

GSMR9

TASMANIA
DEPARTMENT OF MINES

—
GEOLOGICAL SURVEY
MINERAL RESOURCES NO. 9
—

ASBESTOS IN TASMANIA

By

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Issued under the authority of
The Honourable ERIC ELLIOTT REECE, M.H.A.,
Minister for Mines for Tasmania.



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PREFACE.

Since 1866 when Charles Gould made reference to Asbestos in the West Tamar District, many bulletins and reports have been issued on Asbestos deposits and their exploitation. The ever increasing demand for the mineral has necessitated that all the resources should be re-examined and the information collated in one Bulletin.

Asbestos occurs in widely distributed localities in the North and Western parts of Tasmania, but the size and nature of the deposits together with the lack of access to some of the districts have limited past production to small scale operations in the Beaconsfield and Zeehan districts.

This bulletin, which is the result of investigational work undertaken by the Department of Mines in 1948-49 when interest in the production of asbestos had increased, was prepared by Mr. B. L. Taylor, B.Sc. (N.Z.), who made an extensive survey of the known areas. The survey has added greatly to the information available in previous publications and this Bulletin presents all the available knowledge of the Asbestos Reserves of Tasmania.

Where applicable the figures in the report have been altered to bring them up to date at the time of printing. Since the report was originally written in 1949 Mr. Taylor has had extensive experience in the West Coast areas of Tasmania, and his further conclusions are included as an Addendum to this report.

Some 33,888 tons of asbestos fibre were imported into Australia in the year ended 30th December, 1954, a proportion of which was used by industries in Tasmania. Prior to the cessation of operations, the recorded output of asbestos in Tasmania was 3,980 tons, and with further exploration it is possible that the deposits may be able to supply local industries with their requirements of commercial fibre.

J. G. SYMONS, *Director of Mines.*

1st November, 1955.

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INTRODUCTION

SECTION I.

Since August 1866, when Charles Gould wrote his "Report on the Country near Ifracombe in the West Tamar District", intermittent attention has been paid to the asbestos deposits of Tasmania. A considerable amount of information has thus been built up in the files of the Department of Mines, some available to the public in Bulletins of the Geological Survey, some in the form of departmental reports, routine reports of officers of the Department and letters from private persons. With information in such diverse form, it has been difficult to form a clear picture of the asbestos potential of the State. In August 1948, therefore, the writer was detailed to undertake a complete resurvey of all known asbestos-bearing areas and to correlate the results with the existing information.

Fieldwork occupied the period from September, 1948 to June, 1949. The principle upon which fieldwork was based was the inspection of areas in which asbestos is known to occur, the formation of working hypotheses of the mode of formation of the fibre, and the prospecting of other areas of serpentine in the light of these hypotheses.

A considerable amount of pure survey work was necessary in the preparation of plans. The plan of the Spero River areas was compiled from chain and Brunton Compass survey, that of the Argent Tunnel area by sketching on to a base plan prepared by C. L. Knight of the Bureau of Mineral Resources by planetable survey, and the remaining plans from survey by chain and No. 7 Mk 1 Army Director. The final plans were prepared from the field sheets by the Draughting Section of the Department of Mines.

Section II of this report deals with the mineralogy and industrial uses of the asbestos minerals, mining and extraction methods; Sections III to VIII with the various areas of the State in which asbestos occurs; Section IX is a summary of the results obtained; Section X deals with some theories of serpentinisation and the formation of asbestos.

In concluding this section, the writer would like to acknowledge the practical assistance and valuable information given him by the various persons with whom he has come into contact during the course of this survey. To all those who assisted in any way; officers of the Department of Mines, field assistants, launch owners at Strahan, and local residents in the various districts who spontaneously proffered assistance and information, the writer's thanks are gratefully offered.

INTRODUCTION

SECTION II—THE NATURE, PRODUCTION AND UTILIZATION OF ASBESTOS.

The asbestos minerals have a combination of characteristics which make them unique amongst commercial minerals. It has been well said that they combine the workability of animal or vegetable materials with the resistance and durability of a granite block. The following list of qualities indicates the versatility of this remarkable group of minerals.

Workability—Although rock-forming minerals, these substances, when extracted, have the physical characteristics of wool, cotton, or silk; may be spun into thread, rope or tape; woven into cloth; pressed into blocks, felt, paper, or board; or blended with cement or other binding agents and moulded into a variety of shapes.

Durability—These minerals are chemically almost inert and resist weather, corrosion, fire, heat, acid, vermin and fungus growth.

Insulation—They may be used to insulate against vibration, electricity, or sound.

Binding Power—The materials may be compressed to form a felt, or used as reinforcing agents in cement, magnesia and rubber.

Filtering Power—In laboratories and chemical plants the asbestos minerals are often used to filter acids and alkalis.

THE ASBESTOS MINERALS.

As used by the mineralogist, the term "asbestos" refers to fibrous forms of amphibole, near tremolite and actinolite in composition. These minerals, however, form but a small percentage of the fibrous minerals used in commerce and, to the industrialist, "asbestos" connotes all naturally-occurring fibrous materials which have some or all of the qualities enumerated above. This double usage tends to cause some confusion. Since, however, the use of the term in its industrial sense is well established, it appears to the present writer advisable to accept the wider meaning and to refer to the individual members of the group by their correct mineralogical names. This practice is followed throughout this report.

The asbestos minerals are, chemically, complex silicates of magnesium, calcium and iron; rarely of sodium; and occasionally including a small percentage of aluminium and traces of nickel and manganese. Some members of the group are hydrated, other anhydrous. There are representatives of the amphiboles (normal metasilicates sometimes hydrated) and of the serpentines (hydrous orthosilicates).

In the preparation of this section free use of the information in the following publications has been made:—

"Textbook of Mineralogy."—E. S. Dana. 4th Edition.

"The Genesis of Asbestos and Asbestiform Minerals." Stephen Taber (Trans. Am. I.M.E. Vol. LVII 1918, Pp. 62-98).

The various publications of the trade journal "Asbestos" (17th Floor, Inquirer Building, Philadelphia, 30, Pa).

Both fibrous and non-fibrous forms of each mineral are known. The fibrous varieties are shown by their optical properties to be crystalline though they do not usually show the outward form of crystals.

The minerals are listed in Table I, while chemical analyses appear in Table II.

TABLE I.

Amphiboles.	Serpentines.
Anthophyllite.	Chrysotile.
Gedrite.	Picrolite.
Ferroanthophyllite.	
Amosite.	
Tremolite—True Asbestos.	
Actinolite—True Asbestos.	
Byssolite.	
Crocidolite.	

Anthophyllite is an orthorhombic amphibole with the general formula $(Mg, Fe) SiO_3$ and corresponds to the enstatite-hypersthene series of the pyroxenes. Magnesia is usually present in greater amount than iron and alumina usually replaces part of the magnesia. Anthophyllite is usually found in the crystalline schists though it is known to occur in serpentines. It is derived from chrysolite (olivine) by metamorphism.

Gedrite and Ferroanthophyllite are varieties of anthophyllite rich in alumina and iron. Though occurring sometimes in fibrous form they find no commercial application.

Amosite is a long-fibred, ash-grey or greenish asbestos mineral from the Central Transvaal intermediate in composition between anthophyllite and gedrite. It was first discovered in 1907 and was named in 1918, the name being taken from the initial letters of the company most interested in its development—Asbestos Mines of South Africa.

Tremolite $(Ca, Mg, (OH)_2 (Si, O_{11})_2)$ and **Actinolite** $(Ca_2(Mg, Fe)_3 (OH)_2 (Si, O_{11})_2)$ are monoclinic amphiboles which are common and widespread rock-forming minerals especially characteristic of metamorphic rocks. Tremolite is always a product of metamorphism while actinolite sometimes occurs also as a secondary mineral in igneous rocks. The two minerals are closely related chemically, the only difference being that, in actinolite, up to 50 per cent of the Mg of tremolite is replaced by Fe. A tough compact finegrained variety of tremolite or actinolite with a glistening lustre is known as nephrite and forms one type of jade.

In fibrous form actinolite and tremolite form the true asbestos in colours varying from white to green or wood-brown depending upon the amount of iron present. The term "amianthus" is used to denote the finer and more silky varieties. The fibres are sometimes interlaced to form thin flexible sheets known variously as mountain leather, mountain wood, or mountain cork.

Byssolite is a stiff fibrous form of no commercial value.

Crocidolite is also a monoclinic amphibole consisting essentially of $NaFe (SiO_3)_2$ with $FeSiO_3$ in varying proportions. It occurs in

long, delicate, easily-separable fibres and its colours varying from lavender-blue to leek-green are distinctive. It is known commercially as "Blue Asbestos" and the particularly fine product of Cape Province in South Africa is called "Cape Blue". Crocidolite occupies a unique place among the asbestos minerals in that it is the only one containing an alkali and also the only one which does not contain magnesia as an essential chemical constituent. It will be noted from the analyses in Table II that crocidolite from South Africa contains a small amount of magnesia but this is to be considered as replacing iron. Fe_2O_3 and Na_2O are both fluxes and their presence in this material lowers its fusibility considerably and crocidolite cannot therefore be used in products which are required to resist intense heat.

Chrysotile is a fibrous form of serpentine of the theoretical formula $\text{H}_3\text{Mg}_3\text{Si}_2\text{O}_8$. Iron, however, almost always replaces part of the magnesia and alumina is usually present. It is probable that iron is an essential constituent of the molecule and the formula is more correctly written $\text{H}_3(\text{Mg}, \text{Fe})_3\text{Si}_2\text{O}_8$. Chrysotile is the chief source of commercial asbestos and 95 per cent of the world's asbestos production is of this material. It is found in fibres varying in length from a minute fraction of an inch up to two inches though the average length is well under a half-inch.

Picrolite is a mineral having the composition and outward appearance of chrysotile but with a splintery fracture. It corresponds physically to byssolite among the amphiboles and has no commercial value.

TABLE II—CHEMICAL ANALYSES OF ASBESTOS MINERALS.

	(1) Antho- phyllite	(2) Amosite	(3) Tremolite	(4) Actino- lite	(5) Crocidolite	(6) Chryso- tile	(7) Chryso- tile
SiO ₂	55.6	50.24	59.2	53.9	51.1	39.05	44.1
Al ₂ O ₃ .. .. .	....	....	....	....	....	3.67	....
Fe ₂ O ₃ .. .. .	....	7.80	....	....	....	2.41	43.0
FeO	16.6	32.00	....	20.2	35.8	} 40.07	....
MgO	27.8	3.96	24.2	11.3	2.3		
CaO .. .. .	....	....	13.8	12.6	....	....	....
Na ₂ O .. .. .	....	2.12	....	....	6.9	....	....
Comb. H ₂ O .. .. .	....	3.00	2.2	2.0	3.9	14.8	12.9
Total	100.00	99.12	100.00	100.00	100.00	99.68	100.00

- (1) Theoretical composition based on the formula Mg₃Fe (SiO₃)₄, i.e., with a ratio of Mg. : Fe = 3 : 1.
- (2) Actual analysis of Transvaal Amosite.
- (3) Theoretical composition based on formula Ca₃Mg₅(OH)₂(Si₄O₁₁)₃.
- (4) Theoretical composition based on formula Ca₂Mg₅Fe₅(OH)₂(Si₄O₁₁)₄, i.e., with a ratio of Mg. : Fe = 1 : 1.
- (5) Actual analysis of Cape Province "Cape Blue".
- (6) Actual analysis of Canadian material.
- (7) Theoretical composition based on formula H₂Mg₃Si₄O₁₁.

TYPES OF FIBRE.

With the exception of anthophyllite, all asbestos minerals occur as veins in the enclosing rock. The fibres lie either transverse to the strike of the vein (cross-fibre) or along it (slip-fibre). Anthophyllite occurs as bundles of radiating fibres to which the name "mass-fibre" has been given. Crocidolite is known to occur only as cross-fibre but, with this exception, all asbestos minerals may occur in either cross or slip form. Chrysotile usually occurs as cross-fibre and amphiboles as slip. Some confusion of terminology has arisen, the terms "cross-fibre" and "slip-fibre" being used as synonyms of chrysotile and amphibole respectively. It is emphasised that these terms refer solely to mode of occurrence and do not denote mineral species.

The following notes are general only and more detailed information regarding vein types will be found in the descriptions of fibre-bearing areas which follow.

Cross-Fibre Veins.

These usually occur as vein systems, the individual veins from a few inches to several feet in length, continually diverging and reuniting. The width of the vein system remains fairly constant. Although the veins lie at angles to each other, it is found that the individual fibres of one vein system are subparallel. This fact is of importance in considering the origin of veins. Sometimes the fibres are curved or show abrupt changes of direction within the vein, a fact which may indicate movement along the vein. Usually the vein walls are highly irregular so that the length of fibre is by no means constant. The fibres seldom extend from wall to wall except in very narrow veins. More often there is at least one parting, either at the centre or towards one wall, which may or may not be marked by wallrock, amorphous serpentine, magnetite, haematite, chromite, or rarely talc. On close examination, these partings are seen to be irregular surfaces. The width of the material in the parting varies considerably and sometimes the parting is wider than the fibre portion of the vein. The fibres are actually bundles of extremely delicate threads which appear to be divisible ad infinitum much after the style of mica.

Slip Fibre Veins.

These generally occupy planes of weakness such as fault or gliding planes. They may be a foot or more in thickness but commonly are one to two inches. The fibres lie along the strike of the vein and often appear to be a foot in length. This is deceptive, however, and the "long fibres" prove to be but numbers of bundles of short fibres loosely held together. The average length of processed slip fibre is not much greater than that of cross fibre. There is no central parting in slip fibre veins but often there is an intimate intergrowth of magnetite with the asbestos, a fact which introduces some production problems.

Mass Fibre.

As far as is known, mass fibre is always anthophyllite, the type locality being Sall Mountain in Georgia, U.S.A. Discussing the occurrence S. Taber states (p. 86)—"The fibres are arranged in small groups or bundles and range up to an inch in length, though

averaging only about $\frac{1}{2}$ inch. The fibres show a strong tendency to form spherical bunches with radial structure, but because of mutual interference these bodies are, as a rule, only imperfectly developed, and therefore, in most cases, the rock consists of a mass of fibrous bundles and sheaves oriented in all directions. Occasionally, however, cross-fractures show well-formed rosettes of radiating fibres. Individual fibres sometimes appear jointed or broken. They are low in tensile strength and brittle, readily breaking into short lengths so that none of the material is of spinning grade. Because of the lack of flexibility the fibres are broken so many times during the milling process that they are exceptionally $\frac{1}{4}$ -inch long while the bulk is $\frac{1}{10}$ -inch or less".

LOCATION OF WORLD ASBESTOS DEPOSITS.

The four largest asbestos producing countries are Canada, Russia, Southern Rhodesia, and the Union of South Africa. Next in importance are the United States, Cyprus, Italy and Finland.

Canada.

Chrysotile variety found principally in the provinces of Quebec and Montreal.

Russia.

Very extensive deposits of good grade chrysotile are found in the Ural Mountains and have been extensively developed.

Southern Rhodesia.

Excellent quality chrysotile.

Union of South Africa.

Transvaal produces amosite, crocidolite and chrysotile. Cape Province produces the well-known "Cape Blue" exclusively.

United States of America.

Vermont is the source of most of the U.S. chrysotile. The Arizona Mines produce a low iron-content chrysotile. Georgia is the chief world producer of anthophyllite. Amphibole varieties also occur particularly in California and Maryland.

Cyprus.

Good quality chrysotile, mostly of "shingle" grade and lower.

Italy.

Chrysotile of fair grade and tremolite of excellent quality are produced. Mining and manufacture of asbestos on an industrial scale first began in Italy.

Finland.

Produces fair quantities of short anthophyllite.

MINING ASBESTOS.

The mining of asbestos consists in removing the fibre-bearing ore from the rock and delivering it to the mill; it does not therefore differ markedly from other mining or quarrying methods. Emphasis is, however, placed on quantity and the success or failure of a venture may well depend upon the degree of efficiency with which large quantities of material are handled.

Asbestos is notorious for the sporadic nature of its occurrence, channels of rich ore being separated by bands of comparatively poor rock, the proportion of fibre to rock varying up to 10 per cent. Rock carrying below 3 per cent of fibre is not usually considered economically exploitable. Each deposit of asbestos is, of course, a separate problem for the mining engineer.

Opencast mining, or quarrying, is the method usually employed especially in the great Quebec deposits. In these quarries, the whole of the rock is removed, the quarrying being accomplished by means of a series of benches ("spiral benching" or "parallel benching"). The rock is shot down, broken to a reasonable size, and removed to the mill by locomotive, motor-truck, or overhead cableways. The high degree of mechanization is a feature of these mines.

At Beaconsfield, quarrying was undertaken by the two companies which have, in the past, worked the deposits. The method of these companies differed, however, from the Canadian practice in that only the richer rock was removed, the more barren material being left. The Tasmanian Asbestos Company Pty. Ltd. at the Argent Tunnel, near Zeehan, used both opencast and underground mining methods, the latter in places where the removal of overburden was considered uneconomic.

At Takaka, in New Zealand, opencast mining was practised, the material being hand-cobbed before being supplied to the mill. This is a slow and laborious process, the vein-bearing material being chipped from the barren rock using 1½ lb. cobbing hammers. Such a method could only be employed for small scale production and is not to be considered for large works except perhaps for the production of special grades of crudes.

It is emphasized that wise planning is a vital preliminary to the establishment of any mining project. Too often in the past potentially valuable deposits have been abandoned after a short time because of unsound mining practice. In particular, it is the present writer's opinion that the Beaconsfield deposits need never have been abandoned. Only slight modification of the working methods—modification which should not have been necessary had the work been properly planned—would have converted a small working loss to a working profit.

MILLING ASBESTOS.

Milling covers the mechanical removal of the fibre from the ore, cleaning, grading and bagging; is unlike any other type of mineral recovery; and therefore requires special machinery and mill design. It is a mechanical not a metallurgical process. The following notes

apply more especially to the extraction of chrysotile though they are applicable in a general way to the milling of amphibole types.

The extraction of fibre involves four main processes which may be repeated a number of times.

Crushing consists of breaking the rock by means of compression.

In the jawcrusher type, reduction is accomplished by means of pressure between a vibrating and a stationary jaw, the material settling by gravity. In the gyratory cone type of crusher, the ore falls on to the gyratory head and is crushed between the head and the bowl by the eccentric rotation of the head. The size of material discharged may be altered at will by adjustment of the cone.

Fiberizing breaks the rock by blow on impact the fiberizers being similar to hammer mills or pulverizers. The hammers rotate at speeds up to 10,000 feet per minute and the size of fiberized material is controlled by the use of different sized stationary gratings. This process is more severe than crushing and is used only after the longer and more valuable fibre has been released.

Screening.—This process is self-explanatory. The screens are actuated by eccentrics and separate the rock into size fractions.

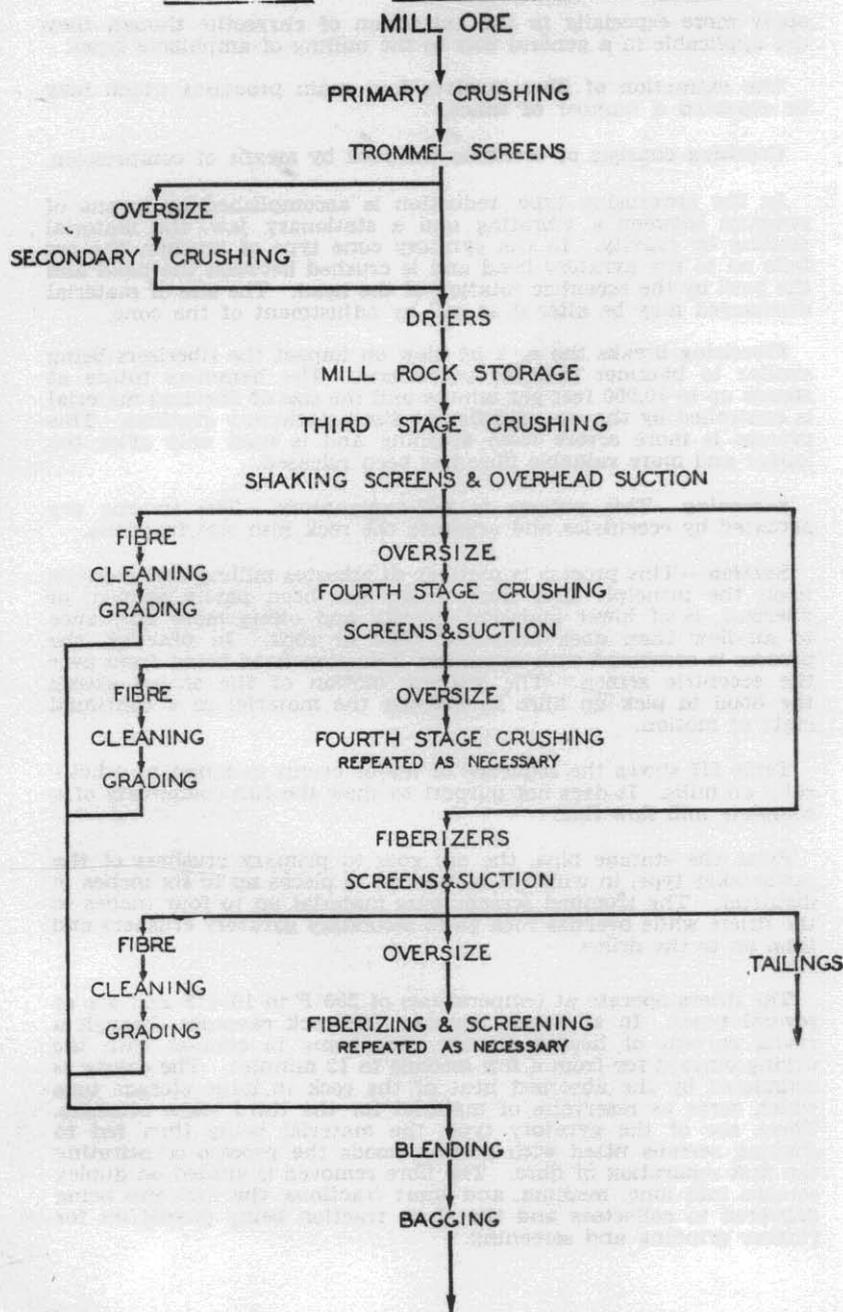
Suction.—This process is peculiar to asbestos milling and depends upon the principle that fibre which has been partly opened, or fiberized, is of lower apparent density and offers more resistance to air-flow than does unopened fibre or rock. In practice, the process is combined with screening, a suction hood being fixed over the eccentric screen. The shaking motion of the screen assists the hood to pick up fibre by keeping the material in a continual state of motion.

Table III shows the sequence of major events common to practically all mills. It does not purport to show the full complexity of a complete mill flow line.

From the storage bins, the ore goes to primary crushers of the jawbreaker type, in which it is reduced to pieces up to six inches in diameter. The trommel screens pass material up to four inches to the driers while oversize rock go to secondary gyratory crushers and then on to the driers.

The driers operate at temperatures of 200°F to 1000°F and are of several types. In all types, however, the rock cascades through a rising current of heated air the rock being in contact with the drying current for from a few seconds to 12 minutes. The drying is completed by the absorbed heat of the rock in large storage bins which serve as reservoirs of material for the third stage crushers. These are of the gyratory type, the material being then fed to shaking screens fitted with suction hoods the process constituting the first separation of fibre. The fibre removed is graded on duplex screens into long, medium, and short fractions, the first two being delivered to collectors and the short fraction being passed on for further grinding and screening.

TABLE III — MILL FLOW SHEET



The material passing over the first screen goes on to fourth stage crushing and the fibre separation process is repeated. All under-sized material from third and fourth stage crushing which has not been collected by the suction hoods goes through fiberizers then over screens and under suction hoods. This process is repeated as many times as is considered necessary, the tailings finally going to dumps.

The large volume of air used in the separation process is heavily charged with fine particles which must be separated before the air is ejected into the atmosphere. This is done by discharging the fan exhausts into huge float sheds in which the velocity of the air is dissipated in a series of chambers. The material deposited in these chambers is sold as "asbestos floats". Final cleaning of the air is by electric precipitation.

