock properties which enhance their value, and the aromatic series are so particularly endowed that they are the best compounds derivable from crude oils. The unsaturated hydrocarbons of the olefin series are excellent antiknock compounds and have important qualities for that reason as motor fuels.

Tests have shown that the straigh-run benzine and the cracked fuel oil derived from tasmanite contain oils of the aromatic series and that the benzine so produced has proved an excellent motor fuel.

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Hobart. 14th June, 1926.