The first stage of cleaning is accomplished in the fibre collectors, the finer material being carried off by the air current. The second stage consists in passing the fibre over wide-mesh screens which allows coarse rock particles to fall through. Finally the material is dropped through a cyclone, the heavier particles of rock and unopened fibre falling to the floor and the lighter fibre being drawn off to the sides by suction and again deposited in collectors.

The process of grading begins with the separation of the fibres into standard size-fractions (see classification). The fibre is fed into rotary screens and forced through the meshes by paddles. Material from 1/10" to 1/4" passes through the finer mesh in the first half of the screen, that from 1/4" to 1/2" through the coarser mesh in the second half and that over 1/2" in length passes out the end of the screen.

Grading is a task for an experienced operator and calls for close co-operation between operators and inspectors since, depending on the results of frequent tests, the flow of material can be adjusted to avoid off-grade fibre.

Grading is accomplished in specially designed machines which blend the correct proportions of the various standard size fractions.

In the final process, the fibre is compressed into 100 lb. bags for shipment.

TESTING METHODS, CLASSIFICATION AND PRICES.

In the literature relating to asbestos and asbestos products it is stressed that "quality" refers solely to length of fibre. Chemical composition can of course be determined by the usual laboratory methods and is of importance where insulation against high electric voltage or resistance to fire are prime considerations. Tensile strength and fineness of fibre do not appear to be the subjects of standard tests and the rating of these qualities probably depends upon the personal opinion of the manufacturer.

The following information is quoted in full from various numbers of the American trade journal "Asbestos" and refer solely to the chrysotile variety. There appears to the present writer, however, no valid reason why the method of testing and classification of grades should not also be applied to amphibole types.

Method of Testing Canadian Asbestos.

The Quebec Standard Asbestos Testing Machine consists of a nest of four boxes measuring 24½" x 14½" resting on a table which is driven by an eccentric with 25/32" throw and 1 9/16" travel. The boxes which are superimposed one above the other are numbered from the top down 1, 2, 3 and 4. The bottoms of boxes Nos. 1, 2 and 3 are made of brass screen of the following specifications:—

Box No.	Screen Opening.	Wire Diameter.
1	0.500"	0.105"
2	0.187"	0.063" (4 mesh)
3	0.053"	0.047" (10 mesh)
4	receptacle for fines	

To make a test 16 ozs. of asbestos is placed on the uppermost tray which is covered and tightly clamped. The machine is started and by means of an automatic device is kept going until exactly 600 revolutions have been made. At the end of this time, the asbestos which remains on each tray is weighed. This gives the grade of asbestos fibre. The longest fibre naturally stays on the screen with the largest openings whereas shorter fibre, according to its length, remains on screens 2 or 3 or drops into the pan. The more fibre retained on the first screen and the less falling into the pan the higher the grade and the greater the value.

The product known as "crude asbestos" is not graded on this machine.

Canadian Chrysotile Asbestos Classification.

(Adopted by Quebec Asbestos Producers Association, March 22, 1943).

The asbestos mines products are divided into two classes—"crude asbestos" and "milled asbestos"—defined respectively as follows.

"Crude Asbestos" consists of the hand-selected cross-vein material essentially in its natural or unfiberized form.

"Milled Asbestos" consists of all grades produced by mechanical treatment of asbestos ore.

Crude and Milled Asbestos are sub-divided into groups and grades designated and defined below.

"Guaranteed Minimum Shipping Test" is that below which the actual shipping test shall not fall.

Group No. 1.

Crude No. 1. Consists basically of crude ¾" staple and longer.

Group No. 2.

Crude No. 2. Consists basically of crude ⅝" staple up to ¾".

Crude Run-of-Mine. Consists basically of unsorted crudes.

Crudes Sundry. Consists of crudes other than above specified.

Group No. 3 (Textile Fibre).

Standard Designation of Grade.	Guaranteed	Minimum	Shipping Test.	
3F	7	7	1.5	0.5
3H	4	7	4	1
3K	2	8	4	2
3T	1	9	4	2
3Z	0	8	6	2

Group No. 4 (Shingle Fibre).

4H	0	5	8	3
4K	0	4	9	3
4M	0	4	8	4
4R	0	3	9	4
4T	0	2	10	4
4Z	0	1.5	9.5	5

Group No. 5 (Paper Fibre).

5D	0	0.5	10.5	5
5K	0	0	12	4
5M	0	0	11	5
5R	0	0	10	6

Group No. 6 (Stucco or Plaster Fibre).

6D	0	0	7	9
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Group No. 7 (Shorts).

7D	0	0	5	11
7F	0	0	4	12
7H	0	0	3	13
7K	0	0	2	14
7M	0	0	1	15
7R	0	0	0	16
7T	0	0	0	16

Group No. 8 (Floats).

8S Under 75 lbs. per cubic foot loose measure.

Group No. 9 (Floats).

9T Over 75 lbs. per cubic foot loose measure.

Current Range of Prices.

(As at 10th August, 1948.)

Canadian.	Per Short Ton F.O.B. Mine.	
	\$	\$
Group 1.	896.00	960.00
Group 2.	350.00	545.00
Group 3.	204.50	378.00
Group 4.	84.50	128.00
Group 5.	69.50	78.00
Group 6.	47.00	51.50
Group 7.	25.00	46.00

Vermont (U.S.A.).	Per Short Ton F.O.B. Mine.	
	\$	\$
Group 4.	97-00	107-00
Group 5.	68-50	85-00
Group 6.	....	51-00
Group 7.	25-50	46-50

USES OF ASBESTOS.

In general, the use to which asbestos minerals are put depends upon the fibre length. The following list details the major uses to which asbestos has been put and makes no claim to be complete.

Long Fibres (Grades 3F-3T) are used as:—

- (1) Textile fibres from which are manufactured yarn, thread, wick-packing and asbestos cloth.
- (2) A filtration medium in laboratories and industrial processes.
- (3) A reinforcing material in asbestos cement products where great strength is required.

Medium Fibres (Grade 3Z and Groups 4 and 5) are used as:—

- (1) Reinforcing fibres in asbestos cement products.
- (2) Major components of asbestos paper and millboard.
- (3) Reinforcing and binding agents in magnesia and other moulded insulations.
- (4) Filtration sheets and pads when felted with cellulose fibres.
- (5) Reinforcing fibres in moulded friction blacks and brake linings.
- (6) Insulating materials in sprayed insulations.

Short Fibres (Groups 6 to 9) are used as:—

- (1) Self-binding insulating cements.
- (2) Reinforcements and filters in asphalt paints, putties and compounds.
- (3) Reinforcement and filter in plaster and stucco.
- (4) Insulating space fibres.
- (5) Mineral reinforcing fibre in rubber and plastics.
- (6) Filler in lubricating grease.
- (7) Silicic flux in welding.

For some special purposes, the chemical composition is important. For instance in work involving insulation against high electric voltages low iron content is essential. The Arizona mines produce excellent long fibred chrysotile which is used almost exclusively for this purpose as it is almost free of iron.

Fire-resistance is one of the general characteristics of the asbestos minerals but some varieties are more resistant than others. Chrysotile and anthophyllite easily withstand temperatures up to 3000°F, tremolite and actinolite fuse at somewhat lower temperatures, while crocidolite, due to its relatively high Na_2O content, fuses easily and is of no use in materials intended for fire insulation.

On the other hand, chrysotile is attacked by relatively weak acids while the amphibole varieties, especially crocidolite and amosite, are exceptionally resistant to both acids and alkalis and are used extensively for filtering these materials.

The asbestos minerals themselves do not have low heat conductivity and their use in heat insulation depends upon the porous structure of the manufactured material.

In the asbestos-cement board industry, the fibre serves two purposes, the first being the more important:

- (1) Reinforcement of the comparatively thin cement sheet giving greater mechanical strength.
- (2) Fire resistance.

A higher grade of fibre (i.e., a higher proportion of long fibres) is required in the manufacture of corrugated sheet than is required for flat sheet as the intrinsic mechanical strength of the former is less than that of the latter. Many factors enter into the selection of the optimum grade of fibre required for a particular product and it is usual for a manufacturer to blend two or more grades to obtain the desired results. The following table is to be taken as an indication only of the relative percentages of standard lengths required for corrugated and flat sheets.

TABLE IV.

Product	+ $\frac{1}{2}$ "	+ $\frac{1}{4}$ "	+ $\frac{1}{10}$ "	- $\frac{1}{10}$ "
	%	%	%	%
Corrugated Sheet	0	13	65	22
Flat Sheet	0	8	23	69

Chrysotile is the material most generally employed in this industry but there is no reason why tremolite and actinolite should not be used provided that the correct lengths are available. Where the finished board is required for fire-proofing, it would be unwise to use crocidolite, though this material would be quite suitable for incorporation in sheets intended for building purposes.

Section II—The Beaconsfield Area

LOCATION AND ACCESS.

The Beaconsfield serpentine belt is situated in the County of Devon, two miles due west of Beaconsfield township. The serpentine belt is roughly rectangular in shape, the long axis of the rectangle lying slightly west of north. The length of the belt is $4\frac{1}{2}$ miles, while the width varies from $\frac{1}{3}$ -mile in the northern portion to $1\frac{1}{2}$ -miles in the southern, averaging a little over 1 mile. The total area is therefore between $4\frac{1}{2}$ and 5 square miles.

The northern half of the belt lies in the South-West corner of the Beaconsfield mineral district, while most of the southern half lies in the North-West corner of the Salisbury district. The extreme South-West portion is in the North-East corner of the Saxon Creek district.

Access to the area is easy and may be gained from three roads, all from Beaconsfield:

- (1) Along the Yorktown road for two miles, thence along the Leonardburgh road to its junction with the old Mt. Vulcan tramway, thence following this tramway across Nicholl's Bridge, entering the area by Tattersall's gate.
- (2) Following the above road but turning off to the left approximately one mile after leaving the Yorktown road and following down the eastern side of Anderson's Creek. This is known locally as the Terrazzo Works road.
- (3) Along the Holwell road for a distance of four miles from Beaconsfield, turning off to the right half a mile past J. W. Hinds' residence. This road leads into the Beaconsfield water race.

The first two roads mentioned follow Anderson's Creek, the first on the western, the second on the eastern side. Both are passable to motor traffic for a distance of one mile after entering the gateways. The third road is passable to motor transport for only $\frac{4}{10}$ -mile after leaving the Holwell road.

Over the belt itself are numerous woodcutter's tracks most of which are now overgrown but which could easily be made passable if required. Some of these tracks are shown on the accompanying plan. Much ironstone occurs in the serpentine belt and makes a useful surfacing material for roads.

Except for a small clearing around and to the east of Tattersall's residence (the only building on the serpentine belt) the whole area is lightly clad in bush mostly gum but with a sprinkling of other types. The bush is quite open with a minimum of scrub on the slopes and crests of the hills but with a thick tangle of undergrowth along the streams. The quartzitic gravels forming low hills along the eastern margin of the belt are fairly open country, supporting only a few stunted gums and some sag.

When the Tasmania Gold Mine was operating at Beaconsfield, the Anderson's Creek area was used as a source of mine timber and was, in those days, almost cleared of bush. The present growth is therefore only about 30 years old.

TOPOGRAPHY.

The chief topographical feature of the district is the Asbestos Range which rises to 1600 feet, forming a prominent range of hills with the axis lying slightly west of north and terminating at the coast in Badger Head and Little Badger Head. Between this range and the Tamar River are two smaller ranges rising to 400 feet. The first (unnamed) lies to the east of Anderson's Creek and the second (Cabbage Tree Hill) lies immediately west of Beaconsfield township. The trends of these two ranges agree with that of Asbestos Range.

Approximately three miles east of the crest of Asbestos Range lies Anderson's Creek, flowing in a N.-N.W. direction to join the Tamar River at the head of West Arm. From Holwell north for three miles Anderson's Creek crosses Precambrian and Permo-Carboniferous sediments which are not easily eroded. Over this section, therefore, the stream valley is narrow and the stream has a high gradient. From the point at which the stream enters the serpentine, however, the valley widens abruptly and the gradient falls. The serpentine belt, therefore, consists topographically of an elongated basin with low hills of quartz gravels on the east and spurs of quartzites, mica schists, clayslates and clay-stones on the west running westwards to Asbestos Range.

A prominent feature of the northern portion of the belt is the Settlers Range rising to 400 feet and situated in the middle of the valley. This range is composed of syenitic rock, much less easily eroded than the enveloping serpentine. An isolated hill of similar material (Simmonds Hill) occurs near the southern margin of the serpentine. A feature of the topography is the cutting of Settlers Range by the creek on the bend just west of the main workings. The stream pattern is probably a reflection of the original topography and is to be regarded as stencilled upon the serpentine belt.

The north-west extension of the serpentine belt extending from W. B. Smith's Prospects to the Frenchman's Quarry is a low range of hills, the axis of which strikes N.W. to W. and merges into a spur running up to the crest of Asbestos Range. The serpentine of this area shows numerous intrusions of aplite and hornblende granite and it is probable that a mass of granite underlies the serpentine. The superior resistance of the granite would account for the existence of these hills. In a similar manner, the existence of a small hill of serpentine and aplite on the western margin of the belt south of Settlers Range may be accounted for.

The only other topographical features of the belt are the three low ironstone hills—Mt. Vulcan and Mt. Scott in the north-west and Barnes Hill in the south-east.

REVIEW OF PREVIOUS LITERATURE.

Geological work has been undertaken in the Beaconsfield area intermittently over the past 80 years and it is considered advisable at this point to review the work that has been done in the past and trace the growth of knowledge of the area. The following reports of the Geological Survey deal either briefly or in detail with portions of the serpentine belt:

- (1) Charles Gould (August, 1866). "Report on the Country near Ilfracombe in the West Tamar District."

- (2) W. H. Twelvetrees (November, 1899). "Report on the Asbestos Deposits, Anderson's Creek, near Beaconsfield."
- (3) W. H. Twelvetrees (June, 1900). "Petrological Report."
- (4) W. H. Twelvetrees (March, 1903). "Report on the Mineral Deposits of the Districts of Beaconsfield and Salisbury."
- (5) W. H. Twelvetrees (May, 1917). "Asbestos at Anderson's Creek."—Mineral Resources No. 4 of Geological Survey of Tasmania.
- (6) A. M. Reid (November, 1919). "Asbestos in the Beaconsfield District."—Tasmanian Department of Mines Geological Survey Report No. 8.
- (7) Loftus Hills (October, 1923). "The Beaconsfield Area."
- (8) P. B. Nye (September, 1930). "Report on the Boring Operations undertaken in connection with the Beaconsfield Chromiferous Iron Ore Deposits."

Gould (1866).

This is the first report dealing with the Beaconsfield area and the writer was concerned mainly with the iron-ore deposits occurring both within and without the serpentine belt. He deals with the following:

- (a) The ancient rocks of Asbestos Range consisting of, at Badger Head, dark mica schists containing thin strings of quartz alternating with thinly bedded grits and dark clay-slates. The average strike of N.20°W to N.30°W is much obscured by foliation. Beds are faulted, lie at high angles, and are repeated in several anticlinals.
- (b) Lower Silurian clayslates, limestones, and quartz sandstones which form a series of ridges parallel to the main range and which are a subordinate feature of the district.
- (c) Tertiary—the lowlands between the Asbestos Range and the Tamar River are principally occupied by a Tertiary drift of sand and pebbles.
- (d) Alluvial material fringing the streams.
- (e) Traps—He included the serpentine belt under this heading.

Brief description of the serpentine is given and mention made of veins of magnetite and the possibility of using the serpentine for ornamental purposes. Brief mention is made of the asbestos but no detailed descriptions are given.

The remainder of the report is concerned with detailed descriptions of the iron ores.

Twelvetrees (1899).

This report is concerned directly with the asbestos deposits. The Australasian Asbestos Company had taken up five leases in the northern portion of the area on both sides of Anderson's Creek. Twelvetrees concerned himself mainly with these leases and reports on:

- (a) The limits of the serpentine, making brief mention of the ironstone deposits.
- (b) The rocks occurring between the serpentine area and Beaconsfield township.
- (c) The age of the serpentine deposits which he gives as post-Silurian.

- (d) First description of rhodonite and scapolite from No. 1 old hill quarry.
- (e) Brief description of the asbestos veins. "I have seen a sample with fibres $2\frac{1}{2}$ " long but this length is exceptional. Veins $\frac{1}{4}$ " to $\frac{1}{2}$ " wide are common; less frequent are those of 1" and $1\frac{1}{2}$ " width."
- (f) The recognition of the parent rock as a peridotite consisting of bronzite (enstatite) and olivine—the variety known as harzburgite. The olivine is nearly all serpentinized and the bronzite is in the process of conversion to bastite.
- (g) The company's workings, giving production figures.

Summarizing, Twelvetrees states: "The seam or filling is not a lode and the continuity cannot be relied upon even though the line of decomposition may be discernible for a considerable distance . . ." and again: "great deal of the permanent success of the mine, however, will depend upon the regularity with which new faces of stone are brought into work, for it must be borne in mind that the seam cannot be trusted beyond the point of the pick."

Twelvetrees (1900).

Describes a sample of the scapolite mentioned in his previous report and also a sample of bronzitite: "This is from the serpentine on the asbestos section at Anderson's Creek. It is a dark granular rock composed wholly of bronzite, which shows in glistening crystals. The pyroxene is largely converted to bastite, the serpentinous modification of enstatite, and contains only small grains of olivine embedded in the pyroxene crystals. No feldspar is visible in this section. The rock is, accordingly, a true pyroxenite and is interesting as being the parent rock from which a good deal of the serpentine on this field has been derived. I have not seen any gabbro here but, from the appearance of scapolite referred to above, its existence is highly probable".

Twelvetrees (1903).

- (a) Recapitulates much of his previous report regarding the general geology and distribution of the serpentine.
- (b) Makes reference to the two types of fibre occurring ". . . the cottony long fibrous kind of a matted habit and with fibres disposed parallel to the jointing of the serpentines; and the short fibre occurring in $\frac{1}{2}$ -inch to 1-inch veins through the rock with the fibres transverse to the direction of the vein. Both are the mineral chrysotile, the hydrous and fibrous silicate of magnesia."
- (c) Gives the first description of the acid igneous rocks of the area.

Settlers Range. "An acidic rock consisting of magnesium mica in great preponderance and quartz and orthoclase feldspar in about equal proportions, the whole forming a medium grained admixture with a structure resembling that of aplites."

"White granite . . . consisting almost exclusively of quartz and feldspar, the crystals of which are frequently interwoven with each other.

- (d) Gives a detailed description of the iron ore deposits together with an account of the methods of working and production figures.

Twelvetrees (1917).

Subsequent to Twelvetrees reporting on the area in 1899, the Australasian Asbestos Company had failed to make good and its leases had lapsed. Three leases over the ground on the east of the creek had been taken out by C. B. Buxton and Wunderlich Limited of Sydney had been prospecting these leases as option-holders. P. Charriol of Melbourne had also taken out a lease in the extreme N.W. corner of the area. Twelvetrees' present report deals with the whole of the serpentine area north of a line drawn $1\frac{1}{2}$ miles south of Nicholl's Bridge, and was made in the light of new information gained as a result of this prospecting work. He deals with—

- (a) General Geology.
- (b) The formation of asbestos.
- (c) Relationship of the igneous rocks to the asbestos deposits.
- (d) Detailed descriptions of the mining properties.
- (e) Methods of treatment and the economics of the industry.

Reid (1919).

Wunderlich Limited of Sydney commenced operations in October, 1917, and ceased in March, 1919. During this period also, several other leases had been taken out on the western side of the creek and some prospecting work had been done. The main objectives of Reid's examination were "... to ascertain whether or not these apparently irregular, scattered occurrences constitute one continuous ore-channel and whether a modification of the methods employed in the exploitation of the deposits would make possible the re-establishment of the industry on a profitable basis."

Reid dealt with the same area as Twelvetrees (1917), recapitulates much of his work and gives in addition—

- (a) Further details of the working areas in the light of conditions then existing.
- (b) Details of the following:—
 - (i) Hartwell Condor's Prospect;
 - (ii) Jackson's Prospect;
 - (iii) W. B. Smith's Prospect.

Loftus Hills (1923).

This is a brief report only and deals with the general geology of the area making only passing reference to the serpentines and aplite. It is interesting, however, as mentioning the presence of serpentine "in the bottom level of one of the properties of Salisbury on the Blue Tier". This is the only reference to serpentine occurring outside the Anderson's Creek area.

Nye (1930).

This report deals with the results of boring operations on Mt. Scott, Mt. Vulcan and Barnes Hill, and includes the results of a large number of assays. Nye's conclusions regarding the iron ore are interesting and worthy of repetition. He states: "It is seen from the above that the chromiferous iron ores are of such a composition that they cannot be used for the manufacture of ferrochrome, refractories or chemicals."

Its only possible use is in the manufacture of chromium iron steel, but at present the process is not favourably viewed by the metallurgists. As to whether this viewpoint will alter in the near future, it is impossible to predict, but unless such happens the Beaconsfield chromiferous iron ores will have no commercial application".

It will be seen from the above review that while considerable attention has been devoted to the Beaconsfield area, no systematic and detailed study of the serpentine belt as a whole has been attempted. Almost no attention has been paid to the southern portion. The reports of Twelvetrees (1917) and Reid (1919) deal with the northern section only and geologically are confined almost entirely to the quarries then opened up. These descriptions are excellent and the present writer has little to add to them, practically no work having been done in the quarries since the time of Reid's visit. There is, however, little in these reports regarding future prospects.

In the 30 years since these reports were prepared much has been learned of the mining and milling of asbestos and its range of uses has been considerably extended. The economics of the industry, in common with those of other industries, have also changed considerably and what was an uneconomic proposition in 1917-1918 is not necessarily uneconomic in 1955.

During the course of the present survey, the whole of the serpentine belt has been mapped in detail, every outcrop has been inspected, and a full assessment of the field made in the light of present-day economic conditions.

GENERAL GEOLOGY.

Asbestos Range, west of Anderson's Creek, is composed of quartzites and mica schists of Precambrian age. This formation is succeeded eastwards by a narrow belt of clayslates and claystones which are frequently rich in iron. Along the contact between this series and the serpentine, the clayslates and claystones are much contorted and baked, the rocks weathering on the surface to a rich red clay. The best exposure of the contact was seen on the water-race, in the southern portion of the field, where the race emerges from the narrow valley of Anderson's Creek.

On the eastern margin, the contact of the serpentine and the rocks which it intrudes is much obscured. However, the marginal rocks appear in a small road metal quarry on the road down the east side of Anderson's Creek near the point at which the track leads off to the Hill Quarries. Although the actual contact does not appear, it is not far away. The intruded rocks are sandstones which have been indurated by the serpentine. No mineral reconstitution has taken place and the rocks retain their original bedding planes striking 125° and dipping N.E. at 37° . It is, of course, highly probable that the true strike and dip have been disturbed by the serpentine intrusion. The question of the relative ages of these intruded rocks has not been investigated during the present survey, which is primarily an economic investigation.

The greater part of the eastern margin of the serpentine is obscured by a thick drift of unconsolidated quartz and sandstone gravels. The pebbles, ranging in size from $\frac{1}{2}$ " to 5", are usually angular and are composed of grey and greyish white sandstones sometimes with red and purple cores and of white and pink

quartzites. They are loosely set in a matrix of fine angular quartz sand. Though angular, the pebbles show some signs of being water-worn but have not been carried very far. The formation is probably late Tertiary or Quaternary in age.

Alluvial deposits occupy portions of the serpentine belt along Anderson's Creek and are found along the floor of the valley of Limestone Creek to the east.

THE SERPENTINE BELT.

In the accompanying plan of the Beaconsfield serpentine belt only those areas over which serpentine actually outcrops on the surface have been mapped as serpentine. Although the whole basin of Anderson's Creek is undoubtedly underlain by serpentine (except for small patches of granite and syenite), it is often obscured by soil, alluvium, swamp and ironstone. Along the main creek, there is a belt of alluvium of variable width and almost all the small streams draining into the main stream run over swampy ground. The whole of the stream system has therefore been mapped as "alluvium and swamp".

The Ultrabasic Rocks.

Serpentine is always the result of metamorphism, being derived by hydration from basic and ultrabasic igneous rocks rich in magnesia, such as pyroxenite, peridotite, and gabbro. At Anderson's Creek, patches of the original rock are frequent, though no perfectly fresh outcrops were seen. Samples of the rock which appear perfectly fresh in the field show, under the microscope, varying degrees of alteration to serpentine. The original rock has been described by Twelvetrees (1900) and during the course of the present survey a sample of the freshest rock obtainable was examined under the microscope (Sample 30A5). A chemical analysis of a similar rock (Sample 30A8) is quoted in column (1) of Table VI. In the hand specimen, the rock is exceptionally hard and coarsely crystalline, the crystals being subequal in size, showing glistening surfaces, and having regular outlines. The rock is melanocratic, the colours varying from deep green to almost black. The chemical analysis shows a preponderance of MgO and SiO₂ with 8 per cent of iron and minor amounts of Al₂O₃, MnO, CaO and Cr₂O₃. Under the microscope, it is seen to be composed mainly of orthorhombic pyroxene showing faint pleochroism in shades of pale to medium brown. Cleavage cracks are filled with fine-grained serpentinous material showing faint flow structure. An occasional grain of corroded olivine with the cleavage cracks outlined by fine magnetite crystals appears.

The orthorhombic pyroxenes are metasilicates of iron and magnesium and are classified on the amount of FeO present into:

Enstatite	<5% FeO
Bronzite	5 — 14% FeO
Hypersthene	>14% FeO

On the analysis quoted, allowing a little iron for olivine, magnetite and chromite (in combination with the Cr₂O₃) the amount of FeO present is a little over 5 per cent and the pyroxene is, accordingly, bronzite. With the bronzite is probably a small amount of diallage and diopside, the amount varying from place to place

as is shown by the variation in the CaO shown in analyses (1) and (2). The olivine is not considered to be an essential component and the original rock may therefore be defined as bronzitite locally grading to websterite. Were the olivine essential the rock would be defined as the peridotite harzburgite grading to lherzolite.

In the field, the pyroxenite, because of its superior hardness forms prominent rugged outcrops projecting 20 feet or more above the surrounding serpentine. These outcrops are much weathered, fluting of vertical surfaces being usual and the rock assumes a dark rusty-brown colour. The general aspect is that of a number of huge boulders piled one atop the other. They usually form patches several square chains in area, or more rarely, narrow elongated zones. Where quarries are located near such outcrops, it is seen that the pyroxenite does not extend to a great depth. Often the best fibre is found in the serpentine adjacent to, or beneath pyroxenite outcrops.

The mechanism of the conversion of pyroxenite and peridotite to serpentine is discussed in a later section. It will be sufficient to state here that the process involves hydration and carbonation by heated waters containing CO₂. There is a rearrangement of the essential molecules MgO, FeO, and SiO₂ and, in general, an excess of one or more of these constituents occurs. This excess is expressed in the crystallization of magnesite, iron oxide (usually magnetite) and opaline silica or chalcedony. The degree of alteration is important and, at Anderson's Creek, the process appears seldom to have gone to completion. There occurs, therefore, a series of serpentine types all closely related, and representing differing degrees of serpentinization, probably under slightly varying physical conditions. These types have been designated A1, A2, B, C, D, E and F.

Type A is the most common and the most important from the commercial point of view. It is the "common serpentine" of Dana and, in the hand specimen appears to be amorphous, though microscopic examination shows that the outlines of the original pyroxenite are still retained. Interference colours ranging from grey to pale brown show the crystalline nature of the material. Generally, the rock has a dark green colour, a slightly splintery fracture, and a greasy or waxy lustre. Minute octahedra of chromite are sparsely distributed throughout the rock and magnetite is of general distribution, sometimes in unoriented grains, sometimes in definite but irregularly disposed veins. In some outcrops, this type approaches the noble or precious serpentine defined by Dana as having "a rich olive-green colour, subtranslucent even in thick slabs". Two divisions of this common type based on the appearance of the weathered outcrops have been recognized in the field.

Type A1 is rich in iron and weathered outcrops are a deep rusty-brown closely resembling bronzitite outcrops. The surface is usually stained to a depth of $\frac{1}{8}$ " with hydrated iron and manganese oxides showing a deep somewhat iridescent purplish colour on the freshly-broken surface. *Type A1* does not usually carry asbestos fibre.

Type A2 is indistinguishable on fresh surfaces from *A1*, but the weathered outcrops are a light greyish-green. The rock is lower in iron and shows no stained surfaces. It is the normal country-rock of the best chrysotile veins.

Type B is closely related to the above. It is a very dark green rock, grading to black, fine even grained and hard. It bears a marked resemblance to fresh basalt. Magnetite in veins is infrequent. On exposed surfaces, this type weathers rapidly to a pale-green to greenish-yellow powder. This type forms bands from a few inches to several feet in width in the common serpentine. It occasionally carries narrow chrysotile veins.

Type C is a light green massive rock usually lustreless. Throughout occur narrow closely-spaced, regular magnetite veins, generally in two systems at right angles. Dendritic growths of MnO_2 are sometimes seen on fresh surfaces. No chrysotile is known to occur in this type which is a variety of retinalite.

Type D, another species of retinalite, consists basically of light-green massive serpentine which is much mottled with patches and streaks of either yellow or red, the patches varying from the size of a pinhead to that of a shilling and the streaks ranging up to several inches in length. The red colour is due to concentrations of haematite and the rock assumes the aspect of a red porphyry. This type does not carry chrysotile veins.

Type E.—Where the process of serpentinization has proceeded to completion, the rock loses all resemblance to the original pyroxenite. The lamellae of green, bluish-green, and yellow serpentine occur in zones showing numerous, closely-spaced, subparallel shearing planes, the lamellae usually being slickensided. It is usual for zones of this crushed serpentine to alternate with bands of less completely altered material usually of types A2 and B. The crushed zones infrequently carry chrysotile.

Type F.—This last type differs markedly from the above types both in the composition of the original material and in the structure of the alteration product. The typical occurrence is in the Frenchman's Quarry in the extreme N.W. portion of the area. The original rock is coarsely crystalline, showing large idiomorphic crystals of glistening pyroxene set in a finegrained groundmass. No chemical analysis of the original rock has been made but from the analysis of the fibre formed therefrom (column (10) of Table VI) it may be deduced that the pyroxene is diopside (calcium-magnesium pyroxene) with a minor amount of hedenburgite (calcium-iron pyroxene) both minerals being slightly aluminous. No olivine appears. As with the bronitite all the rock shows varying degrees of alteration and no perfectly fresh original rock was seen. A feature of the serpentinization here is that it has proceeded beyond the stage at which fibre is produced, and talc is a frequent constituent of the alteration products.

The structural features of the serpentine are complex, the main one being the intricate system of movement planes which are a result of the relief of compression stresses set up in the rock mass owing to the increase in bulk engendered by the process of hydration. In all except the more highly serpentinized rocks, these planes form three systems of parallel planes, the systems being inclined at angles to each other so that rhomoidal blocks, varying greatly in size, are formed. One system is usually dominant, the rock splitting most easily in the direction of its planes which have the superficial appearance of bedding planes. In the following detailed description of areas the "direction of the structural planes" refers to the direction of the planes of the dominant system.

In the highly serpentized areas, the secondary system of planes has disappeared and the dominant system is represented by the crushed zones of Type E serpentine.

Along the movement planes, slickensiding is general and often incipient slip-fibre is found. The fibre is only a veneer in most cases but locally veins up to 1" in width are found. The fibre often grades to picrolite.

Intermediate and Acidic Rocks.

Four separate types are found, viz., syenite, aplite, hornblende-granite, and quartz/feldspar dykes.

The syenite is perhaps the most interesting and has been the subject of much diversity of opinion. The typical occurrence is in the series of four low hills west of the main quarry known locally as Settlers Range. During the course of the present survey, five more outcrops have been mapped in the Mt. Scott—Mt. Vulcan area and also a prominent hill in the southern part of the field to which the name "Simmond's Hill" has been given.

The rock shows two distinct facies. The first has all the physical characteristics of a granite except that it is somewhat more finely crystalline. Crystals are, however, visible to the naked eye and consist of biotite, muscovite, quartz, feldspar and a little apatite and tourmaline. It is melanocratic, sometimes having almost a basaltic aspect. In the second facies, occurring near the edges of the mass, the mineral assemblage remains the same but schistosity is developed to a marked degree.

W. H. Twelvetrees (1917) quotes the opinion of Dr. E. W. Skeats: ". . . it was originally a rather coarse grained sediment containing quartz, aluminous or argillaceous material and some partly decomposed feldspars" and states that in a sample submitted to Prof. Rosenbush he ". . . was unable to recognize in it the structure of an eruptive rock". Twelvetrees did not commit himself and mapped the Settlers Range as "Schisose metamorphosed material of uncertain origin". A. M. Reid (1919) recognized that the proximity of aplite was strong evidence in favour of an igneous origin for the Settlers Range material while admitting the difficulty of explaining the schistosity, and mapped the occurrence as "granitoid rock".

The rock has recently been analysed, the results of which are revealing:

SiO ₂	61.96	
Al ₂ O ₃	15.04	
Fe ₂ O ₃	1.44	
FeO	6.30	
MnO	0.10	
TiO ₂	1.45	
P ₂ O ₅	0.23	
CaO	2.80	
MgO	3.55	
Na ₂ O	1.36	
K ₂ O	3.74	
Moisture at 105°C	0.06	
Ig. Loss	1.94	
Cr ₂ O ₃	....

Total: 99.97 C. Penman, Analyst.

The silica content definitely brings the rock into the intermediate division, assuming for the moment an igneous origin, and the amount of magnesia is important. The chemical analysis is, otherwise, what was to be expected from the mineral assemblage.

All the evidence points to an igneous origin. The rock shows no sign of original sedimentary structure and it appears incredible that a sediment could have been so completely reconstituted. Within a few chains of Settlers Range, where the serpentine abuts against sandstones, these sandstones are merely indurated and retain their original structure almost unaltered. The two distinct facies are also difficult to explain on the assumption of an original sedimentary material but support the igneous theory as detailed below.

The present writer is of the opinion that the rock is the result of the injection of granite magma into the pyroxenite. This magma, being charged with mineralizers, was able to dissolve a portion of the pyroxenite, thus lowering its silica and increasing its magnesia content. As the magma was injected, crystallization commenced at the sides, the first-formed crystals being embedded in a plastic mass. The upward progress of the intrusion drew out the plastic mass which was simultaneously crystallizing. Finally crystallization of the whole mass was complete, normal rock forming the core of the intrusion, and schistosity being developed near the margins. The rock has been mapped as syenite from its chemical composition but it is emphasized that it is actually granite with incorporated pyroxenite and is therefore an hybrid type.

Numerous small outcrops of aplite have been mapped in the N.W. portion of the field. They are light coloured rocks consisting of quartz and feldspar with a variable proportion of ferro-magnesium minerals. Each outcrop differs slightly from its fellows and it is obvious that the aplite, too, is a hybrid rock and includes a proportion of dissolved pyroxenite. A comparatively large mass occurs between Settlers Range and Simmonds Hill. Here and there throughout the field small boulders of aplite have been seen and undoubtedly small intrusions are frequent. They probably represent the tops of small dykes which have stopped their way upwards from a larger granite mass lying beneath.

Hornblende-granite has not previously been described from this field. Several patches occur associated with aplite and diopside-pyroxenite near the Frenchman's Quarry. The rock forms low outcrops weathering to dark rusty-brown and have a superficial resemblance to bronzitite outcrops. It is finely crystalline and consists of crystals of hornblende set in a groundmass of quartz and feldspar. There appears to be a genetic relationship between the hornblende-granite and the amphibole-asbestos.

Quartz-feldspar boulders have also been found on the surface in the N.W. portion and an occasional dyke was seen. One such, varying from 3" to 12" in width appears in the face of Frenchman's Quarry and several along the crest of the range N.W. of Smith's Prospects.

The Iron Ores.

The iron ores of the field are widespread and are of two types. They have been well described by Twelvetrees (1903) and Nye (1930) details the results of a diamond drilling programme which

was carried out on the area. They will, therefore, receive only passing mention here.

The true iron ores are confined to Mt. Vulcan, Mt. Scott and Barnes Hill and consist of pebbles of chromiferous iron oxide ranging in size from a pea to large boulders loosely set in a red ochreous soil. Locally there are concentrations of ore and the old quarries, abandoned some 70 years ago, were located on these richer patches. In Table V (quoted from Nye's report) the average assays of material from each of the three main areas are presented together with the average percentages of metallic iron and chromium.

On the west slopes of Mt. Scott is a rich red soil with a minimum of ironstone pebbles. This deposit was at one time worked as a source of ochre for paint pigment.

The second type of ironstone deposit forms a veneer from a few inches to several feet in thickness over the serpentine at many places throughout the area. Magnetite from the serpentine has been hydrated to limonite and forms a cementing material for quartz pebbles derived by erosion from the tertiary quartz gravels nearby so that the material is more correctly termed "quartz conglomerate with limonitic matrix". However, both types have been mapped, for convenience, as ironstone.

TABLE V.

	Mt. Vulcan	Mt. Scott	Barnes Hill
	%	%	%
SiO ₂	12.28	17.72	14.17
Fe ₂ O ₃	59.10	51.50	51.74
FeO	2.20	2.93	2.31
Cr ₂ O ₃	5.18	5.63	7.80
Al ₂ O ₃	10.11	13.39	11.39
MgO	0.85	0.53	0.95
CaO	.....	.....	.....
TiO ₂	0.14	0.04	0.42
P ₂ O ₅	0.0006	trace	0.02
S	0.07	0.12	0.12
NiO	0.10	0.02	0.07
MnO & MnO ₂	0.47	0.07	0.16
M ₂ O &c.	9.07	7.89	9.75
Metallic Fe	43.086	38.335	38.021
Metallic Cr	3.522	3.828	5.304

ECONOMIC GEOLOGY.

Chemical Composition of Fibre Veins.

Three analyses of fibre (columns 6, 9, 10) and one of picrolite are quoted in Table VI and the following points may be noted:

- (1) The analyses of natural chrysotile correspond reasonably closely with the theoretical composition shown in column 11.
- (2) The MgO content is lower than the theoretical amount, the difference being accounted for by the replacement of MgO by FeO and Al₂O₃.

- (3) There is a variation shown in the compositions of the two samples of chrysotile analysed. This shows that the chrysotile is not of constant chemical composition throughout the field.
- (4) The chrysotile is of approximately the same chemical composition as the country rock.
- (5) Picrolite is noticeably higher in iron than the chrysotile.
- (6) The analysis of amphibole asbestos shows a higher percentage of silica and iron, low magnesia, and the presence of calcium. By comparison with the theoretical compositions of the amphibole minerals quoted in columns 3 and 4 of Table II, it is seen that the composition of the material is about half way between those of tremolite and actinolite, i.e., the ratio of Mg to Fe is about 3 : 1. There is undoubtedly with this material a variation in chemical composition similar to that observed in chrysotile.

Structural Features of Fibre Veins.

The cross-fibre veins are the important ones in this field and will be described first. The veins occur throughout the field in narrow bands on vein systems varying or in width up to six feet. The term "ore channel" used by A. M. Reid for these vein systems is incorrect. The individual veins are usually composite and bear one or more of the following minerals—chrysotile, amphibole, serpentine country rock, amorphous serpentine, magnetite, haemetite, chromite and talc. The chrysotile fibres lie transverse to the strike of the veins, the fibres usually being normal to the walls, though occasionally inclined at high angles, and more rarely being curved. The narrower veins, under 1/32" in width are usually simple, i.e., with fibre running the full width of the vein. The wider veins are always composite. In the theoretically perfect vein, there should be equal development of fibre against each wall, the length of fibre being half the width of the vein with a central plane parting. Occasionally veins approaching this ideal were seen but all variations therefrom occur. The following types may be noted:

- (1) There is an unequal development of fibre, that on one side of the vein being longer than that on the other but with the parting essentially plane.
- (2) The fibre is either equally or unequally developed but with the parting more or less irregular.
- (3) Fibre extends almost the full width of the vein from one wall but with a series of layers of very short fibre merging into the country rock on the other, the vein wall on this side being indefinite.
- (4) The full width of the vein is occupied by fibre in thin lensoid layers.
- (5) The parting is marked by angular inclusions of country rock, often lensoid; by a band or amorphous serpentine; or by magnetite grains.

The vein walls are usually highly irregular and, though the veins are roughly parallel throughout the system, there are abrupt local changes of direction so that the veins constantly merge and diverge. The fibres, however, remain parallel to each other and normal to the strike of the vein system throughout the system.

There are, therefore, local gradations from cross to slip fibre. Sometimes two generations of fibre occur forming two series of systems inclined one to another. Where such systems intersect an intricate development of fibre occurs.

The fibres are usually loosely-attached to the vein walls and separate readily therefrom. It is often possible to break out a complete section of a vein with the hammer. This fact is of importance when considering milling problems.

Some colour variation in the chrysotile veins has been noted. In the normal occurrence of chrysotile as veins in dark-green massive serpentine, the fibre is dark-green on freshly-broken surfaces and has a distinct shining lustre. On weathered surfaces, the veins show up as glistening silvery streaks which are very obvious, particularly on a sunny day. When the fibre is removed from the veins and teased out, it shows its true colour which varies from pale-grey to almost white, having a silky lustre and feel. Some veins, particularly those which occur in weathered Type B serpentine range in colour from yellow to light-brown, the fibres retaining these colours when removed from the veins. These fibres probably have a higher iron content.

An unusual development of fibre in pyroxenite was noted near the track some six chains south of the Greenstone Quarry. Two short $\frac{1}{8}$ " veins traverse very dark bronzitite showing coarse crystalline structure. The veins are simple, the fibres are bronze in colour, have a glistening lustre, and are frozen to the vein walls.

Slip fibre veins are of two types. The first type is represented by the development of thin layers of slip fibre along planes of movement, the fibre apparently being generated by the gliding of the rock. Occasionally veins of commercial size are developed but, in general, this type is only of academic interest. The second type is the typical development of amphibole asbestos. The veins may be up to a foot in width but average one or two inches. The fibre lies parallel to the strike of the vein and often appears to be exceptionally long. On examination, however, the veins are found to consist of bunches of quite short fibres loosely held together by the ends. The average true fibre length would not exceed $\frac{1}{2}$ ". Chrysotile also occurs in the slip form in veins up to 2" in width. The above remarks on fibre length apply here also but the average true length is a little greater. In these slip-fibre chrysotile veins, the fibre is always accompanied by fibrous magnetite which forms black streaks along the veins. All gradations up to veins consisting entirely of magnetite occur. If slip-fibre chrysotile were worked for asbestos, provisions would have to be made for the removal of the magnetite.

The Picrolites.

Picrolite is of general occurrence throughout the chrysotile-bearing areas both in the pseudo-slip and pseudo-cross fibre forms. It bears a remarkable resemblance to true fibre and often close examination is necessary to distinguish the one from the other. The colours vary from white to grey and light-green. Sometimes the picrolite, though columnar in appearance, is massive in structure, sometimes it can be split into splinters and resembles wood. In the cross fibre type the picrolite does not grade to fibre but in the slip type the picrolite is often seen to grade into true fibre.

Talc.

Talc is a common associate of amphibole asbestos in the field. Talc is the final product in the alteration of original pyroxenite and is thus usually pseudomorphous after fibrous amphibole. It occurs in both slip and cross fibre forms and veins of pure white material showing an apparently fibrous structure reduce to a fine smooth powder when removed from the vein. The process of alteration does not appear, however, to be complete as a slightly harsh feel, not characteristic of true talc, can usually be detected.

Magnetite.

The occurrence of fibrous magnetite is a feature of this serpentine belt. Its association with slip-fibre chrysotile has been noted above. There is, however, in many places, a remarkable development of cross-fibre magnetite, notably in the main quarry. While bearing a general resemblance to the chrysotile veins except, of course, for the colour, certain differences may be noted in the magnetite veins; the fibres are not normal to the strike of the vein system but are at high angles to it; and the fibres are often curved or wavy. Parting, such as is characteristic of chrysotile veins does not appear but there is often a thin layer of normal crystalline magnetite against each wall. The veins are seldom over $\frac{1}{4}$ " in width.

Superficially, it would appear that the magnetite is pseudomorphous after chrysotile but the evidence presented above does not support this theory. It appears more probable that the veins were originally filled with normal crystalline magnetite released during the process of serpentinization and have subsequently been reconstituted in situ in response to the same change in physical conditions which produced the chrysotile. The formation of fibrous magnetite was contemporaneous with, not subsequent to, that of chrysotile.

NOTES ON TABLE VI.

(1) Lab. sample 886—field sample 30A8. Pyroxenite from near Terrazzo Quarry.

(2) Lab. sample 887—field sample 30A9. Pyroxenite from near Terrazzo Quarry. Shows original structure but the pyroxene crystals are much serpentinized. The rock is pale bluish-green and somewhat friable.

(3) Lab. sample 888—field sample 30A1. Serpentine from near Terrazzo Quarry. The rock is dark-green, dense, fine-grained and shows few planes of weakness.

(4) Lab. sample 889—field sample 30A2. The weathered portion of 30A1.

(5) Lab. sample 890—field sample 30A10. Dark-green massive serpentine with greasy lustre from near Terrazzo Quarry—the rock which carries most of the chrysotile veins.

(6) Lab. sample 891—field sample 30A3. Chrysotile veins from Greenstone Quarry showing $\frac{1}{2}$ " fibre.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Ignition											
Loss	5.81	3.90	11.56	12.05	12.11	12.75	12.32	12.20	8.46	1.20	12.9
SiO ₂	48.64	51.97	38.41	40.00	43.04	43.17	41.69	37.90	42.80	54.88	44.1
Al ₂ O ₃	2.06	1.66	1.38	1.02	0.91	1.00	0.87	3.20	2.24	2.60	—
Fe ₂ O ₃	—	—	—	—	4.07	2.64	—	—	—	—	—
FeO	—	—	—	—	1.06	1.47	—	—	—	—	—
Total Fe expressed as Fe ₂ O ₃	8.36	4.28	14.08	8.07	—	—	5.17	12.40	5.04	10.04	—
MnO	0.12	0.12	0.05	0.09	0.09	0.04	0.04	—	—	—	—
CaO	3.60	9.81	—	—	—	—	trace	0.86	—	12.15	—
MgO	31.43	27.10	33.96	37.34	38.35	38.91	39.67	33.66	41.86	18.94	43.0
Cr ₂ O ₃	0.57	0.56	1.03	1.84	0.33	—	0.67	—	—	—	—
Na ₂ O	—	—	—	—	—	—	—	—	—	—	—
K ₂ O	—	—	—	—	—	—	—	—	—	—	—
P ₂ O ₅	trace	—	—	—	—	—	—	—	—	—	—
TiO ₂	trace	—	—	—	—	—	—	—	—	—	—
Total	99.59	99.40	100.47	100.41	99.96	99.98	100.39	100.16	100.40	99.81	100.00

ASBESTOS IN TASMANIA
TABLE VI.

(7) Lab. sample 892—field sample 30A3. Dark-green massive serpentine enclosing chrysotile vein (6). Nos. 6 and 7 constitute the one field sample, the serpentine of No. 7 being taken as close to the vein as possible. In hand specimens, No. 7 is identical with No. 5.

(8) Picrolite.

(9) Chrysotile.

(10) Amphibole asbestos from Frenchman's Quarry.

(11) Theoretical composition of serpentine assuming the formula $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$.

Notes on Analyses.

(1) The analyses in columns 1-7 were made by the Mines Department Laboratory, Launceston, during November, 1948. The analyses as supplied included "moisture at 105°C" varying from 0.48 per cent to 3.80 per cent. These analyses have been recalculated to a moisture-free basis. Tests were made for all components listed and a dash in the column indicates that the appropriate component was not found to be present.

(2) Analyses in columns 8-10 are quoted from A. M. Reid ("Asbestos in the Beaconsfield District" pp. 7-8), the first two being unacknowledged and the third attributed to W. D. Reid, Government Assayer. It is not clear whether tests for minor constituents were made and, in these analyses, a dash in the column does not necessarily mean that the appropriate component is not present. The figure given as "Ignition Loss" is shown on the originals as "H₂O". There is doubt, therefore, whether this is the true ignition loss or ignition loss plus moisture at 105°C.

(3) Column 11 is not an actual analysis.

DESCRIPTION OF SERPENTINE AREAS.

For descriptive purposes, it has been found convenient to divide the serpentine belt into a number of areas lettered from A to R.

Area A.

This area includes the hill quarries, a small patch near Tattersall's bridge, and three further small patches on the western side of Anderson's Creek. The angle of the creek is occupied by two prominent, roughly circular, hills of syenite with serpentine occurring around them. From the old tramway the hill rises sharply to the old quarries which are all on approximately the same level. From the flat above the quarries, there is a further sharp rise from the contact of the serpentine and the sandstones, the latter forming Dan's Hill. Patches of bronzitite are frequent around the slopes of the hill and the quarries are located in serpentine belts occurring between them.

No. 1 hill quarry was the first opened in the area by the Australasian Asbestos Co. Ltd. in 1899. The quarry was driven along a vein system but no fibre now appears in the face. The country rock is well serpentized, crush zones being frequent and slickensiding prominent. Picrolite is general along the gliding planes. A band of white scapolite bearing pink rhodonite and some dendritic growths of manganese dioxide was cut in this quarry but is now obscured by scree material.

No. 2 quarry is of considerable dimensions, the face being 35 feet high. The serpentine here is similar to that in No. 1 quarry. Except for a few $\frac{1}{8}$ " veins near the entrance, no fibre now shows. Two small prospects east of the entrance show well-serpentinized material carrying veins of hair width resting on bronzitite. Midway between these two quarries a vein system occurs carrying veins of $\frac{1}{8}$ " to $\frac{3}{16}$ " in width. The fibre varies in colour from light-green to bronze. The system was followed for only a few yards and does not appear to be rich.

No. 3 quarry is quite small and apparently a narrow vein system was followed and soon worked out. The country rock is well-serpentinized. Near the entrance are several very small prospect trenches in good type A2 serpentine. The stone heaps show good quantities of fibre from $\frac{1}{8}$ " to $\frac{3}{8}$ " in length and it is probable that another vein system occurs but was not worked.

Nos. 4 and 5 quarries are in type A2 serpentine and also followed vein systems. In No. 4, a shaft was sunk to 30 feet. It is now water-filled but A. M. Reid states that: "Good cross-vein chrysotile up to $1\frac{1}{4}$ " in length was passed through but the average was only $\frac{1}{4}$ " and at the bottom there was very little of it". No fibre now shows in No. 5 quarry.

From quarries 3, 4 and 5 downhill towards the creek, the serpentine is much obscured by soil but such outcrops as do occur are of A2 serpentine which is likely to carry fibre. Trenching in this area would probably bring to light further vein systems. In the small patch near Tattersall's bridge, $\frac{1}{8}$ " veins are scattered throughout the rock. Similar veins occur north of the smaller syenite mass and between it and the creek. A good vein system with veins up to $\frac{3}{8}$ " wide occurs just west of the large syenite mass with narrow veins occurring southwards. Soil covering prevents the following of these veins for more than a few yards.

Across the creek in Jackson's Prospect, is an "ore channel" 2-3 feet wide with veins up to $\frac{1}{2}$ " wide. The veins are fairly regular and the colour of the fibre is usually dark-green though varying locally to bronze. This system can be traced for 50 feet in a northerly direction. Further north along the west bank of the creek, another small patch of serpentine occurs abutting syenite. At least one vein system occurs here, the veins averaging $\frac{1}{4}$ " in width and grading locally to cross-fibred picrolite. On the flat between Tattersall's house and the creek several small quarries have been opened up in A2 serpentine but the fibre showing is short and the quantity poor.

South of the hill quarries, the serpentine is much obscured by soil and such outcrops as do occur show no fibre. Several prospect trenches occur around the mill site but all are in barren rock.

Summarizing then, it may be stated that the hill area carries comparatively short vein systems, most of which have now been worked out. Several systems probably still occur on the slopes of the hill but it would seem that the quantity available is small. In the area between the tramway and the creek and including the two small areas across the creek, however, good signs of fibre appear; though the soil covering renders tracing of vein systems impossible. There is a strong possibility that several systems occur trending

northerly. This is considered a possible producing area and preliminary prospecting by trenches to prove the existence of vein systems would be warranted.

Area B.

From the creek, the serpentine rises gently to the road and thence eastward somewhat more steeply to the eastern margin of the area which is marked by quartz gravels overlying the serpentine and forming steep hills. The line of contact between the serpentine and the gravel is ill-defined, being obscured by talus material. Ironstone veneer covers the serpentine in the north-east, small outcrops of serpentine showing through the ironstone. A small isolated patch of serpentine shows in the east from beneath the gravel.

Between the creek and the road lies the main quarry of Wunderlich Ltd.; south-east of this is the Terrazzo Quarry; and numerous other quarries and prospects are scattered over the area. Bronzite patches forming prominent rugged outcrops are common over the area particularly south of the Terrazzo Quarry and east of the road. All the smaller quarries are in serpentine patches occurring between the bronzite masses.

In the main quarry, three parallel vein systems trending N.W. were worked, the systems paralleling the dominant structural planes of the rock. In the S.W. limb, the walls are mostly partially altered bronzite grading to serpentine, thin veins of fibre occurring sporadically. At the end of the limb, two vein systems appear. On the west side, almost vertical veins of fibre averaging $\frac{1}{4}$ " appear over a width of 3 feet in dark-green serpentine. Although the veins are individually discontinuous, the vein system appears of constant width. On the east side, the serpentine is much weathered and veins averaging $\frac{3}{16}$ " occur in both weathered and unweathered rock. The veins here are sporadic and hardly constitute a definite system. Much picrolite occurs along the cut and veins of fibrous magnetite appear on the S.W. side of the entrance.

The N.W. limb, a continuation of the above, is alleged to have been opened along the richest vein system. The fibres showing in the end of the cut are poor, however, averaging $\frac{3}{16}$ " in a vein system 9" wide.

In the S.E. limb, conditions are similar to those in the S.W. The vein system occurring in the end of the cut shows $\frac{3}{16}$ " veins in a system 2 feet wide. Halfway along the limb a short prospect drive heads eastward but shows no fibre. From this limb, a crosscut leads to the eastern limb. Both ends of this are unfortunately obscured by slips and the vein system could not be inspected.

In the centre of the quarry, on the western vein system, a wide shaft was sunk to 40 feet. This is now waterfilled but it is stated by residents that the best fibre was found in this shaft though the cost of mining was prohibitive. This shaft shows, however, that the vein system extends to a depth of at least 40 feet and it is highly probable that all systems in the area run deep. Numerous small trenches have been excavated around the main quarry but

few are deep enough to disclose the presence of fibre. Surface outcrops, however, show the existence of at least one further vein system parallel to those in the main quarry and occurring one chain east of the N.E. limb. Further eastward, the serpentine is obscured by soil and small patches of ironstone.

In the Terrazzo Quarry, the continuation of the central vein system of the main pit is seen at a somewhat higher level. This quarry occurs on the edge of a bronzitite mass and was opened several years ago as a source of raw material for Terrazzo ware. Good fibre up to $\frac{3}{8}$ " in length is scattered throughout the country rock which is dark-green A2 serpentine. A small shaft sunk in this pit is now filled with debris but the writer has been informed by a reliable local resident who worked on the quarry that, at depth, a considerable quantity of fibre appeared and showed every indication of improving in both length and quantity.

In the remaining quarries and trenches mapped in this area, little fibre appears. They were obviously opened on outcrops showing fibre on the surface, and their number and distribution serve only to emphasize the fact that fibre is sporadic and capricious in its occurrence.

Towards the eastern margin of the area, the character of the serpentine changes gradually, the rock becoming a lighter green and grading at times to retinalite. Throughout this portion of the area, slip-fibre chrysotile occurs in joint planes varying from the thickness of tissue paper to 1" in width always accompanied by a variable amount of fibrous magnetite. The occurrences are discontinuous, however, and the tracing of continuous veins was found impossible. Apart from the magnetite impurity, however, the fibre is of good quality though having a somewhat lower tensile strength than the cross-fibre type and it is probable that workable veins occur in this area. Developmental work would be necessary to prove sufficient quantities of material.

Some developmental work has been done in area B. The existence of at least four parallel vein systems has been proved and, while their lateral extent is variable, their extension at depth is highly probable. There appears to be still a fair quantity of fibre in this area and prospecting at depth, either by shaft or by diamond drill, would be warranted. For the slip-fibre occurrence on the slopes of the hill, shallow trenching to prove lateral extent is recommended.

Area C.

This is a natural extension of the above area. The serpentine outcrops on the surface, is of type A2, and shows strong structural planes striking N.W. A quarry and several shallow prospects have been opened up near the creek. Good fibre up to $\frac{1}{4}$ " in length shows in the stone heaps, and somewhat shorter material in the vein systems exposed in the quarry. Magnesite in streaks and blebs is sporadic throughout the rock. It appears that at least two vein systems occur here, parallel to those in the main quarry. Towards Settlers Range, the outcrops are obscured by red soil and further vein systems may be found beneath this covering. Prospecting by trench would involve a minimum amount of work in this area and is the obvious way to prove the existence or otherwise of further vein systems.

Area D.

This area extends on both sides of the creek. The Greenstone Quarry is situated near the southern margin; two small prospects in the bend of the creek and four on the western side. Bronzite masses are a feature of this area. One occurs south of the Greenstone Quarry, whilst a prominent ridge parallels the creek on the western bank and expands to occupy almost the whole of the patch shown across the creek from the quarry. Particularly good fibre up to $\frac{1}{2}$ " in length shows in the Greenstone Quarry beneath the bronzite in massive dark-green serpentine showing rhomboidal jointing. Numerous indications of fibre occur around the quarry and it is highly probable that fibre occurs surrounding and dipping beneath the bronzite. Further north, in the angle of the creek, much fibre up to $\frac{3}{8}$ " in length occurs, seemingly not in regular vein systems but scattered generally throughout the rock. Good fibre of comparable length is general throughout the serpentine on both sides of the bronzite ridge across the creek. A particularly fine patch was noted in the extreme south of the area between the bronzite and the syenite. The bronzite mass across the creek from the Greenstone Quarry is much obscured by scrub. It is probable, however, that fibre-bearing serpentine surrounds this mass also.

It is impossible to predict how deep the fibre goes the prospect trenches being only a few feet deep. The surface occurrences here are, however, excellent and prospecting at depth is to be recommended.

Area E.

This is a natural extension to the west of Area D. Prominent ridges of bronzite parallel Settlers Range and good fibre occurs in the surrounding serpentine. Definite vein systems have been observed in this area striking north, particularly near the western track where two systems were followed at intervals for several chains. Another system was followed in the N.W. corner of the area close to the syenite. Other indications of fibre were noted at intervals across the area but, owing to the soil and scrub covering, it could not be determined whether they were part of definite systems though such is probably the case. The fibres average $\frac{3}{8}$ " in length and are of first class quality. Developmental work in this area should consist first of cutting E-W trenches to pick up vein systems followed by N-S trenches to prove lateral extent.

Area F.

This small patch of serpentine is associated with syenite and ironstone. Outcrops of A1 serpentine protrude sporadically from beneath the soil covering. There is no bronzite and no fibre was noted.

Area G.

From the track, a narrow ridge of bronzite runs eastwards to the hills. The bronzite is fairly fresh and is very dark-brown, almost black in places. Occasional veins of bronze coloured cross-fibre occur in the rock but is of no commercial importance. Locally, the bronzite grades to dark-green serpentine but nowhere are there signs of fibre, though picrolite simulating cross-fibre was occasionally noted. As the hills are approached, the nature of the

rock alters, and the northern extension of the belt is characterized by the same type of serpentine as occurs along the eastern margin of Area B and is to be considered a natural extension thereof. Some small veins of cross-fibre, mostly under $\frac{1}{8}$ " in width, are scattered through the rock but their lengths are only a few inches. Some small prospecting trenches have been opened up on these veins but have shown that the patches are small and do not constitute vein systems. There appears, however, to be a fair development of slip-fibre chrysotile associated with magnetite and some very good veins up to 1" in width were seen. The quality of the material is similar to that described in area B but the quantity here appears to be larger. The early prospectors apparently paid no attention to this material and some preliminary trenches along zones showing on the surface would be warranted.

Area H.

This area is a hill consisting of a core of aplite almost surrounded by a narrow zone of serpentine which abutts against claystones on the west and disappears beneath ironstone veneer on the north-east. One small patch of bronzitite appears on the crest of the hill adjacent to the aplite on the west and much A1 serpentine occurs in the northern section of the area. On the eastern slopes of the hill below the bronzitite are at least two vein systems which were traced for several yards trending N.E. The fibre is short, average $\frac{1}{8}$ " and the quantity is limited.

In the western section, some narrow bronzitite ridges trending north appear near the aplite and a little fibre in short veins averaging $\frac{1}{8}$ " in width is associated with them. One vein of $\frac{3}{8}$ " width was seen near the northern end of the belt. This cross-fibre is associated with low-grade slip-fibre chrysotile occurring in narrow veins. A small prospect has been opened up on the crest of the hill in a vein-bearing area but has not shown a satisfactory vein development. Westward from the bronzitite ridges, the rock is highly serpentized and crush zones are frequent. No fibre appears in this area. The small patch of serpentine on the S.E. margin of the aplite is likewise barren.

Area J.

Outcrops of serpentine are almost continuous over the hill slopes, disappearing beneath quartz gravels to the north and ironstone to the east. Bronzitite is conspicuous by its absence, the serpentine is light-green and is mostly of type C, grading at times to type D. In some places it has the appearance of an indurated sandstone with a strongly developed series of close-spaced structural planes striking east. Rarely, short veins of cross-fibre from hair width to $\frac{1}{10}$ " occur but the quantity is extremely limited and the area not worthy of further investigation.

Area K.

This is similar to area J and is probably a natural extension thereof. Some small patches of bronzitite occur, but the area is quite barren of workable fibre.

Area L.

Serpentine appears to the west from below a steep, elongated hill of quartz gravels. The slopes are much obscured by talus material from the hill which, on the lower slopes, has been cemented by limonite.

Just below the southern end of the gravel hill, and near the heads of the two small streams, is a good development of $\frac{1}{8}$ " fibre veins in A2 serpentine. The veins are discontinuous, averaging only a few inches in length but they are plentifully distributed. Definite vein systems do not occur, the veins being scattered throughout the rock but appear in two generations—one, following the structural planes of the rock strikes N.E., the other S.E. In the veins, the fibre is blackish-green but becomes a pale greenish-white when teased. A little magnesite is present here but no magnetite was seen. Traced northwards along the narrow serpentine band below the hills, the fibre persists for about four chains. Thereafter the serpentine is of the same type but fibre is absent.

Type A2 serpentine continues south of the gravel hill with small patches of bronzitite appearing here and there on the slopes. Fibre veins similar to those described above continue to the south but diminish in frequency. An E-W line drawn 10 chains south of the southern end of the hill marks the limit of the fibre-bearing area. The two generations of veins still appear but the NE striking system is dominant and the SE striking system gradually disappears. The veins are still short but the width is somewhat greater, many veins of $\frac{1}{4}$ " and $\frac{3}{8}$ " width appearing. Veins above $\frac{1}{8}$ " are, however, composite and the average length of fibre obtained from this area would not be above $\frac{1}{8}$ ".

From the southern edge of the producing area, northwards to the water-race, the same type of serpentine persists but shows a gradual change to type D with the incoming of red and yellow blebs. Veins in the serpentine still appear but prove to be picrolite in either the pseudo-cross-fibre or amorphous form. It appears that slightly different physical conditions prevailed in this southern portion of the area. The whole of the area from the water-race eastwards is a mixture of types C and D serpentine with occasional small patches of types A1 and A2. Some traces of fibre are to be seen here and there as, for instance, in a road metal quarry on the northern side of the track 16 chains eastwards of the main road, both the veins are very narrow and short. No commercial quantities of fibre occur in the area.

Area M.

This elongated area surrounds a syenite mass on three sides and extends south as far as the track. Three patches of ironstone occur, that on the track being a true chrome-iron deposit similar to that on Mt. Vulcan. It is several feet deep. The other two are veneer deposits only. The area generally has a gentle slope, breaking away sharply from the steeper slope of the syenite core. Partially altered bronzitite masses of low relief are general. Two such masses form low ridges on either side of the small streamlet flowing north. Another runs from the northern end of the syenite to a point between the two ironstone veneer patches. A narrow belt of type A2 serpentine lies between this ridge and the alluvial flat on the west. Outcrops are sporadic but there are signs of fibre veins

striking N.W. in a system 1 to 2 feet wide. Hair veins abound, but the average vein width is a little below $\frac{1}{4}$ ". The veins are not above 1 foot in length. The fibre in the veins is dark-green and of good quality.

On the east side of the bronzitite ridge, there is a small development of slip-fibre chrysotile and, although hair veins are common over the whole area, in no place were any veins of commercial size seen. With the exception of the small strip of serpentine described above, the area must be considered barren.

Area N.

This area includes the remainder of the serpentine in the extreme southern portion of the field. From the track south to the point at which the water-race crosses the creek, the serpentine is mostly of types C and D with small patches of type B. Some hair veins of fibre appear but their distribution is scanty. Similar conditions apply on the west of the stream and almost as far north as the sharp curve on the water-race where it emerges from the clayslates. Northwards of this point, however, there is a change to type A2 which is fibre-bearing. The veins are similar to those occurring in area L being $\frac{1}{10}$ " to $\frac{1}{4}$ " in width but strike almost north. The distribution is sporadic, not in regular systems but the veins are general throughout the rock mass. In the vein, the fibres are somewhat brownish and not of such good physical quality as those appearing elsewhere.

Serpentine continues south of the point at which the water-race crosses the stream and eastwards of the latter. It is mostly of types C and D but two ridges which require special mention occur. The first is on the northern side of a small ephemeral stream. It is a prominent rugged outcrop of partly altered bronzitite riddled with prominent veins of pale-green amorphous serpentine grading to pseudo-cross-fibre picrolite up to $\frac{3}{4}$ " wide. The veins conform to no particular pattern, criss-cross through the rock in all directions, and make up roughly 30 per cent of the total rock volume. A minor proportion of the veins carry cross-fibre chrysotile on either edge, the length of the fibres varying up to $\frac{1}{4}$ ". When present, the chrysotile is continuous along the vein and retains its width fairly well. Some few veins of chrysotile occur unassociated with picrolite and, from a study of vein intersections, it is apparent that the generation of pure chrysotile veins preceded that of the composite and picrolite veins.

The second ridge occurs between the two streamlets. In the distance this appears to be composed of conglomerate with well-rounded pebbles up to 2" in diameter. On closer inspection, however, it is seen that the "pebbles" are almost fresh bronzitite and the "matrix" amorphous serpentine sometimes carrying wide picrolite veins which do not penetrate the bronzitite. Small areas of rock similar to that on the first ridge occur and some chrysotile is associated with them.

The remainder of the area surrounding these ridges is of normal A2 and C types with a little type D. Hair veins of chrysotile are sporadic but no commercial grades of fibre appear. The total quantity of fibre available in the ridges is small and the outcrops are more in the nature of geological curiosities.

Area P.

This area, roughly oval in outline, forms a range of hills with a flat crest. The serpentine here is associated with aplite and hornblende granite, the lines of contact often being distinct except around the edges of the smaller aplite intrusions. A diversity of serpentine types occur. Much of the southern slopes of the hill consist of ridges of A1 serpentine trending south and bordered by A2 material sometimes showing strong crushing. Magnetite is general throughout this latter material but chrysotile is only sparsely distributed in small veins. On the S.E. tip of the area, just across the small stream, is a patch of bronzitite and westward thereof some cross-fibre occurs in veins of $\frac{1}{8}$ " to $\frac{1}{4}$ " in width striking N.E. Further along the track are Smith's prospects consisting of an upper and a lower cut. These are in A2 serpentine which extends west from the road some seven chains. Some magnetite occurs in these cuts. Fibres in the stone heap and on the walls of the prospect are up to $\frac{3}{8}$ " long and a vein system has been traced at intervals from the bronzitite mass mentioned above through these cuts but it disappears northeastwards some two chains past the cuts. Up the slopes of the hill behind this vein system, the outcrops are more sporadic and though veins of fibre comparable in width with those just described occur, the tracing of vein systems was found impossible. It is highly probable, however, that they do exist.

The remainder of the area appears to be quite barren of fibre though some A2 type serpentine occurs along the southern margin of the hills. The flat along the crest is unfortunately soil covered and outcrops are poor. However, it is not considered likely that fibre occurs here as, if it did so, indications would be found along the southern margin.

Area Q.

This small area is adjacent to hornblende-granite and in it is situated the Frenchman's Quarry. The original rock here is not the bronzitite which characterizes the greater portion of the field but a pyroxenite of the diopside-hedenbergite series rich in lime. In no case was perfectly fresh rock seen but all gradations to completely serpentinized rock occur. Near the western margin of the area normal bronzitite occurs, indicating that the area of calcium-rich pyroxenite is limited.

The Frenchman's Quarry is a narrow opencut 100 feet in length which is now waterfilled for its entire length. In the face of the quarry, however, veins of fibre can be seen. The best fibre, however, according to a local resident who used to be in charge of the quarry, occurs well below water-level. The fibres occur in both the cross and the slip forms and gradations between the two exist. The cross veins are commonly 1" in width and the slip veins may be several inches. The cross veins are all simple so that the width of the vein is also the length of the fibre. Physically, the fibre differs markedly from the chrysotile type. The fibres are usually pure white when dry but are somewhat coarser than chrysotile having more the appearance and feel of cotton as opposed to silk. In many of the veins the process of alteration has proceeded a stage further than the production of asbestos and the veins are actually composed of talc. The fibrous structure is, however, still retained and the talc is pseudomorphous after asbestos. It has been stated

that the amphibole type of fibre has a lower tensile strength than the chrysotile and such would appear to be the case here. However, different veins of amphibole appear to have different tensile strength and it appears to the present writer that the tensile strength of the fibre is a function of the degree of alteration. Almost all veins, on close inspection, show some degree of alteration to talc and it is this degree of alteration which determines the strength. Veins which are composed entirely of amphibole have quite good tensile strength.

The quarry appears to have been driven along the strike of the veins and small prospect trenches round about have failed to reveal other vein systems. It is not considered likely, in this small area, that other workable veins of fibre will be found. The only possibility of obtaining this type of fibre is to deepen the present pit, a course which would involve pumping operations, the pit having previously been closed down owing to the strong influx of water.

Area R.

This final area is of calcium-rich pyroxenite showing alteration in an exactly similar manner to that observed in area Q. No prospect trenches have been cut here but, on the surface, talcose veins of cross and slip fibre similar to that found in the Frenchman's Quarry occur. As the two areas are closely analogous it is highly probable that amphibole asbestos in workable veins occurs and preliminary prospecting work would be warranted.

CONCLUSIONS AND RECOMMENDATIONS.

The present survey has shown that, while a quantity of asbestos still remains in the Beaconsfield district, it is scattered over a wide area and much of it is too sparsely distributed to form an economically workable proposition. The fibre is mostly cross-fibre chrysotile, with a minor amount of slip-fibre chrysotile and both types of amphibole asbestos in small quantities. The tensile strength of both types of chrysotile is consistently high while that of the amphibole asbestos is somewhat lower and variable. The length of fibre varies considerably and is mostly short but it will be found that the grades to be obtained will be satisfactory for the manufacture of asbestos cement products and for use in insulating fillers, packing materials and insulating plasters. Fibres of spinning length will not be found in appreciable quantities.

The central and northern portions of the field offer the most encouragement for further work. With the exception of the area west and north of the water-race, the southern portion only carries scattered short fibre and appears to offer little possibility of commercial deposits.

The following areas are recommended for prospecting and developmental work:

- (1) The whole of areas D and E, the most promising in the field.
- (2) Area A, west of the tramline and including the two small patches west of the creek.
- (3) Area C.
- (4) The S.E. portion of area P along the base of the hills.
- (5) For slip-fibre—the eastern margin of area B, the northern extension of area G, and area R.

In preliminary prospecting, the ideal is to obtain the maximum information with a minimum of expenditure of money. In this field, this object will be attained by first of all proving the areal extent of the deposits. This may be termed "first stage prospecting". In the selected areas, it is recommended that, having found a vein system and determined its direction, shallow cross trenches be cut at right angles to the strike of the system. These trenches should merely be clearings of the soil and scrub covering and only penetrate far enough into the rock to disclose the presence or otherwise of further veins. In an area such as area D, two cross channels near either end should be sufficient. The object of this is to pick up all the vein systems in the area. Having accomplished this, the next step is to cut channels along the strike of the vein systems. From these two series of channels, an accurate idea of the quality of fibre present and the width of the veins may be gained, and a decision made whether it be worthwhile to prospect at depth.

Second stage prospecting consists of proving the depth of the systems and will be more expensive than the first stage. This may be done either by sinking shafts at selected points along the vein system or by the use of a diamond drill.

If this type of prospecting be conscientiously carried out an extremely accurate picture of the field will be obtained. The writer would stress the necessity of obtaining information of this character before any definite plans for establishment of a mill are made. Too often in the past, money has been wasted in mining ventures through lack of prior knowledge of the reserves of ore available.

A further step in the prospecting programme will be to determine the grade of fibre available. This could be done after the network of trenches has been opened up by sampling the vein systems at regularly spaced intervals obtaining a fairly large composite sample, having this sample crushed and the resulting fibres graded on a Quebec Standard Testing Machine.

It has been found impossible to form any accurate estimate of the amount of fibre available or of the average effective grade, but the production figures of Wunderlich Limited who worked the main pit for 18 months may be taken as a guide. From 48,854 tons of rock quarried, 4,414 tons were selected for milling from which 441 tons of fibre valued at approximately £10,000 (in 1918) were extracted. In other words, the effective grade of the rock in the pit was 1 per cent which was concentrated by hand-selection to effective grade 10 per cent for milling.

From the size of the pit which produced the 441 tons of fibre, the writer estimates that the quantity of fibre available in areas D and E will be between 5,000 and 10,000 tons. This, however, is to be taken only as an estimate and prospecting work as outlined above will be necessary before any approximately accurate figure can be obtained.

Areas D and E appear to contain a fair concentration of fibre veins and it is probable that the average effective grade of the total rock mass will be between 2 per cent and 3 per cent which by selection in the quarry will easily give 10 per cent milling ore.

At the Tasmanian Asbestos Pty. Ltd. workings near the Argent Tunnel, Zeehan, average effective grade of rock was 2 per cent which was concentrated by selection to 6 per cent, i.e., three tons of rock

were mined for one ton of ore, the total cost of mining and selecting being 3s. 6d. per ton mined. Milling costs were 10s. per ton of ore milled. The cost per ton of fibre produced, neglecting capital outlay and depreciation, may, therefore, be calculated as follows:—

	£	s.	d.
Mining and selecting 50 tons at 3s. 6d.	8	15	0
Milling 16 tons at 10s.	8	0	0
Total	£16	15	0

At Beaconsfield, owing to the difference in the nature of the fibre occurrence and the fact that costs have risen since 1945, the cost of producing a ton of fibre is likely to be much higher. When, however, it is realised that overseas asbestos fibre of grade suitable for the manufacture of asbestos cement products exceeds £100 per ton landed in Tasmania, there is a reasonable margin for profit.

In conclusion, the writer would like to state that he feels that, while no spectacular developments may be expected at Beaconsfield, there is a reasonable quantity of medium grade ore available which may serve as the basis of a profitable small industry capable of supplying Tasmania's requirements of asbestos fibre, but he would again stress the necessity for systematic prospecting and wise planning before the establishment of a production plant is considered.

Section IV—The Ulverstone Area

LOCATION AND ACCESS.

The Ulverstone serpentine is situated in the valley of the Clayton Rivulet, two miles east of Ulverstone and between one and three miles south of the coast. A very small patch of serpentine also occurs on the west bank of the Forth River, one mile south of Forth township.

On the Clayton Rivulet field, five small patches of serpentine occur over a distance of two miles. Area A can be reached by a track which leads south from the Bass Highway just west of the bridge over the Clayton. Areas C, D and E are best reached by travelling along the Ulverstone Rifle Range road for three-quarters of a mile, thence following a timber-getters track along the rivulet. Area B is most accessible by turning off the Bass Highway two miles east of Ulverstone and traversing the Sandpit road for a mile. A foot track then leads eastwards along the boundary fence between Purton's and Howards properties, crosses the serpentine, and joins the timber-getters track mentioned above.

TOPOGRAPHY.

The country between Ulverstone and Forth stands at an elevation of 400-500 feet above sea-level. The surface of this area is conditioned by an extensive sheet of basalt weathered to a friable red soil. It is "rolling" country with but gentle slopes.

In recent times, the area has been strongly uplifted and the streams have cut deep channels. They have now reached their base-level of erosion and are now engaged in widening their valley floors. The Clayton is typical of the streams hereabouts and now has a gentle gradient, flowing sluggishly along a winding channel cut in its own floodplain.

Between the elevated platform and the sea coast is a coastal plain half a mile wide which consists of a thin veneer of alluvium covering eroded ancient rocks. This plain lies at an elevation of only a few feet above sea-level.

The weathered basalt of the elevated platform and the alluvium of the valley floors and the coastal plain provide rich soils eminently suited to agriculture. These areas are, therefore, cleared of bush and provide a pleasant vista of cultivated land. The ancient schists exposed in the valley walls do not, however, provide a rich soil and have been avoided by the agriculturalist. The valleys are, therefore, marked by narrow belts of bush and scrub.

GENERAL GEOLOGY.

The basal rocks of the area are quartz-schists, mica-quartz schists and quartzite of precambrian age. In many places the schists contain an appreciable amount of graphite which imparts a dark colour and an unctuous feel to the parent rocks. Several small pockets of pure graphite were noted during the course of the present survey but they are too small to be considered as commercial propositions. However, careful search may reveal larger pockets.

Into the schist series was injected the serpentine. As stated above, five small patches have been observed. These patches do not appear to be physically connected. They appear, rather, to be separate bodies and it is probable that they are concordant intrusions of the sill type. Around the serpentine bodies the planes of schistosity of the schist series are disturbed—away from the serpentine they lie almost flat. It is quite evident that the serpentine is intrusive into the schist series.

An exceptionally long time interval following the period of the serpentine intrusion in unrepresented by rocks. The next later series is the Tertiary basalt which was laid down directly on to the precambrian schists. These basalts are of the Plateau type. They were extruded, not from volcanic vents, but from rifts. They were probably in a very fluid condition, filled all the hollows and valleys and, when solidified, presented a plane surface.

Since the period of the basalt extrusion the only major feature of the geological history of the area has been the uplift which has caused the present streams to cut deep valleys to base levels. Weathering of the basalts has proceeded to an advanced stage and small streams are now in the process of dissecting the soft soil produced and stripping it from the precambrian basement.

THE SERPENTINE AREAS.

The serpentine patches all occur along the valley walls and have been exposed during the course of the incising of the stream consequent upon the periods of uplift.

Area A is an ill-defined area. The slopes of the Hill are covered with a thick mantle of soil which has been washed down from the weathered basalt above. However, scattered small outcrops serve to delimit the size of the patch. On the eastern margin of the hill, a quarry has been opened for the supply of road metal. The quarry is rectangular in plan, with a face 20 feet in height. The serpentine is greenish-yellow in colour and consists of bands of material much mottled with yellow and red blebs, alternating with unmottled bands. The bands are very narrow, the structural planes being rather wavy, but in general striking at 135° and dipping vertically. A marked foliated appearance is thus produced. The material in this quarry is much more completely serpentinized than that in the other areas of this field. There is no sign of asbestos fibre, either in veins or along partings. The remaining small outcrops in this area are of similar material.

Area B.—The serpentine does not form a continuous outcrop over this area. On the northern side of the track, it is fairly continuous along the eastern margin but the western margin consists of scattered outcrops showing from beneath a covering of basaltic soil. South of the track, along the steep valley wall, the serpentine is mostly obscured by soil and scrub and is exposed in a few places only.

The serpentine of the northern section of the area is pale yellowish-green with red and yellow blebs. Narrow veins of haematite and opaline silica are frequent and stand out in relief on the weathered surfaces. Alternating with this type of serpentine are bands 6 feet to 10 feet wide of dark-green greasy serpentine. The dominant series of structural planes which separates these two types strikes at 330° and dips steeply to the N.E. In the dark-green ser-

pentine a subordinate series of structural planes strikes at 80° and dips steeply to the N.W. These bands of dark-green serpentine carry veins of cross-fibre chrysotile, the trends of which agree with that of the subordinate series of structural planes. The fibre veins are usually short and much branching occurs. They appear not to be confined to definite vein systems but rather are scattered sparsely along the serpentine belts. As they lie, in general, normal to the strike of the belts, the maximum width of serpentine over which they occur is about 10 feet. It was found impossible to form an estimate of the percentage of fibre present owing to the scattered nature of the outcrops but it would be less than one per cent.

The fibre veins average 1/16" in width, rarely they are 1/4" wide and there are many veins of hair width. The average length of veins is 3" to 6". The narrow veins do not show a central parting but veins above 1/4" width are composite. The fibre is good dark-green material which teases to a white silky mass of good tensile strength.

Some slip fibre chrysotile has been generated along planes of movement but it forms a veneer only, often grades to picrolite, and is of no commercial importance.

Several shallow prospect trenches have been cut along fibre-bearing zones near the eastern margin and north of the track. These are only several feet deep and serve merely to show that the fibre continues at least to the depth of the trenches without showing any improvement in length or quantity.

On the extreme eastern margin, a shaft was sunk to 30 feet and a drive of 40 feet taken westward. At the time of the present writer's visit, the shaft had collapsed and could not be inspected. From information supplied by the party who sank the drive, however, it appears that it followed the margin of the serpentine and that the drive cut into serpentine. On the dump heap appears a quantity of very white slip-fibre of the amphibole type similar to that found in the Frenchman's Quarry at Beaconsfield. Bunches of fibre a foot or more in length are frequent but the length is deceptive. When teased out, these bunches break down into a mass of very short fibres. Much of this material has been converted to talc pseudomorphous after asbestos. The conversion, however, is not quite complete and the talc still retains a slightly fibrous form when reduced to a powder. Almost all the fibrous material is more or less altered to talc and only with difficulty are specimens of asbestos of good tensile strength obtained.

No specimens of cross-fibre chrysotile were found on the dump heap and this would indicate that the chrysotile showing on the surface does not live at depth. It is, of course, possible that the drive missed the fibre-bearing hands and the question of whether or not the chrysotile lives at depth must be considered not proven.

South of the track, along the western side of the valley, scattered outcrops and bluffs show that the serpentine is a light-green variety mottled with red and yellow blebs and contains bands of opaline silica mixed with haematite. Several patches of bluish-green serpentine mark the presence of crush zones. There is no dark-green greasy serpentine, no sign of asbestos fibre and no reason to suppose that fibre exists.

Area C.—This small area consists mostly of massive dark-green greasy serpentine with mottled brown patches. Much magnetite occurs, mostly in disseminated grains but occasionally in veins.

Some narrow bands of yellowish-green mottled serpentine occur rarely. The structural planes of the mass are rather ill-defined and, where apparent, strike out at 50° and dip vertically. The serpentine appears to be a good host for fibre and a careful search was made. However, only a very few short veins 1/32" to 1/16" wide were found. They are very scattered and rare, and do not bear a systematic relationship one to the other or to the structural planes of the serpentine.

There is a fair development of slip-fibre chrysotile along planes of movement, but the total quantity available is very small indeed. The area is poor and does not warrant further investigation.

Area D.—This area is possibly connected physically with Area C. Some bands of dark-green serpentine appear but the greater part of the mass consists of light-green serpentine with occasional patches mottled red and yellow. Much disseminated magnetite appears. There is no sign of fibre.

Area E.—This area is much obscured by soil and scrub. The main mass of the rock is light-green serpentine with patches mottled red and yellow. Crush zones marked by bluish-green serpentine are common and there is a subordinate amount of dark-green greasy serpentine with magnetite veins. In this latter type, a few hair veins of fibre were found, an inch or two in length. Apart from this there appears to be no development of asbestos.

The Forth River Area.—This small area of approximately 5 square chains is located on the west bank of the Forth River, on the N.W. corner of Mrs. Woods 13½ acre block, 0.9 miles from Forth township. The serpentine is intruded into Precambrian quartzites sometimes showing a little mica. It is capped by almost unweathered olivine-basalt. A small road-metal quarry has been opened in the outcrop but has not been used for many years. The rock is very dark-green greasy serpentine, compact and dense, with a somewhat splintery fracture. The hand specimen does not show jointing but some planes of weakness are visible in the face. On exposed surfaces, the serpentine has weathered to a pale greyish-yellow soft material in which specks of resistant magnetite are common. A few crush zones were noted.

Only a few scattered veins of fibre were seen, none of which are of commercial size. The best are 1/16" in width, up to 3" in length and they range down to mere hair veins. In such a small outcrop, it would have been impossible to miss any veins of fibre of commercial size and it must be concluded that none exist.

Besides the area mapped, a thorough search of the country between Ulverstone and Forth was undertaken. As the serpentine occurs intrusive into the Precambrian rocks and is only exposed by erosion, this search was conducted up the streams—Buttons Creek, Clayton and little Clayton Rivulets, Chinaman's Creek, and the Forth River. In each case the stream was followed until the Precambrian rocks disappeared beneath the basalt covering, beyond which point no serpentine would have been found.

The areas above described are the only ones found and it must be concluded that no further patches of serpentine are exposed in this area.

CONCLUSIONS AND RECOMMENDATIONS.

The present survey has shown that a little serpentine occurs in the Ulverstone area unassociated with original pyroxenite or peridotite. Only in one place—the eastern section of Area B, does cross-fibre chrysotile occur. The known distribution is too sparse and the length of the fibre too short for the area to be considered commercially. A small amount of work only has been done on the area.

The writer is unable, therefore, to recommend that any further exploratory work be done on this field at the present time. If an asbestos extraction plant were erected at Beaconsfield, it may be possible to supply a small quantity of selected stone from the Clayton Rivulet.

Section V—The Spero River Area

LOCATION AND ACCESS

The Spero River, at its mouth 90 to 100 feet wide, flows in a general westerly direction and enters the ocean four miles south of Point Hibbs, at the southern end of Spero Bay on the West Coast of Tasmania. The mouth of the river is 35 sea-miles from Cape Sorell and 50 sea-miles from Strahan, the nearest port. Spero Bay faces south-west and is divided into two portions by a low headland (un-named) a mile north of the river mouth. The long ocean rollers approaching the coast are deflected by Point Hibbs and, when nearing the coast, commence to break opposite the river mouth and the low headland, sweeping then up on to the beach. In rough weather, these rollers are exceptionally large and, even in calm weather, there is a fair ocean swell. Periods of calm are infrequent and of short duration. Thus, the approach to the Spero by sea is, at any time, a hazardous undertaking and, when the wind is in the prevailing west to south-west quarter, impossible. A further fact which militates against the use of the sea approach, is the sand bar across the mouth of the river which prohibits the entrance of vessels drawing more than about four feet. In calm weather, launches are able to enter the river which is navigable for one mile.

An alternative method of approaching the river is via the overland route from Birch's Inlet. The Inlet is at the head of Macquarie Harbour and distant 25 sea-miles from Strahan. Two fairly large rivers enter the head of the Inlet within half a mile of each other and are known locally as the "left-hand" and "right-hand" rivers respectively. The correct names for the left-hand (eastern) river is "Sorell River". The other river is un-named. Approximately 1½ miles up the right-hand river is the site of the old Birch's Inlet camp, now burnt down. From here, the track to the Spero River runs in a general southerly direction over button-grass "plains" for a distance of four miles before entering the forest. From this point on to the Spero River, a distance of nine miles, the track is in dense forest all the way. At the present time, the track is disused and in a very bad condition, being overgrown and difficult to follow. Many small streams and one river are crossed on the route and all bridges are down. The track finally strikes the Spero River about two miles from the mouth.

Some years ago a party of timber-getters were cutting Huon Pine in this area. There were two camps at the point where the track meets the river, one on either bank. Of these camps, only one hut now remains, on the southern side of the river. The bridge across the river has been washed away, but two stringers remaining provide access to the camp. Another camp was located at the mouth of the river, on the northern bank but was not visited during the present investigation. Its condition is, therefore, unknown. From the top camps a formed road, now much overgrown, leads to the mouth of the river. This road proceeds along the northern bank for half a mile, crosses the river, and then follows the southern bank to the sea-coast. The bridge crossing has now entirely disappeared.

The whole of the area south of Macquarie Harbour is quite uninhabited, and it will be realized from the above description that access to the Spero River by land is difficult and, by sea, hazardous and at times impossible.

TOPOGRAPHY

The whole of the area between Macquarie Harbour and the Spero River is part of the Tertiary coastal penepplain standing at an elevation of from 300 to 400 feet above sealevel. This area is strongly dissected by the rivers and their tributary streams. That the rate of erosion has been rapid is evidenced by the steep-sided valleys, gorge-like in places, which these streams have cut. The gradients of the streams are high and practically no alluvial deposits occur in the upper reaches of the valleys. At the Spero, which is probably typical of all the rivers of the area, base-level of erosion has been reached at a distance of about two miles from the mouth and from this point westwards the river flows sluggishly. Upstream, however, the river is still actively engaged in deepening the valley floor. The main activity of the streams has been the incising of the valleys and, except in the lower reaches, lateral erosion has not occurred to any marked extent. The general result, then, is that there is a series of deep valleys separated by flat-topped ridges. From a vantage point such as the top of the serpentine ridge, the summit accordance of these ridges is most striking.

The serpentine ridge strikes in a north-south direction and crosses the Spero about half a mile from its mouth. It forms a comparatively bare ridge rising steeply from river level to 350 feet and was named "Garibaldi" by the timber-getters. The serpentine has proved more resistant to erosion than the enclosing rocks and the river, therefore runs for several chains through a small gorge, the serpentine rising steeply on either side. This resistant ridge has, in the past, created a local base level of erosion on the river and caused the formation of an extensive alluvial plain on the eastern side of the ridge. West of the ridge, between it and the coast, is a further, more recent, alluvial plain.

The differential cover of vegetation in this area is most marked. The sedimentaries are covered with dense myrtle forest in which patches of gum and Huon Pine occur, the alluvial flats with thick scrub up to 15 feet in height, the gravel capping of the serpentine with button grass, and the serpentine with a dense mass of stunted gum and associated scrub. The northern slopes of Garibaldi between the track and the river, and the upper reaches of the small stream flowing near the eastern margin of the serpentine are comparatively bare and good outcrops occur in these areas. Elsewhere, the scrub covering prevents inspection of the serpentine for asbestos veins. In order to make a complete investigation, it would be necessary to burn off the scrub.

PREVIOUS LITERATURE

The first official report dealing with the Spero River area is by Loftus Hills in Bulletin 18 of the Department of Mines, 1914, entitled "Geological Reconnaissance of the Country Between Cape Sorrell and Point Hibbs." He states:—

"The occurrence north of the Spero consists of a belt of basic and ultrabasic rocks of various types, and can be seen outcropping on the sea beach, and extend inland for an undetermined distance. There are many varieties of these basic rocks here which seem to grade by insensible gradations into each other. Gabbro, saussurite-gabbro, bronzite rock, and serpentine are all present. The serpentine, however, is in relatively small amount. These basic and ultrabasic rock types are certainly of Devonian age, as they intrude the silurian strata at the base of Point Hibbs. They represent the basic facies of the Devonian igneous intrusives."

Loftus Hills also records the presence of mica-syenite at Birthday Creek, some 13 miles up the coast from the Spero. A similar rock occurs in the form of dykes south of the Hibbs River and

"... South of Point Hibbs it is again seen in close proximity to the basic rocks. South of the Spero River it occurs in the form of numerous narrow dykes intruded into the Pre-Cambrian rocks... the rock may be called a minette or mica-lamprophyre. South of the Spero River the dykes are characterised by the numerous inclusions of angular fragments of quartzite which have been occluded in the igneous mass after having been torn from the walls of the fissure by the movement of the pasty mass within it."

It will be noted that the area of basic and ultrabasic rocks which Loftus Hills describes lies along the seacoast north of the Spero. As serpentine is only of scant occurrence, this area was not inspected during the course of the present survey.

The asbestos deposits of Garibaldi were first brought to the notice of the Department of Mines by Mr. A. Barrett of Strahan in 1941. In 1942, Mr. K. A. Rae, Inspector of Mines at Queenstown made a brief departmental report on the occurrence and again, in 1946, Mr. J. S. Proud visited the area and reported thereon. His conclusions were as follows:—

1. The fibre veins are sporadic and of scant occurrence. The quality of the fibre is good but somewhat dry.
2. The serpentine developed is mainly antigorite, which is not considered favourable to fibre development.
3. It does not appear that a vein system, adequate for the existence of a commercial deposit of chrysotile asbestos has been developed.
4. Future prospecting of the area between the Spero River and Macquarie Harbour may bring to light new serpentine areas more favourably situated for the occurrence of chrysotile asbestos."

GENERAL GEOLOGY

The soil and scrub covering and the alluvial flats occurring on both flanks of Garibaldi obscure the relationship between the serpentine and the enclosing rocks. The oldest rocks in the area occur on the seacoast south of the river mouth. They are purple slates showing occasional tuffaceous bands and are associated with grey, impure limestones often showing irregular veins of calcite up to an inch in width. The slates bear a general resemblance to those occurring in the Dundas district and the whole series is considerably crushed and contorted. The general dip, however, appears to

be easterly. About a mile upstream from the serpentine, there is a good exposure of pale yellowish-brown fine sandstone grading to mudstone. These are fairly hard, but show no development of slaty cleavage. They weather readily, the weathering being slightly spheroidal and, on exposed surfaces, large pieces can easily be picked out. They dip south at low angles and are evidently younger than the slates occurring at the coast. East of this occurrence, near the top camp, conglomerate is seen in the river banks. This conglomerate is quite hard and contains pebbles of quartzite and sandstone which are well rounded but slightly discoidal and which show a wide variation in size. The conglomerate dips below the sandstone and mudstone series. About half a mile south of Garibaldi a similar conglomerate is seen. It appears in a stream bed overlying a grey, fairly soft, coarse grit bed containing un-oriented carbonaceous fragments up to several inches in length. It is not clear whether these two exposures of conglomerate represent the same bed.

In only one place was the contact between the serpentine and the enclosing rocks seen—on the eastern margin of the serpentine south of the river. The adjacent rock is a grey, impure, coarse, grey-brown quartzite and represents an original impure sandstone which has been reconstituted by the heat of the ultrabasic intrusion. This type of rock is seen to continue along the eastern margin of the serpentine on the northern side of the river also. Along the contact zone on the south side of the river, there are signs of a zone of mineralization. A narrow zone of gossan, a foot or two in width shows sporadically. No trace of metallic ores was seen on the surface in the gossan but may well appear at depth.

Capping the serpentine ridge, is a series of unsorted gravels, the pebbles being composed of quartzite, quartz-schist and quartz-sericite-schist. The pebbles range in size up to six inches, are well rounded, but generally have a somewhat elongated form. They are unconsolidated, show no signs of bedding, and are upwards of 50 feet in thickness. This series is part of an extensive sheet of gravels which must, at one time, have covered the greater part of the Tertiary peneplain. They appear on the higher portions of the button grass plains south and east of Birch's Inlet, and at intervals on the crests of the ridges on the track through the forest though here they are often obscured by the thick deposits of soil and humus. Their age is probably late Tertiary.

THE SERPENTINE

As stated above, the serpentine and associated ultrabasic rocks form a prominent north-south ridge extending across the Spero River. Two distinct facies occur.

(1) **Antigorite-serpentine.**—This is a pale bluish-green variety occurring in thin lamellae, often translucent, and showing distinct signs of crushing. The lamellae split off easily. No sign of asbestos was found in this type.

(2) **Banded Rock.**—This is the most abundant ultrabasic material on the field and the occurrence is distinctive. A series of vertical, closely-spaced bands varying in width from one half to three inches extends over a wide area. From a distance, these bands give a superficial appearance of bedding. On closer inspection, it is seen that two main varieties of rock are represented alternating one with

the other. Occasionally, a third type is seen. The varieties are as follows:—

(1) A fine-grained green-black iron-rich serpentinous material. This is the more resistant type and weathers to a smooth grey surface. Differential weathering has caused bands of this material to stand out in relief.

(2) A coarsely crystalline green-black material showing olivine and pyroxene partially altered to serpentine, i.e., an altered lherzolite. This type is less resistant to weathering, forms the recessive series of bands, has a deep brown surface, and usually shows horizontal flutings across the bands.

(3) More rarely, bands of very coarse bronzitite occur. The crystals range up to half an inch in length and are packed closely together. They show incipient serpentinization. Bands of this material are generally wider than those of types (1) and (2), the weathered surface is very rough, and bunches of crystals stand out in relief. The colour of the weathered surface is dark-brown.

The banding of the rock, therefore, is due to the alternation of layers of varying composition and the occurrence can be explained by postulating the successive injection of small quantities of ultrabasic magma of slightly different composition each injection being a differentiate of the one stock magma. The injections were most probably between bedding planes of horizontally bedded sediments the whole mass, after injection was completed, forming a concordant intrusion of the composite sill type. It has been brought into its present vertical position by strong folding movements.

No mass of gabbro was found in this area, but two small boulders of gabbro were picked up on the track. The rock shows partial saussuritization of the feldspars, is light-green in colour strongly mottled with white, and is reminiscent of the gabbro developed in the Dundas-Rosebery area.

That the serpentine and associated ultrabasic rocks are iron-rich is evidenced by the deep red soil sparsely developed along the slopes of the hill. The beds of the small creeks are also deep red and magnetite and limonite grains are found in the crevices of the rocks. A small patch of Tertiary gravels cemented by limonitic material derived from the serpentine occurs on the track rising up the eastern margin of the ridge.

The similarity of the whole serpentine mass to the known osmiridium-bearing serpentine east of the Wilson River is most striking. In many ways the above description fits the Wilson River serpentine. At Riley's knob at the southern end of the latter field, considered to be the source of the osmiridium in the creeks, exactly the same type of vertical banding of the ultrabasic occurs. During the present investigation, it was not possible to find time to search for osmiridium, but, in the writer's opinion, there is strong presumptive evidence that it may occur at the Spero River. It is considered that prospecting for osmiridium would be worth while in this area.

It is difficult to draw precise boundaries for the serpentine in this area owing to the dense scrub cover. On the accompanying plan, only those portions which were seen to contain fibre were mapped. The serpentine extends westwards almost to the coast, a distance of a quarter of a mile, and south of the button grass

plain another quarter of a mile. North of the river, the differential cover of vegetation shows that the serpentine cuts out abruptly about 12 chains from the river bank. Although fibre was not seen outside the area shown on the plan, this does not preclude the possibility of its existence.

It has been suggested by the previous investigators that there is a strong possibility that the serpentine extends as a continuous belt from the Spero River to Asbestos Point on Macquarie Harbour. This supposition is not supported by the present writer for the following reasons:—

- (1) There is a marked difference in the type of serpentine occurring in the two areas.
- (2) The differential cover of vegetation in the Spero River area shows quite clearly that the serpentine cuts out a few chains north of the river.
- (3) It is shown in the section dealing with the Asbestos Point occurrence that the serpentine there definitely disappears a little over half a mile south of the coast.
- (4) It is unusual for large masses of ultrabasic rocks to appear at the surface. The distance between the two occurrences is about 25 miles and, were the serpentine to appear continuously over this distance, the exposure would be unique.

The above statements do not preclude the possibility that patches of serpentine may appear along the Spero River—Asbestos Point line. Were the known exposures of asbestos of high grade, it would be a strong inducement to search for more occurrences along this line. As, however, the known occurrences are of poor grade, and the nature of the area to be searched rugged and difficult rendering much track-cutting necessary, it was considered that such an investigation was not warranted.

DEVELOPMENT OF ASBESTOS

The fibre occurrences are confined to the areas of banded rock: the antigorite-serpentine is barren. In the banded rock, fibre occurs in two generations.

(1) The major development is in veins at the junctions of bands of serpentine and altered lherzolite. Not all such junctions are fibre-bearing, however, and there appear to be no criteria for determining which junctions will be fibre-bearing and which barren. In all cases, the serpentine-bronzitite contact is barren. The fibre is developed on the extreme edge of the serpentine band and does not penetrate into the lherzolite. Occasionally, thin veins occur within the serpentine itself. In all cases the fibre developed is cross-fibre chrysotile, deep-green in the vein, but an off-white colour when teased out. The fibre is rather dry but has good tensile strength. The veins occurring at the junctions of bands are always composite. The side of the vein adjacent to the lherzolite is sharply defined but that adjacent to the serpentine shows a series of exceptionally narrow veins bordering the main vein and merging into the enclosing rock. Veins occurring within the serpentine are usually simple with both sides sharply defined. The veins are generally narrow, averaging $3/16$ " to $1/4$ " in width. Allowing for the general composite nature of the veins, the average length of fibre available would

not be much greater than $\frac{1}{8}$ ". The writer has been informed that veins of cross fibre up to an inch in width occur in the area, but a careful search failed to reveal such veins.

(2) Occasionally veins of cross-fibre chrysotile occur cutting across the bands at high angles. The fibre in these has obviously been developed along tension cracks. These veins are similar in width to those described above, are usually composite, but show sharp definition of both sides. Whereas the veins of the major series are generally continuous and of constant width over many feet, those of this latter series show much variation of width and are only a foot or two in length. In some cases, the fibre of these veins is curved, indicating movement along the cracks either during or subsequent to fibre development.

The veins are fairly generally distributed over the whole of the area over which banded rock occurs and form the nearest approach to a stockwork of asbestos veins which has been seen in Tasmania. However, the actual percentage of fibre in the rock is low. As mentioned elsewhere in this series of reports, it is difficult to arrive at an exact percentage figure. In the Spero River area not more than 1 per cent of the total rock bulk is fibre. The nature of the occurrence does not favour the possibility that areas of local concentration will occur. That the fibre will continue to occur at depth is reasonably certain, but, again the nature of the occurrence does not favour the assumption that strong makes of fibre lie concealed beneath the surface.

The best exposures of fibre-bearing rock were seen on the ridges marked A, B, and C on the plan, in the headwaters of No. 1 stream (D), and No. 2 stream (E).

CONCLUSIONS AND RECOMMENDATIONS.

The writer's conclusions are as follows:—

- (1) The fibre developed is cross-fibre chrysotile of good tensile strength, but rather short.
- (2) The veins are sporadic over a wide area and represent less than 1 per cent of the total rock bulk.
- (3) The fibre will continue at depth much the same as it is showing on the surface.
- (4) No strong makes of fibre can be expected either laterally or at depth.
- (5) Access to the area by sea is dangerous and, at times, impossible. To work the deposits, access by land would have to be provided. The cost of this would be considerable and is not warranted by the present showing of fibre.

If further prospecting of the area is to be undertaken, it is considered that the nature of the occurrence would render preliminary prospecting by open-cut an easy matter. On the steep northern slopes of Garibaldi, east-west crosscuts could be opened up to expose the rock. If the results of this work were encouraging, these cuts could be deepened to expose the rock at depth.

Section VI—The Asbestos Point Area

LOCATION AND ACCESS

Asbestos Point is a prominent headland on the south coast of Macquarie Harbour, two miles due east of Settlement Island and distant 18 sea-miles from Strahan. The area is uninhabited and isolated, the only means of access being by launch from Strahan. Macquarie Harbour is frequently lashed by gales and at such times landings at Asbestos Point are hazardous. A safe anchorage is provided on the eastern side of Settlement Island. From the point, an old track runs south along the crest of the serpentine ridge thence over sedimentaries to the Muddy Bay Creek at which point it terminates. It is not known for what purpose this track was formed but it is probably an old timber-getters' route.

TOPOGRAPHY

The Tertiary coastal peneplain extends north and south of Macquarie Harbour at an elevation of 200 feet to 300 feet above sea-level. On the south side, the peneplain is deeply dissected by streams, being represented by the summit accordance of the divides. Several miles inland from the southern shore of the harbour, a watershed occurs roughly paralleling the coastline. From the southern side of this watershed rise streams which flow south-west towards the open sea. From the northern side the streams flow north and north-east to the harbour. These streams, travelling only a few miles, are small and ephemeral. They have, nevertheless, cut deep and steep-sided valleys and are still actively engaged in this process. In the area described in this report two streams are of importance. The first, Main Creek, flows in a general northerly direction to meet the shoreline about five chains east of the serpentine belt. For 14 chains this stream marks the eastern margin of the serpentine. At approximately $1\frac{1}{2}$ miles south of the coast and east of the serpentine belt are the headwaters of the Muddy Bay Creek. This stream, incised in a narrow, deep valley, runs eastwards for half its length, then turns north-east and finally north to empty into the harbour in Muddy Bay, east of Brickyard Point, the next prominent headland a mile east of Asbestos Point.

The coastline along the south side of the harbour consists of a series of headlands jutting out from five to 15 chains, separated by narrow beaches of fine gravel or coarse sand. The area is covered with virgin forest right to the water's edge. Along the coast gums predominate, but further inland there are some fine stands of celery pine and myrtle. The forest is reasonably open and progress through it is not difficult. Isolated patches of horizontal scrub occur especially along the creek beds and, where the forest has been cut, there occur patches of bauera and swordgrass.

PREVIOUS LITERATURE

Three reports on the Asbestos Point occurrence have been made by officers of the Department of Mines:—

(1) **Loftus Hills (1914)** "Geological Reconnaissance of the Country Between Cape Sorell and Point Hibbs" (Geological Survey Bulletin 18) "The rock type at Asbestos Point is almost wholly

serpentine, which is in places seamed with veins of chrysotile asbestos. The serpentine belt here is about two chains wide, and strikes roughly north and south. Bands or bars of unserpentinized rock, such as bronzite rock, occur within the serpentine, as well as approximately spherical masses up to a foot in diameter of partly serpentinized rock (saussurite-gabbro, &c.)

Dealing with the history of the area he states:—"The existence of asbestos in this locality has been known for some years, and an asbestos reward was granted to H. Grice on 1st July 1900, the section number being 4767-93M. The reward was in force for five years, and the section became vacant in 1905. Practically no work was done on the section during the currency of the lease. Quite recently, however, attention has been paid to the deposits by Mr. J. R. Ross who has done some trenching work on the outcrops, and a company is now being formed to investigate the extent of the asbestos-bearing zone.

In his concluding remarks he states:—"Inland the country rises rather rapidly, and as the serpentine belt extends in a southerly direction, it is probable that the asbestos zone will also occur in this higher land. Search for this southern continuation of the asbestos deposits is desirable and even necessary, for any attempt to work the deposits on the seashore by open-cut methods will be greatly hampered by water troubles.

The writer, therefore, would strongly urge the desirability of thus exploring the southern continuation of the serpentine belt for asbestos veins, and the opening up by further prospecting work of the known asbestos zone to ascertain in a more decisive manner the probable amount of fibre that is present. Certainly the present indications are such as to warrant the expenditure of some capital in thus investigating the occurrence.

(2) **P. B. Nye (1929)** "Report on the Asbestos Deposits at Asbestos Point, Macquarie Harbour".

This report deals briefly with the general geology of the area, describes the mode of occurrence of the fibre, details the results of an inspection of a series of trenches and opencuts, and discusses the economics of the industry. In his concluding remarks Nye states:—

"Very little developmental work has been carried out. From statements made as a result of these limited operations, but which cannot be officially verified, it would appear that the proportion of asbestos in the rock is sufficient to render the deposit one likely to be of economic importance."

The most important matter requiring attention at present is to determine the extent of rock carrying such proportions of asbestos. It cannot be said at present that any proved reserves of profitable rock exist and it is recommended that future work should be devoted to determining this factor.

(3) **K. A. Rae (1941)** This is a departmental report and details the results of a three day investigation of the area because of the renewed interest which had been shown in the deposit by a commercial concern. At the time of Mr. Rae's visit, two men had been prospecting the area for six weeks and had decided that the asbestos content of the serpentine did not warrant further prospecting inland more than six chains from the point. In a quarry situated three chains south of the point, Rae found by measurement across

the face that the serpentine contained 5 per cent of asbestos veins. He concludes that "The value of this asbestos deposit, as now developed, appears to be on the borderline of profitable exploitation and requires prospecting at depth by shafting and driving".

GENERAL GEOLOGY

The whole of the coastline on the south side of the harbour shows rock outcrops ranging from 2 feet to 20 feet above sea-level. As the structural planes of the area strike north-south and the coastline strikes a little south of east, the shoreline gives a good section across the strike of the country. Along the section inspected, extending from one mile east of Asbestos Point to half a mile west of the point, all rock series showing are dipping westwards at about 40°.

Brickyard Point consists of pale sericite—and quartz-sericite-schists, fine-grained and finely laminated. These are succeeded westwards by fine and medium grained green to brownish-grey slates. The slates contain tuffaceous members and occasionally bands of fine conglomerate. These conglomerates have been rendered partly schistose, but the outlines of the pebbles remain. While the strike and dip of the slate series generally accords with that given above, the bedding planes are frequently contorted and crumpled. Occasionally the slates show bands of finely-divided iron pyrites oxidised at the surface. No trace of other metallic sulphides was seen.

West of Asbestos Point, similar slates appear containing tuffaceous bands and also bands of fine-grained basic rocks. These bands are much altered and their origin is obscure. No sulphide zones were seen on the west side of the point.

At Asbestos Point, basic and ultrabasic rocks occur separating the slate series into two divisions. The basic group is represented by gabbro which outcrops prominently in a small un-named headland some 15 chains east of Asbestos Point and again over a distance of 18 chains along and east of Main Creek. Between these two exposures, a small patch of slates shows along the shore. Whether these two exposures of gabbro are part of the same body was not definitely determined but seems highly probable. The gabbro is dense and hard, is of a general pale-green colour faintly mottled with white, and shows incipient saussuritization of the feldspars. Alteration of the feldspars has not, however, proceeded to any marked degree. Unlike the other rocks of the area, the gabbro shows no structural planes and its outcrops along the shore are distinctive.

West of the gabbro, the ultrabasic rocks, pyroxenite and serpentine occur. They are described in the next section.

Along the coastline, between the serpentine and the gabbro, outcrops a belt of rocks showing a marked variation of characteristics. On the western margin they appear to be laminated mudstones, yellowish-brown in colour, with abundant streaks of chloritic material conforming to the direction of the laminae. Narrow partings, intersecting the laminations at high angles are filled with limonite, probably deposited from percolating solutions. As the eastern margin of the exposure is approached, the rock becomes a somewhat soft, green, chloritic schist. There is no definite boundary between the two types. They probably represent an original mudstone rendered partly schistose by the igneous intrusions.

THE SERPENTINE.

The ultrabasic rocks occur as a long narrow belt striking north-south in conformity with the strike of the enclosing rocks. The average width of the belt is five chains, it protrudes into the harbour at Asbestos Point a distance of five chains and extends south for 45 chains from the point. The ultrabasics outcrop continuously south of the point for 18 chains, disappearing then beneath the covering of soil, and then re-emerging at the surface between 40 and 45 chains from the sea. Outcrops are intermittent along Main Creek. Part of the area mapped as pyroxenite and serpentine is, therefore, inferred.

The pyroxenite occurs as irregular "boulders" in the serpentine ranging from a few inches to many feet in diameter. No continuous outcrop of pyroxenite was seen. It is a heavy compact rock, grey-black in colour and consists entirely of unoriented, equi-dimensional, crystals of bronzite. The size of the crystals is mostly about 2 mm. but occasionally clusters of crystals up to a centimetre in length are seen. On a fresh surface, the cleavage cracks of the crystals impart a scintillating appearance to the rock. The weathered surface is usually slightly rough owing to differential weathering of the variously oriented crystals. Boulders of pyroxenite are most frequent over a distance of five chains south of the point and in trenches 12 and 13 at the southern end of the field. Elsewhere no pyroxenite was seen.

Three types of serpentine occur:—

- (1) Dark-green massive serpentine. This type is, in every way, similar to type A2 occurring at Beaconsfield and which is the host rock of the asbestos veins in that area. It shows the three series of structural planes with the dominant series paralleling the strike of the serpentine belt, i.e., striking north-south. At Asbestos Point, this type occurs associated with pyroxenite boulders over the first five chains of the exposure and at trenches 12 and 13. Unassociated with pyroxenite, it occurs along Main Creek and generally along the eastern margin of the belt.
- (2) The most distinctive type is a brownish-green foliated serpentine typically developed along the whole of the exposed western margin of the belt. This type has a marked schistose appearance and consists of irregular laminae of green and brown serpentine striking north-south and dipping west almost vertically. The laminae are loosely held together and quantities of rock can readily be picked out. In some places, the rock is so soft and friable that it can be shovelled out of the face. Pyroxenite boulders are uncommon in this material, though some small occurrences were noted along the coastline, particularly near the western end of trench 4.
- (3) Near the southern end of the field appear small patches of pale yellowish-green serpentine carrying abundant disseminated magnetite and chromite particles. A feature of this type is the abundant development of narrow veins of calcite. Cavities in the rock are lined with this material in rather squat, singly-terminated crystals up to 1 cm. in length.

A noticeable feature of the serpentine of this field is the almost complete absence of veins of magnetite which are so characteristic of the Beaconsfield and Zeehan-Rosebery occurrences. Disseminated grains of magnetite do occur in the Asbestos Point serpentine, but only rarely are veins seen.

South of the point at which Main Creek crosses the serpentine belt, the serpentine does not appear on the surface. For several chains south of this point, however, ironstone is developed on the surface and gradually disappears beneath the soil covering. On digging into this deposit, it is seen that the ironstone is merely a capping a foot or two in thickness resting on a serpentine basement. The two types of material show no clear-cut division, merely merging into each other. Along the contact zone which parallels the surface, can be found rather vesicular serpentine, pale-green in colour, with ironstone on the upper side extending downwards as irregular "fingers" into the serpentine. The ironstone has a similar vesicular structure to the serpentine on which it rests and is probably a recent development resulting from the deposition of material at the surface from iron-rich solutions rising through the serpentine by capillary action.

South of the ironstone deposit serpentine does not appear. About $1\frac{1}{2}$ miles south of Asbestos Point, the Muddy Bay Creek flows eastwards and north-eastwards to enter the harbour east of Brickyard Point. This stream was followed from its headwaters west of the serpentine belt, to its mouth. Over the first half of its length, the stream flows over shales and sandstones containing quartzite pebbles and, as it nears the coast, over slates and schists. The section followed in this stream should have disclosed a southern extension of the serpentine belt had such existed. It must be concluded, therefore, that the serpentine disappears a few chains south of the point at which Main Creek crosses the belt.

The conformity of the structural planes of the serpentine with those of the enclosing rocks of the slate series, taken in conjunction with the areal extent of the exposure show that the Asbestos Point serpentine is in the nature of a sill about 200 ft. to 250 ft. in thickness. The original pyroxenite was injected along a bedding plane of the slate series and has been brought into its present inclined position by regional folding movements. It appears that there was only one injection as a laminated appearance such as characterizes the Spero River serpentine does not appear. The present eastern margin of the belt is, therefore, actually the lower side of the serpentine intrusion.

DESCRIPTION OF TRENCHES

Altogether 19 old trenches have been discovered. Some, such as those near the point, are comparatively large. Others, such as those along Main Creek, are mere clearings of the outcrops which failed to reveal fibre and were abandoned. It is considered that detailed descriptions of these trenches will give a clearer picture of the occurrence of asbestos in this area.

Trench 1—A hole 6' x 6' x 6' in light-green massive serpentine, showing thin veins of fibre mostly parallel to the dominant structural planes of the rock. The veins are only a few inches in length and the fibre averages $3/16$ " in length. Very little fibre is showing.

Trench 2 is 8' x 2' x 5'. The serpentine is a darker green massive type showing a strong development of intersecting structural planes. Many small and some large boulders of pyroxenite appear but very little fibre shows in the contact zones.

Trench 3—An irregular cut. The western portion crosscuts the structural planes, the central follows them and the eastern crosscuts them again. The maximum height is 10' and the maximum width 12'. Mostly massive dark-green serpentine locally grading to black and with large boulders of pyroxenite plentifully distributed throughout. The structural planes are marked by bands of slip-picolite up to three inches wide. Some fibre veins are associated with these bands while others traverse the serpentine. The maximum width of fibre veins is $\frac{3}{8}$ " but the average is much smaller. Even wide veins are simple but some composite veins occur. The present showing is poor. The dumpheap, however, shows a fair quantity of fibre in veins up to $\frac{1}{4}$ " in width. It appears that here a reasonably rich patch of fibre was discovered, the longer material selected and the shorter discarded. The patch has now been practically worked out.

Trench 4—A hole 6' x 6' x 20' at the eastern end shows several veins of nice fibre up to $\frac{1}{2}$ " in length striking north and dipping east at 80° in dark-green massive serpentine. Structural planes are marked by picolite bands as in trench 3. In the remainder of the trench (3' depth) the foliated mottled brown serpentine appears but shows no fibre. Along the coastline west of this trench, the foliated serpentine contains boulders of pyroxenite up to 6" in diameter around which occur thin bands of fibre-bearing serpentine. The veins are discontinuous, mostly composite, and rarely range above $\frac{1}{4}$ " in width. The showing is poor.

Trench 5—A small hole in the western end discloses dark-green massive serpentine without fibre. The remainder of the trench is in clay and exposes serpentine in the floor at 6' depth. No fibre appears.

Trench 6—A small hole showing foliated serpentine without fibre.

Trench 7—This trench is 3' wide with a maximum depth of 12' and is cut across the strike of the serpentine. Where the track crosses the trench, a large boulder of pyroxenite shows in the floor surrounded by dark-green massive serpentine. There is a small development of fibre around this boulder but the total quantity showing is very small. The remainder of the trench is in foliated serpentine containing picolite but no fibre.

Trenches 8 and 9—Very shallow trenches merely exposing serpentine in the floors beneath the soil cover. The serpentine is the foliated type. At the eastern end of trench 8 is a small patch of ironstone.

Trench 10—Width 8', depth 6'-8'. Western portion as far as the angle is in foliated serpentine without fibre, remainder in massive dark-green serpentine. No fibre shows in the cut but appears in a hole which was sunk at the southern end. This hole is water-filled, but the dump heap shows nice fibre up to $\frac{3}{8}$ " long and averaging $\frac{3}{16}$ ".

Trench 11—Mostly dark-green massive serpentine grading to black. There is an abundance of slip-picolite in massive bands 4" to 6" wide. Locally this grades to a coarse, rather brittle fibre but otherwise no fibre appears.

Trench 12—The eastern portion is in foliated serpentine followed by a 12' zone of dark-green massive serpentine containing pyroxenite boulders. Some fibre averaging $\frac{1}{8}$ " in length is found in this section but the quantity is very small. East of the track, there is an abrupt change to the pale-green type containing calcite veins. This type extends to the eastern margin of the belt and appears in the stream cascades. It does not contain fibre.

Trench 13—A shallow trench in light-green serpentine with occasional darker bands carrying a little narrow golden fibre.

Trench 14—A shallow trench with a cut 6' deep at the stream end. Contains dark-green serpentine somewhat foliated. No sign of pyroxenite and very little fibre showing. Such fibre as does appear is of hair width and in very short veins. A quantity of thin picrolite appears along gliding planes and some narrow veins of calcite occur.

Trench 15—A small cut showing massive dark-green serpentine carrying a little fibre in short veins up to $\frac{1}{4}$ " wide.

Trenches 16, 17, 18 and 19—These are all small cuts showing massive dark-green serpentine similar to that appearing in trench 15. Abundant slip-picrolite occurs but only the merest trace of fibre in hair veins was seen.

DEVELOPMENT OF FIBRE

In all cases, the fibre developed is cross-fibre chrysotile usually pale-green in the vein but locally grading to golden-yellow owing to subsequent impregnation by percolating iron-rich solutions. The green fibre teases out to a pure white mass, the golden to a brownish mass, somewhat drier, and of poorer tensile strength.

Three generations of fibre having different associations occur:—

- (1) The major development is that typical of fibre occurrence in the Zeehan-Rosebery district, i.e., the fibre is developed in the serpentine in zones paralleling the serpentine-pyroxenite contact. At Asbestos Point, these zones are narrow, extending only a few inches from the pyroxenite masses. Wherever bodies of pyroxenite occur in either the massive or the foliated serpentine, it is safe to assume that a development of fibre will be found. Whether it will be found in good quantity cannot, of course, be guaranteed.
- (2) Occasionally fibre is found in the massive serpentine associated with the development of slip-picrolite along movement planes. Usually a thin vein of fibre is found along either side of the picrolite band. Although the fibre is usually of good quality, the sporadic nature of its occurrence and the consequent low percentage content of the rock, render it unsuitable as a commercial proposition.
- (3) Throughout the massive serpentine, and confined thereto, occasional thin discontinuous veins of fibre are developed along tension cracks. In this area, these veins are usually a few inches in length and only of hair width. They cannot be considered as a commercial proposition.

CONCLUSIONS AND RECOMMENDATIONS

The writer's conclusions are as follows:—

- (1) The Asbestos Point serpentine is a thin sill emplaced concordant with the bedding planes of the enclosing slates.
- (2) It does not extend south more than about 60 chains from the point.
- (3) There is, therefore, no connection with the Spero River serpentine body.
- (4) There are three main varieties of serpentine present associated with original pyroxenite.
- (5) The fibre developed is cross-fibre chrysotile of high quality but somewhat short.
- (6) The main development of fibre is in massive serpentine along the serpentine-pyroxenite contacts. These zones are only a few inches in width.
- (7) It appears that those who have previously prospected and worked the area have found and worked out the few rich patches of fibre.
- (8) In its present state, the area offers little inducement for further exploration.

If, further exploration be decided upon, it is recommended that prospecting work be confined first to the tracing of bodies of pyroxenite. These are most likely to occur in the central and eastern portions of the belt. If bodies of pyroxenite be found, it is possible that reasonably good makes of asbestos will be found in the associated serpentine. It is not considered likely that good makes of fibre will be found in the foliated serpentine along the western margin.

Section VII—The Dundas - Rosebery Area

LOCATION AND ACCESS

This area lies midway between the old silver-lead districts of Zeehan and Dundas and the present zinc-lead district of Read-Rosebery. It includes the present tinfield of North Dundas-Renison Bell and the old tinfields of Dundas and Exe River. The first decade of this century saw all the above fields, with the exception of the the Read-Rosebery, in full production. Mines were in operation and prospectors were busy searching the countryside for more mineral wealth. In consequence, access within the area was good. The Emu Bay Railway had recently been opened connecting Zeehan with Burnie, 88 miles distant on the shores of Bass Strait and the Government Railway connected Zeehan with Strahan, 28 miles away on the Macquarie Harbour. These two railways were the sole links between the area and the outside world. Within the area, the Dundas Tram connected Dundas with Zeehan, the North-East Dundas Tram wound its tortuous way from Zeehan to Williamsford at the base of Mount Read, the Boulder Tram connected the tin leases of North Dundas with Renison Bell and the Exe River Tram connected the tin leases of the Exe River with the E.B.R. In addition, numerous tracks were open and kept in good repair viz: track from Zeehan to Renison Bell: from Confidence Saddle on the N.E. Dundas Tram to Renison Bell: from Boulder Tram to the Exe River Tram: and numerous tracks in the Dundas area. At the present time, the E.B.R. and the Zeehan-Strahan Railway are still in operation and access to the rest of the State has been improved by the construction of a road from Zeehan to Queenstown and thence to Hobart and Launceston. Access within the area is now difficult. Rosebery, Dundas and Renison Bell are connected to Zeehan by road but, of the numerous trams, only the Boulder Tram remains. The others have been pulled up and, while the formations remain, the growth of scrub makes progress along them difficult. All foot-tracks are similarly disused and overgrown. With the exception of one settler at Dundas, and one prospector living alongside the Renison Bell Road near the Argent Tunnel, the population is confined to Zeehan, Renison Bell, Rosebery and Williamsford.

TOPOGRAPHY

The area is one of strong relief. From the Argent Tunnel on the E.B.R., a range extends eastwards through Serpentine Hill and Melba Siding, turns south-east to Carbine Hill and then continues north-east towards Williamsford. This range forms the watershed separating the drainage basin of the Pieman in the north from that of the Little Henty in the south. From Carbine Hill (2400') a range runs west terminating near the junction of the N.E. Dundas Tram and the Renison Bell Road. The same range runs north from Carbine Hill to the Confidence Saddle (1506'), the whole being known as the Confidence Range. South of this range lies the Dundas Flat with Mount Razorback (1800') on the west, Carbine Hill on the north, Moore's Pimple (2800') on the north-east, and Mount Dundas (3920') on the east.

From Confidence Saddle, the range continues north and north-east from Pine Hill (1860'), Commonwealth Hill (2100'), Renison Bell Hill (1450'), Stebbins Hill (1120') and terminating in Dreadnought Hill (1220') near Renison Bell railway station. From Pine Hill, a low range runs north to within a mile of the Pieman River. This range is cut by the Ring River and Colebrook Creek. A little south-east of the junction of the Exe River Tram and the E.B.R. Colebrook Hill forms the prominent northern peak of the Colebrook Range which runs south for $2\frac{1}{2}$ miles almost as far as the deserted site of Ringville.

The largest stream in the area is the Ring River which heads just north of Williamsford and flows north-east to join the Pieman $1\frac{1}{2}$ miles north of Renison Bell. Its main tributaries are the Colebrook Rivulet heading in the Colebrook Range and Dalcoath Creek heading near Commonwealth Hill. The Exe River also heads in the Colebrook Range and roughly parallels the Ring to the east. The Argent River heads near Confidence Saddle, flows west to the Argent Tunnel and then north to the Pieman. A dam on the Argent provides water for Renison Associated Tin Mines.

The Little Henty heads in the range west of the Argent Tunnel and is joined by Melba Creek heading near Melba Siding, Nevada Creek heading south of the Confidence Range and flowing between that range and Mount Razorback, and the Dundas Rivulet which has numerous headwaters on the southern side of Carbine Hill.

In Geological Survey Bulletin No. 6, L. K. Ward discusses the topography of the region fully and concludes:—"The physiography of the region considered is that of one which has passed through a mature cycle of erosion. The nature of the surface before this cycle attained its maturity is not discernible, for there remain no traces of sediments which may have existed in the region in the long period between Early Palaeozoic and the Late Cainozoic times. The Late Tertiary alluvial terraces rest directly upon Cambro-Ordovician slates. The physiography resulting from this erosion cycle has been seriously modified by an uplift of at least 460 feet. The streams, rejuvenated by the latter movement, have cut down deep gorges into the hills and valleys of the older surface, and this cycle still continues in active operation."

Most of the ranges mentioned above are covered with a dense growth of virgin forest. Noticeable exceptions are Pine Hill and the hills south of Renison Bell. The lower lying areas between the ranges have, in general, been burnt off in days past but during the years since active operations ceased these cleared areas have become overgrown with the usual dense mixture of manuka, bauera, pear-tree, stunted gum, swordgrass, fern, &c., often rising to 15 to 20 feet. It is a melancholy fact that those areas which the prospector cleared and which were therefore most accessible are now the most difficult to penetrate. In fact, it is often easier to traverse the virgin forest than the once-clear areas nearby. Likewise tracks which were cut through the forest are now much overgrown and difficult to find let alone follow.

PREVIOUS LITERATURE

Prior to 1908, the only official literature dealing with this region were the reports of the Government Geologists, A. Montgomery and W. H. Twelvetrees. As these reports were concerned solely with the

metal mining properties, they need not be reviewed here. A summary may be found in Geological Survey Bulletin No. 6 (pp. 4-7). Since 1908, the following publications of the Geological Survey dealing with parts of the field have been made.

- (1) **L. K. Ward** (1909) "Tin Field of North Dundas" G.S. Bulletin No. 6.
- (2) **L. K. Ward** (1912) "The Exe River Tin Field" G.S. Bulletin No. 12.
- (3) **Hartwell Condor** (1918) "The Tin Field of North Dundas" G.S. Bulletin No. 26.
- (4) **A. M. Reid** (1921) "Osmiridium in Tasmania" G.S. Bulletin No. 32.
- (5) **A. M. Reid** (1925) "The Dundas Mineral Field" G.S. Bulletin No. 36.

In addition the following reports have been made:—

- (6) **Thomas and Henderson** (1945) "Some Fossils from the Dundas Series, Dundas". Proc. Royal Soc. Tas. 1944.
- (7) **C. L. Knight** (1946) "Report on Asbestos Deposits near Renison Bell, Tunnel, Zeehan District, Tasmania." Bureau of Mineral Resources Report No. 6/1946 compiled at the request of the Tasmanian Department of Mines.

- (1) **L. K. Ward** (1909) made a detailed study of the ultrabasic group of rocks dividing them into—
 - (a) Gabbro and norite; and
 - (b) Pyroxenite and peridotite.

Ward's conclusions were as follows:—"Reviewing the basic group as a whole, the characteristic features are the variability of the different types and the close interassociation of different types in the field. Variations are most commonly caused by differences in mineral composition, but are also marked by changes of texture while the mineral components remain the same. The intrusion was in almost all instances unaccompanied by any great shattering of the surrounding rock. Only one well-marked dyke was detected. The contact metamorphic effects produced were very slight, being restricted to a slight silicification of the slate. This can be seen at the southern entrance of the Argent Tunnel."

He records the occurrence of ultrabasics on Commonwealth Hill and in the valley of the Ring River, there being a difference in elevation of 1300' between the two areas and concludes:—"The several exposures of the basic rocks must necessarily be regarded as possessing continuity in depth; and the slate of the greater portion of the field is therefore resting upon an igneous foundation, the upper portions of which are exposed at the surface here and there."

In discussing the age of the ultrabasics, he says:—"There are no rocks representative of the succeeding periods in the tinfield until, ascending the geological column, we come to the Devonian. The great igneous complex of basic and acidic rocks is assigned to this period on evidence which has been fully stated by the writer in G.S. Bulletin No. 3, 'The Mount Farrell Mining Field.'"

This question of age will be discussed later in the present report.

(2) **L. K. Ward** (1912) describes briefly the belt of ultrabasic rocks flanking the west side of the Colebrook Range which he refers to as "a broad dyke of basic to ultrabasic composition and varied

lithological type". He concludes that the serpentine of the southern portion of the belt has been derived from peridotite and that of the northern portion from a saussurite-norite. The north-west branch is stated to consist of norite with bronzite as the ferro-magnesian constituent. There is no mention of asbestos in either of these two reports of Ward.

(3) **Hartwell Condor (1918)** resurveyed the area covered by Ward in the North Dundas and Exe River Districts. With regard to the ultrabasics, he adds little fresh information. Following Ward, he concludes that the difference of level at which the rocks occur ". . . almost forces the conclusion that a batholith of these basic rocks extends continuously beneath the surface, of which the projecting peaks and ridges only are at present exposed." He does, however, mention the occurrence of asbestos as follows:—"In addition to the picrolite, chrysotile or commercial asbestos seems invariably to accompany the serpentine, but so far its distribution seems to be too scanty to be of economic value. It is found near the track above the Argent Tunnel on the Serpentine Hill, just east of the Exe Tram Siding, and on the ridge that stands across the Exe River-Boulder Tram track. From the last place a specimen with good fibre, three-quarters of an inch long, was secured, but the quantity seems scattered and limited." This, as far as the writer can determine, is the first mention of asbestos in the Dundas-Rosebery district.

(4) **A. M. Reid (1921)** makes brief mention only of the ultrabasic types in connection with the scanty distribution of osmiridium in the Melba Flat, Star Creek, Ring River and Dundas districts. He mentions the belt west of the Colebrook Range as a "Dykerock (which) is a pale to dark-green serpentine of peridotite to norite types studded with minute octohedra of chromite" and states that, at Dundas, "Peridotite occurs in fairly large bodies". No mention is made of asbestos.

(5) **A. M. Reid (1925)** contributed little in the way of fresh knowledge of the ultrabasics. His description is as follows:—"The olivine-rich basic rock peridotite was transformed into serpentine shortly after its injection as dykes into the overlying rocks. At Dundas, the serpentine dyke is over half a mile in width, and is well exposed in the central area, but southwards the covering of sedimentary rocks is removed in parts only. It is part of a great intrusive body extending north and south many miles . . . Accompanying the serpentine as original accessory components of its parent peridotite are chromite, picotite, osmiridium and gold". In dealing with the Razorback tin mine situated on the serpentine-Dundas slate contact some three-quarters of a mile NNE of Dundas township he included a short description of a development of chrysotile as follows:—"On the eastern side of the section the chrysotile variety of serpentine is fairly abundant. Chrysotile comprises the bulk of what is locally termed asbestos, and usually occurs in the form of slip-fibre several inches in length. In dry condition it does not present many peculiarities, having a silky texture and yellowish-green colour; but in wet condition the lustre increases to a light-golden sheen, and in appearance and feel the mineral becomes like the fresh skin of a sheep . . . Chrysotile is notoriously erratic in occurrence. In small areas it appears to be prominent, but no works of any kind have been performed to ascertain its extent and value."

Reid includes an analysis of the chrysotile which is reproduced in column 4 of Table VII of this report.

(6) **Thomas and Henderson (1945)** Discussing the geology of the area east of the Razorback tin mine at Dundas, these authors state that:—"Although the ultrabasic rocks are here intrusive into the sedimentary rocks, the normal relationship is masked by faulting in this locality". This is noteworthy in that it is the only reference in the literature to a fault relationship between the ultrabasics and the enclosing rocks. The work of these authors is important in fixing the age of part of the Dundas Series as "Low in the Middle Cambrian".

(7) **C. L. Knight (1946)** This is the most recent work on asbestos deposits in Tasmania and deals solely with the 80 acre lease held by the Tasmanian Asbestos Pty. Ltd. on Serpentine Hill east of the Argent Tunnel. Knight classified the rock types occurring there as sediments, gabbro, serpentine and hypersthenite and discusses the relationship between them. He describes the fibre occurrence—"One is forced to the conclusion that the presence of hypersthenite was a pre-requisite to the formation of chrysotile and that mineralisation affected only fractured hypersthenite and the serpentine adjacent to it . . . there is no important exception to this generalisation . . . Results of underground development work and of surface mining confirm the surface mapping, i.e., that fibre is, in the main, restricted underground to definite sections which correspond with the surface occurrences." His section on 'Descriptions of Ore Bodies and Workings, Estimates of Grades, Estimates of Ore Reserves, and Possible Extensions of Ore' are the results of careful work and are reproduced in their entirety in the section of this report dealing with the Argent Tunnel Prospect.

DISTRIBUTION OF ULTRABASIC ROCKS

The accompanying plan (Plate VII) shows the surface distribution of ultrabasic rocks in this area. It is a sketch plan only and the boundaries drawn are to be taken as approximate only. This plan will be found to accord in general with those of Ward published in G.S. Bulletin Nos. 6 and 12 but to differ somewhat from that of Reid in G.S. Bulletin No. 32.

Three main belts occur:—

- (1) An arc commencing north of Mt. Razorback and swinging clockwise through the Dundas Flat to terminate in Stitchite Hill.
- (2) An arc commencing south of the Argent Tunnel, swinging anti-clockwise around Pine Hill and terminating just north of the Colebrook Rivulet. This arc is not continuous on the surface. Two small patches appear south of the tunnel and one patch west of Salmon's Hut. The patch on Commonwealth Hill may or may not belong to this arc.
- (3) A belt subparallel with the above arc flanking the Colebrook Range on the west.

(1) The Dundas arc has been exposed by denudation in the Dundas Flat. In the flat itself, the serpentine is mostly covered by a thin layer of alluvium and is only exposed in the creek beds. On the north-west extremity and to the south, the serpentine forms

prominent hills. Stichtite Hill, between Comet and Adelaide Creeks is a knife-edge ridge and is the type area for the chrome-talc mineral "stichtite". Except at the north-west end of the arc, the ultrabasic rock is everywhere a light-green massive serpentine with copious narrow veins of magnetite and shows no trace of the original rock type. At the Razorback Prospect, however, bronzitite kernels occur in the serpentine.

(2) The Pine Hill arc commences at the Argent Tunnel. Here there is a series of original ultrabasic types, serpentine and gabbro which are described later. At Pine Hill, the arc is cut by a quartz porphyry dyke (not shown on the plan). Gabbro is the chief rock present on both sides of the dyke and extends to the eastern limit of this portion of the arc north of Kapi Siding. Some quarter of a mile north of the dyke, the character of the ultrabasic changes to a deep green massive serpentine and this type continues to the termination of the arc north of the Colebrook Rivulet. The small patch of ultrabasic west of Salmon's Hut appears from beneath fluvio-glacial material and is composed of deep-green massive serpentine identical with that described above.

The two patches south of the Argent Tunnel are mainly of gabbro but are associated with a minor amount of deep-green magnetite-bearing serpentine.

(3) The Colebrook belt is composed mainly of dark-green massive serpentine. The north-western extension which cuts the Exe River Tram is mainly gabbroid with bronzite as the major constituent. In two places, at the Exe River Asbestos Prospect and at the small asbestos prospect near the end of the tram, kernels of bronzitite indicate the nature of the parent rock.

It must be noted here that A. M. Reid's map in Bulletin 32 showed a connection between the Pine Hill arc and the Dundas arc swinging south from the Melba Siding through the Confidence Range to near the Razorback Asbestos Prospect. This does not exist. The whole of the Confidence Range from Kapi Siding to a point half a mile east of the junction of the NE Dundas Tram and the Renison Bell road is capped with at least 100' of Dundas Breccia, a member of the Dundas Series. In fact it is the type area for this material.

RELATIONSHIP BETWEEN ULTRABASIC AND ENCLOSING ROCKS.

It may be stated at the outset that, as the author was concerned primarily with the asbestos deposits, his field work was confined to the ultrabasic belts. There has, however, been so much difference of opinion regarding the general geology of the West Coast, which differences are still far from being resolved, that it has been considered advisable to present here the author's observations regarding the relationship existing between the ultrabasics and the enclosing rocks.

In G.S. Bulletin 6 (p. 32) L. K. Ward states:—"The greater part of the North Dundas tinfield consists of slate, together with the coarser-grained sediments—sandstone, grit and conglomerate. The whole are to be considered as one series and to them the term 'Dundas Slates' has been applied, since the typical rock type is a slate." Thus was the term "Dundas Slate" born and it has been retained by officers of the Geological Survey either in this or its more modern form of "Dundas Series" (vide Thomas and Hender-

son 1944, p. 2) as a convenient names for the geological group represented. The age assigned by Ward was Cambro-Ordovician and the work of Thomas and Henderson has substantiated this in part. However, in the Handbook for Tasmania published for the A.N.Z.A.A.S. meeting in Hobart in January, 1949, Hills and Carey discard the use of the term. They have been able to subdivide the group of rocks lying between the basal complex (Davey Group) and the West Coast Range Conglomerate and to this they have given the name "Pieman Group" the age assigned being Upper Proterozoic to (?) Cambrian. Although not explicitly stated in the above paper, it appears that the Dundas Series covers part of the Lower Pieman Group, above the Smithton Dolomite. As the subdivision of the rocks below the West Coast Range Conglomerate is outside the scope of this report, the old term Dundas Series will be retained here for convenience.

It has been shown in the section on "Previous Literature," that the early workers of the Geological Survey viewed the ultrabasics showing on the surface as part of an extensive complex not far beneath—in fact Hartwell Condor spoke of a "batholith" of ultrabasics. A cursory inspection of the area will certainly give the above impression and A. M. Reid's incorrect plan showing a connection on the surface between Pine Hill and the Dundas arcs has helped to perpetuate this idea.

Contacts between the ultrabasics and the enclosing rocks are hard to find. One, however, appears in the railway cutting south of the Argent Tunnel, where the western extension of the Serpentine Hill mass crosses the line. A plan and section of this exposure are shown on Plate VIII. The dips and strikes of the enclosing rocks are somewhat disturbed but those shown give a general indication of the attitude of the rocks. The structural planes of the serpentine here are parallel to the contacts. A metamorphic aureole surrounds the ultrabasics but does not extend more than about 30 feet from the contacts. There is no widespread shattering of the enveloping rocks. These enveloping rocks are members of the Dundas Series and consist of fine sandstone and mudstone members usually pale-grey in colour but becoming purple as the tunnel portal is approached.

Along the tramway on the northern side of Serpentine Hill, the sandstones are seen again close to the serpentine. They strike E-W parallel to the contact and dip at high angles to the south, i.e., the dip would carry them under the serpentine. South of the hill, the serpentine margin is masked by a small stream. On the south side of this stream is an indeterminate igneous rock showing structural planes striking E-W and dipping south at moderate angles. This rock is much altered by impregnation with iron and towards the surface has assumed the character of a ferruginous clay. Some 20 chains south of the serpentine Melba Creek crosses the Renison Bell Road. Just north of the stream a ridge paralleling the stream crosses the road. This is composed of keratophyre tuff considerably altered by iron impregnation. This type may be followed as a discontinuous series of outcrops north along the road until the serpentine and gabbro are reached. The alteration increases as one proceeds north until near the serpentine the original character of the rock has been completely obscured by the conversion to red-brown clay. Although the contact is masked by alluvium along the south-eastern margin of the serpentine, the same occurrences of altered keratophyre tuff may be found between the eastern margin

of the Serpentine Hill mass and the western margin of the outcrop near the Melba Siding. At this point the actual contact zone is obscured.

Turning now to the Razorback Asbestos Prospect, it may be noted that the contact rocks of the serpentine on the southern margin are Dundas Slates again showing little disturbance in attitude but considerably altered by impregnation with iron. These rocks are identical with the Dundas "Red Rock" mentioned by Hartwell Conder (G.S. Bull. No. 26, pp. 23-24) as occurring along the Renison Bell spur. Similar red rock envelopes the serpentine at the Exe River asbestos prospect and separates this isolated patch of serpentine from the main mass west of Colebrook Hill. As far as can be determined, the same type of rock forms the marginal rock along the whole of the eastern flank of this belt. The evidence on this point is not, however, conclusive.

Nowhere in the above localities does a fault contact occur along the serpentine and that mapped as a fault by Thomas and Henderson is open to doubt. No fault appears on the Razorback Asbestos Prospect half a mile NW of the graptolite area and Thomas and Henderson's section B (p. 3) shows a normal relationship between the serpentine and the underlying dolomite.

At this point, it is convenient to refer to the previous sections of this report dealing with the Asbestos Point and the Spero River areas. It has been shown definitely that the ultrabasics of Asbestos Point are in the form of a sill 200 feet to 300 feet in thickness brought into their present inclined position by folding movements. At the Spero River, the evidence is not so conclusive, the contact zones being masked by alluvium. However, assuming that the author's theory that the banding of the ultrabasics is due to successive injections, there is strong presumptive evidence that this body also is a sill, or at least a concordant intrusion.

It appears to the present writer that the ultrabasics of the Dundas-Rosebery area are concordant intrusions perhaps showing transgressive relationships to the enclosing rocks locally and therefore not strictly sills but "sill-like". On this theory, it must follow that the three separate belts showing on the surface are indeed separate and have no subsurface connection, i.e., there is no great "batholith" of ultrabasics lying beneath the Dundas Series. This theory has an important bearing on the economic question of whether the asbestos zones will "live" at depth. This will be discussed later.

Finally, it must be stated that it would be foolish to deny that dykes of ultrabasic rock do not exist. Locally where the intruded rocks had planes of weakness, the intruding ultrabasic magma would undoubtedly stope its way along these planes forming dykes. The north-western extension of the Colebrook belt is probably of this type.

PETROLOGY OF THE ULTRABASIC ROCKS

Previous workers have remarked that the most notable feature of the ultrabasic rocks is their diversity. In many places, it is possible to find a variety of types within a few yards. It is convenient to divide the group for descriptive purposes as follows:—

- (1) Pyroxenites and related types.
- (2) Gabbro and Norite.
- (3) Serpentine.

(1) **Pyroxenites and related types.**—It may be noted at the outset that by far the greater proportion of the original ultrabasic rock of the field belongs to the pyroxenite group. Previous workers have spoken of the peridotites but a careful search by the present writer has failed to reveal any specimens showing olivine as a major constituent. In an area showing such a diversity of types, it would be foolish to assert that no peridotite at all occurs. If it does, however, it must be considered merely as a local variation of the main pyroxenite types. The weathered outcrops of pyroxenite are distinctive. They assume a rusty-brown colour and, especially when associated with serpentine, the boundaries are clearcut and visible for several chains. This feature is especially well shown on Serpentine Hill. The pyroxenite, being hard, dense, and with few planes of weakness, is much more resistant to erosion than the serpentine and its characteristic field occurrence is in the form of cores or ridges standing out above the enveloping serpentine. Three main varieties of pyroxenite occur.

(a) The most interesting from an economic point of view, is the bronzitite because of its genetic association with the asbestos fibre. The rock is similar to that occurring at Asbestos Point, both in petrological characteristics and in field occurrence. The "boulders" or kernels are, however, grouped in definite areas and at times almost assume the form of continuous ridges. This rock was named "hypersthene" by Knight (1946). An analysis of the rock is quoted in column 1 of Table VII. The Fe_2O_3 content of the rock brings it into the bronzite division of the metasilicates and the rock is, accordingly, a bronzitite. The following points may be noted:—

- (i) The small percentage of alumina indicates a minor amount of aluminous pyroxene.
- (ii) The low percentage of CaO indicates that only a trace of the diopside molecule is present.
- (iii) The ignition loss shows that the rock has been partly hydrated indicating a passage to serpentine.
- (iv) The general similarity of the rock to the pyroxenite at Beaconsfield (vide Columns 1 and 2 of Table VI).

(b) The most striking rock of the field is the coarse-grained pyroxenite typically developed on the low hill west of the E.B.R. south of the Argent Tunnel. It also shows in patches along the eastern side of the railway. It is composed of large crystals of pyroxene ranging up to $1\frac{1}{2}$ inches in length, of random orientation and packed closely together. No analysis of this rock was made, but the crystals appear to be almost entirely of bronzite with perhaps a minor amount of diopside. Most crystals show incipient conversion to serpentine along parallel cleavage cracks. This has led to the characteristic appearance of the weathered outcrops which show slightly rounded crystals standing out in relief above the general rock surface as much as half an inch. Crystals lying with the a axis normal to the weathered surface have been relatively unaffected by weathering of the serpentine as the cleavage cracks are subparallel to the surface. On the other hand, those crystals with the c axis (and thus the cleavage cracks) normal to the weathered surface have been more prone to suffer from the weathering agencies and have thus been etched away. This process has no doubt affected the bronzitite described above but in the present case its effects are more noticeable owing to the unusually large size of the crystals.

(c) The remaining type present is the banded ultrabasic rock typically developed on the ridge south of the "Mill Cut" on the Argent Tunnel Asbestos Prospect and at the Razorback Prospect. A similar type occurs on Riley's Knob at the southern end of the Wilson River osmiridium field and at the Spero River. The type occurring on this field, while showing the distinctive etching out of more easily weathered bands, giving a pseudo-bedding appearance, is much more altered than the Spero River material and it is more difficult to determine the original rock types. There is, indeed, little difference to be noted in the hand specimen between successive layers when a fresh surface is exposed. By analogy with the Spero River material it is probable, however, that the bands represent alternations of bronzitite and lherzolite but that the olivine of the lherzolite has now been completely altered to serpentine. Occasionally bands of coarsely-crystalline bronzitite similar to that described above occur. These bands are very obvious as they are marked by bunches of crystals standing out in relief.

(2) **Gabbro and Norite.**—Whilst not strictly ultrabasic rocks, these are included here for the sake of convenience. They are typically developed on the south of Serpentine Hill east of the Renison Bell road, south and east of Pine Hill, in two patches west of the road south of the tunnel and in the ridge of ultrabasics crossing the Exe Tram formation. L. K. Ward describes a patch occurring on the summit of Commonwealth Hill but this was not inspected during the present survey. As the asbestos occurrences are confined to the serpentine areas, no detailed work was done on the gabbros. For the sake of completeness, however, the following quotations from Ward's Bulletins are included. In Bulletin 6, page 19 he says:—"Microscopically, the rock does not prove as fresh as it appears. The texture is holocrystalline and coarse, and there is a marked poikilitic growth of diallage about the feldspars. The latter are all clouded by kaolin, and the extinction angles are not recognisable. There are both orthorhombic and monoclinic pyroxenes present. Of these, the earlier crystals are orthorhombic, and are either partially or wholly surrounded by the larger areas of diallage. The orthorhombic forms are much altered, and for the most part are represented by areas of serpentine and uralitic hornblende. This is the case even when there is a complete envelope of unaltered diallage surrounding the crystals. The serpentine is faintly tinged green, and the secondary amphibole pale-yellow to light-bluish green. Brown biotite is also present. Of the iron ores, ilmenite in patches which show the characteristic partial decomposition to leucoxene, is abundant." In regard to the rock seen crossing the Exe Tram he says (Bulletin 12, page 8):—" . . . consists of a rock which has in its original condition possessed a considerable feldspathic content. The ferromagnesian constituent appears to the naked eye to be bronzite and the feldspar seems to have undergone alteration to saussurite. Hence it appears advisable to call the rock a saussurite-norite . . . The surface of this type of rock is greenish in colour, and the medium to coarse-grained habit can usually be detected on weathered surfaces."

There is no clearcut division between the gabbros and the remaining types in the field. On the southern slopes of Serpentine Hill the serpentine merges gradually without special feature into a coarse gabbo. In fact it is impossible to determine on the weathered surface which is gabbro and which serpentine. In all cases the ultra-

basic fringing the gabbro is found to be serpentine. In no case was the association of pyroxenite and gabbro noted.

No gabbro was found in the Dundas arc south of the Confidence Range.

(3) **The Serpentine.**—There is more variation among the serpentines than among the pyroxenites. The chief type from the economic point of view is associated with the bronzite kernels. It is a pale waxy green rock much cut about by movement planes and thus possessing a blocky appearance. On weathered surfaces it is pale-grey and thus can easily be distinguished from the associated pyroxenite. The movement planes generally show polished slickensided surfaces usually somewhat irregular and often with a veneer of picrolite. This is the host rock of the asbestos veins. An analysis is shown in column 2 of Table VII.

The most widespread type is a dark-green massive serpentine, much more blocky than the above and occurring some distance from the pyroxenite kernels. The weathered surface is light-grey and indistinguishable from the fibre-bearing type. Usually no asbestos is found in this type but picrolite frequently accompanies it along movement planes. Very occasionally, the picrolite grades to slip-fibre chrysotile but the quality of the fibre is poor and the quantity limited.

Typical development of this type is seen in the second railway cutting south of the Argent Tunnel, and the greater part of the belt west of the Colebrook Range, while the serpentine of the Dundas arc is almost entirely of this type.

This type of serpentine is almost always associated with veins of magnetite assuming the slip-fibrous habit. The most striking development is to be found on the west side of the E.B.R. some 30 chains south of the tunnel mouth. On a bare ridge, abundant veins of magnetite occur up to 1½ inches thick criss-crossing the serpentine in all directions. The magnetite is remarkable for its strong polarity—a rare feature. It is therefore a true lodestone. There is considerable variation in the fibrous nature. All gradations are found from massive magnetite showing faint striation parallel to the vein walls to types from which individual fibres may be separated. A further interesting feature is the complicated nature of some of the veins. The magnetite seems to have been squeezed in a plastic form into highly irregular cracks. The fibres, however, continue faithfully to parallel the vein walls. At the Razorback Prospect some nice specimens of normal cubic magnetite were found. Crystals up to ¼" in diameter show dominant octahedral faces with the edges truncated by dodecahedra. On the west flank of Colebrook Hill several specimens were found showing the migration of individual particles of magnetite through the serpentine towards a vein.

At stichtite Hill at the southern end of the Dundas arc, the serpentine is a dark-green massive type showing layers of lighter green. These two types of layer merge one into the other. They are not affected by differential weathering and the banded nature of the rock cannot be detected on weathered surfaces.

Another familiar type of serpentine is the crushed and contorted type noted in other areas. This tends to have a bluish tinge which is distinctive and the crushed lamellae separate readily owing to the closely-spaced movement planes. This type does not carry asbestos.

The final type to be described is peculiar to this field and only appears rarely. It is a rather massive type with fewer movement planes than other types. Its characteristic feature is an alteration of bands 1" to 3" in width. Differential weathering has caused alternate bands to stand out in relief. This type is undoubtedly the serpentinous modification of the banded pyroxenite mentioned above. This type sometimes carries asbestos fibre veins which parallel the banding.

THE DEVELOPMENT OF FIBRE.

The main asbestos veins occur in zones in light-green massive serpentine associated with bronzitite kernels. The best exposure of the type of occurrence is to be found in the "Mill Cut" on the workings near the Argent Tunnel. Here, a series of bronzitite kernels ranging from a few inches to many feet in diameter occur as a parallel series trending N-S. Around each kernel is a zone of fibre-bearing serpentine, the width of the zones varying directly as the diameter of the kernels. In the exposed portion, the width of the asbestos zone averages two feet and over this width parallel veins of cross-fibre chrysotile make up 22 per cent of the total rock volume. The line of demarcation between the serpentine and the bronzitite is reasonably sharp and, in general, the asbestos veins do not occur within the bronzitite. This is the chief type of asbestos occurrence on the field and the only one likely to prove of economic importance. An analysis of chrysotile from this area is quoted in column 3 of Table VII. It will be seen, on comparison with column 11 of Table VI, that the material has almost the theoretical composition of true chrysotile, the only impurities being 1.15 per cent of Al_2O_3 and 1.43 per cent of Fe_2O_3 . It is noticeably lower in iron than the Beaconsfield material. In the vein, it is much the same colour as the enclosing serpentine on a fresh surface, has a silky sheen, and teases to pure white fibres.

The banded serpentine referred to above sometimes carries good chrysotile veins paralleling the banding. This fibre is usually of good length, specimens up to $\frac{3}{4}$ " in length having been seen, and the veins are persistent. The percentage of fibre in the rock is usually above 2 per cent and, if reasonably large areas occur they would be economically workable.

In the neighbourhood of the bronzitite kernels, isolated veins bearing no apparent relationship to the main occurrence can often be seen. These veins are irregular in outline, and the fibre consequently of variable length, but the veins usually persist for many yards. The fibre they contain is equal in quality to the chief type but, the veins being sporadic, the percentage of fibre available is low.

Almost anywhere in the true serpentine, it is possible to find veins of hairwidth, mostly less than one inch in length. In Prospect six east of Pine Hill numerous veins of this type occur, but the occurrence is of academic interest only.

Throughout the serpentine areas there is a sporadic distribution of slip-fibre chrysotile mostly as a gradation from picrolite. Sometimes veins of pure chrysotile unassociated with picrolite and up to half an inch in width occur. The quality of this type of fibre as regards length and tensile strength is good but the quantity is limited and the percentage of fibre available well below 1 per cent.

THE ASBESTOS PROSPECTS

Asbestos has been found at seven localities in the area. Only the first three are likely to prove of economic importance.

(1) **The Argent Tunnel Prospect**—This is the area once held by Tasmanian Asbestos Pty. Ltd. and has been described in detail by C. L. Knight. The asbestos zones are practically confined to the lease but not all the zones have been properly prospected. As far as he went, Knight was accurate in his work. His investigation was carried out while work was actually in progress and he had access to information unavailable to the present writer. For this reason and also since his report is not generally available, it has been considered advisable to reproduce the essential part of it here. Additional information obtained by the present writer will follow and the the whole of the available information summarized.

Descriptions of Orebodies and Workings—Surface mapping has shown that a high percentage of visible fibre is contained within nine separate areas, outside of which only occasional minor patches of fibre have been found. The company has carried out mining and developmental work on the five most promising areas. The other areas are either too small or obviously too low grade to be worth attention. General descriptions of the five principal orebodies are given below.

Mill Ore Body—This outcropped on the crest of the ridge on which the mill is built. It has a proved length of 140 feet and width of 90 feet, strikes at 65° and appears to dip steeply west. There is a probable narrow extension to the south for 100 feet. The orebody is divided into two sections by 25 feet of barren serpentine. All ore above R.L. 853, the level of the cracker in the mill, has been mined in the opencut and the maximum height of the face above this level is 16 feet. To the south and north barren serpentine cuts right across the line of strike. There is a well defined elongation of fibre areas, kernels and fractures on a bearing of 65°.

The No. 4 Cut Orebody has been mined in No. 4 opencut. It consists of the usual admixture of serpentine, kernels and fibre-bearing serpentine. In the face, which was 39 feet high at the time of inspection, hypersthenite and serpentine were exposed to a height of 25 feet and the top 14 feet of the face was occupied by barren serpentine. An adit driven into the hill for 70 feet and short crosscuts put out on either side passed through hypersthenite and serpentine all the way. To the east of these workings there are outcrops of hypersthenite and serpentine with a few isolated patches of fibre showing. Average grade of this eastern area on the surface appears to be very low. The presence of fibre and hypersthenite throughout the length of the adit indicates a general flat dip of the hypersthenite body and of the ore.

No. 5 Cut Orebody—The orebody has been mined in No. 3 cut, No. 5 cut, and a small cut below tram level. It is 300 feet long and up to 55 feet wide at the outcrop. Developmental work consists of an adit 135 feet long with 120 feet of crosscutting and rising. An adit has also been driven from No. 3 cut for 215 feet and a short crosscut and drive put out. In No. 5 cut there is the usual mixture of hypersthenite, serpentine and fibre-bearing serpentine. Ore showing in the face at the time of inspection was low in grade and the thickness of barren serpentine overlying the ore was consider-

able. The east wall of the cut is serpentine and appears to constitute the eastern wall of the orebody. In the No. 3 cut, the fibre could be seen in the orebody to a height of 16 feet above the floor of the cut. Above this point the face consisted chiefly of hypersthénite with only trace of fibre. The distribution of hypersthénite and fibre in the underground workings indicates that the hypersthénite mass and the orebody dip fairly flatly into the hill.

No. 1 Cut Orebody appears to have small dimensions. Fibre-bearing rock extends on the surface for a short distance only to the east and west of the cut and an adit driven south-west from the cut failed to locate ore. Very large kernels of hypersthénite are prominent.

North-East Orebody—The orebody has been opencut at tram level and at a higher level, and a total of 815 feet of prospecting and developmental work carried out. Distribution of ore in this area is so erratic that the grouping of the fibre occurrences into one orebody is a somewhat artificial one. It may be that there are two ore-bearing sections, but for the purposes of opencut mining they must be regarded as one. The limits of the orebody have been taken as the limits of the fibre on the surface. Within these limits, there are large areas with no fibre. Outside of these limits ore has been cut in the No. 2 Bottom, Upper and Top adits, which may belong to one band up to 25 feet wide trending south-west parallel with the pyroxénite contact on the surface.

Estimates of Grades—Throughout this report grade of ore is expressed as "effective grade", i.e., the percentage of fibre recoverable by the methods of mining and milling practised during 1945.

Mining practice consists of breaking a face in opencuts or underground, hand-sorting to 5 or 6 per cent grade for delivery to the bins, and dumping rejects at the mine. Between one quarter and one half of this rejected material was hard hypersthénite which was practically devoid of fibre. The remainder was serpentine which carried some 5D fibre possibly of the order of 1 per cent or more. The only way of determining an approximate average grade of the rejects would be to crush bulk parcels. In the estimates of effective grade given below it has been assumed that rejected material was barren because it does not reach the mill.

The manager has carried out tests on mill efficiency, and estimates that for every five tons of fibre of grade 5D recovered, one ton of similar grade was lost and about three tons of fibre of grade 7D and lower grades was also lost. This implies an actual mill efficiency of approximately 55 per cent. It is questionable whether it would be profitable to instal and operate additional plant to improve the recovery of 5D fibre. The capital outlay and operating costs of plant which would be necessary to recover the finer fibre lost, the efficiency of the plant if installed, and the market, if any, for the fine fibre are all unknown factors. In the absence of information on these points the economic possibilities are assessed in terms of actual recoveries effected.

The distribution of fibre through the various orebodies is so irregular that the only effective way of sampling is to mill large parcels. Fortunately excellent records of mill crushings have been kept by the manager and these were made available.

About 6141 tons of ore were put through the mill to the end of October, 1945, for a recovery of 360 tons of bagged fibre. This is equivalent to an average effective head value of 5.8 per cent for ore delivered to the mill. For the first 2200 tons milled the recovery was 4.7 per cent but later rose to slightly above 6 per cent.

Millcut Orebody 4211 tons were mined for 1762 tons of milling ore of assumed grade 4.7 per cent. Later 875 tons were mined selectively for 634 tons of milling ore of assumed grade 6.3 per cent. Effective grade was 2.4 per cent.

After the latter operation, the company regarded as waste rock all material left standing above the level of the floor of the open-cut. This would have to be mined as part of the orebody if an open-cut were developed at a lower level. The quantity of waste rock left standing is estimated as 2000 tons. Average effective grade of the orebody over an area of 140 feet by 90 feet at this level is therefore 1.7 per cent.

No. 5 Cut Orebody

No. 5 cut—1854.5 tons were mined for 867.5 tons of ore of assumed grade 6.3 per cent, i.e., an effective grade of 2.9 per cent.

No. 3 cut—3002 tons were mined for 357 tons of ore of assumed grade 5.8 per cent, i.e., an effective grade of 0.7 per cent.

No. 5 Adit workings—835 tons were mined for 373 tons of milling ore of assumed grade 6.3 per cent, i.e., an effective grade of 2.8 per cent. Average grade in the adit was 3.5 per cent and in the cross-cuts and rise 0.9 per cent.

No. 3 Adit workings to limit of ore—160 tons mined for 40 tons of milling ore of assumed grade 6.3 per cent, i.e., an effective grade of 1.6 per cent.

An assessment of the average grade of the orebody as a whole is difficult. A figure of 2.8 per cent may be taken as an upper limit. If due weight is placed on the low grade of ore in No. 3 cut, and in the crosscuts and rise from the adit, the average grade is probably of the order of 1.8 per cent.

No. 4 Cut Orebody

No. 4 Cut—1273.5 tons were mined for 543 tons of milling ore of assumed grade 6.3 per cent, i.e., an effective grade of 2.7 per cent.

No. 4 Adit workings—average effective grade approximated 1.5 per cent.

To the east of the adit the orebody has not been opened up.

No. 1 Cut Orebody

No. 1 Cut—2450.5 tons were mined for 140.5 tons of milling ore of assumed grade 5.8 per cent, i.e., an effective grade of 0.3 per cent.

No. 1 Adit—No ore.

Large knobs of hypersthene were left standing in the open-cut so that the overall effective grade would be lower than the figure given above.

North-East Orebody

Bottom Cut—2770 tons were mined for 919.5 tons of milling ore of assumed grade 6.3 per cent, i.e., an effective grade of 2.1 per cent.

Top Cut—355 tons were mined for 45 tons of milling ore of assumed grade 6.3 per cent, i.e., an effective grade of 0.8 per cent.

The underground workings are not well placed for determination of the grade of open-cut ore. The No. 2 first adit workings averaged 1.1 per cent. From the portal of No. 2 bottom adit, 3 per cent ore extended south for 20 feet. How far this ore extends west is not known, but it continues east of the adit for only a few feet. In the No. 2 upper adit workings a shoot of ore of milling grade 20 feet long and 10 feet wide was intersected in the adit and driven on east and west. The ore was later stoped out and effective grade was probably about 5 per cent. In the No. 2 top adit, apart from the initial cut, no ore was intersected for a distance of 30 feet south.

It is highly improbable that the grade of the block as a whole will exceed the average grade of the two open-cuts, i.e., 1.9 per cent. Judging from the absence of fibre over large areas of the surface here, the grade will probably be very considerably lower than the above figure, probably of the order of 1 per cent.

Outside the limits chosen for the North-East Orebody a band of ore of effective grade 1.5 per cent and about 25 feet wide was cut in the No. 2 bottom adit. It is separated from ore to the north by barren serpentine. If the ore cut in the No. 2 upper and top adits is part of the same band, its disposition would be vertical and the grade approximately 1.5 per cent.

Estimates of Ore Reserves.

Mill Cut Orebody—All ore has been removed from above mill level and there are no partly developed reserves.

No. 5 Cut Orebody—Partly developed reserves above tram level are estimated at 40,000 tons of possible effective grade 1.8 per cent.

No. 4 Cut Orebody—There are no developed reserves.

No. 1 Cut Orebody—Developed reserves are very small.

North-East Orebody—The block of ground within the limits shown comprises 35,000 tons to tram level. Average grade of this block will not exceed 1.9 per cent and is possibly of the order of 1 per cent.

Possible Extensions of Ore and Developmental Programme—Geological mapping has shown that no orebodies will be located away from the hypersthene bodies. Furthermore, it is considered that all outcropping bodies of possible commercial value have already been located. This does not preclude the possibility of locating orebodies which do not outcrop. Such almost certainly exist but, as there is no reason to expect the grade to be higher than those already discovered, they must be disregarded as potential sources of fibre.

Possibilities of adding to reserves can be looked for only in extensions of the already known orebodies. As the latter have very limited surface dimensions, extensions in depth can also be expected to be limited.

The **Mill Cut Orebody** may extend to a depth of 50 to 100 feet below bench level. Any ore mined from the orebody would have to be hoisted. If prospecting is undertaken, an adit should be driven at R.L. 800 from co-ordinate position 160E/1100N on a bearing of 110°. If ore were intersected, drives could be put out along the middle of the orebody, short crosscuts developed from these and a rise put up to the surface through the body.

The **No. 4 Cut Orebody**—There is a possibility of developing ore to the south of No. 4 adit mainly below tram level although surface indications are anything but encouraging.

To prospect the orebody, an adit should be driven due east at a point about 100 feet south of No. 4 adit and located near the bottom of the fibre-bearing area.

The **No. 5 Cut Orebody** appears to dip flatly into the hill. Developmental work such as the extension of both eastern crosscuts from the No. 5 adit to the limits of the ore, and rising from the crosscuts would define ore limits and the grade of the ore above tram level more definitely. Prospecting below tram level could best be accomplished by driving an adit crosscut 50 feet vertically below the tram line on a bearing of 120° from co-ordinate position approximately 640E/1450N.

North-East Orebody—A 70 foot adit driven from tram level midway between No. 2 bottom adit and No. 2 first level is necessary to enable a more reliable assessment of grade of opencutting ore.

Ore goes underfoot at tram level in the opencut areas. An adit crosscut driven directly below the opencut at a level 50 feet lower would prospect the continuation of the ore in depth. Any ore located would be very expensive to mine as hill slopes are steep and the overburden-ore ratio in an opencut would probably be very high.

TABLE VII

	(1)	(2)	(3)	(4)
Ignition Loss	7.84	13.51	13.49	16.96
SiO ₂	46.95	41.53	42.07	34.99
Al ₂ O ₃	2.69	1.46	1.15	4.08
Fe ₂ O ₃	6.63	2.15	1.43	4.95
FeO	—	—	Nil	9.00
MnO	0.19	Trace	Trace	0.96
CaO	0.97	Nil	Nil	—
MgO	34.65	41.72	42.23	29.36
Cr ₂ O ₃	0.70	0.48	Trace	—
TiO ₂	Nil	Nil	Nil	—
P ₂ O ₅	Nil	Nil	Nil	—
Total	100.62	100.55	100.37	100.30

Column (1)—Pyroxenite (bronzitite) from kernel in Mill Cut in Tasmanian Asbestos Pty. Ltd. workings at the Argent Tunnel. This sample is typical of the bronzitite which is associated with the fibre-bearing serpentine.

Column (2)—Pale-green waxy serpentine from the Mill Cut. Sample taken approximately six inches away from the bronzitite kernel which is the subject of the analysis in column (1).

Column (3)—Sample of pale-green silky chrysotile fibre enclosed in the serpentine which is the subject of the analysis in column (2). This sample is typical of the chrysotile occurring as cross-fibre in the Serpentine Hill area. Analyses in columns (1), (2) and (3) made by Mines Department, Laboratory, Launceston, February, 1949.

Column (4)—Analysis quoted from G.S. Bull. No. 36 (p. 51) being of slip-fibre from Razorback Tin Mine, Dundas. Original analysis includes 6.3 per cent hygroscopic moisture. Analysis has been recalculated by B.L.T. to a moisture-free basis.

With regard to No. 1 Cut, No. 4 Cut, No. 5 Cut and the North-East Orebodies, Knight's descriptions and estimates of quantities appear to be accurate.

From the end of the tramway which terminates at the North-East Cut, the steep slopes of the hill continues south-east till the eastern boundary of the lease is met. This boundary runs through a low saddle which marks the contact between the ultrabasics and the enclosing rocks. The crest of the ridge between the tram and this boundary is composed of bronzitite kernels forming an almost continuous series. At the base of this series, roughly on the same level as the tramway, a series of fibre-bearing zones associated with the kernels occurs. The region is heavily timbered and it is difficult to get an accurate picture of the zone without prospecting. It appears, however, to be similar to the Mill Cut area, the zones around individual kernels forming an almost continuous belt averaging 10 feet in width and from 220 to 250 feet in length. The percentage of fibre over this belt appears on inspection to be not less than 5 per cent. The fibre zones occur some 50 feet below the crest of the ridge and this amount of overburden, combined with the steep face, would make opencutting a difficult and expensive operation. Such a zone, however, would constitute an economical underground mining proposition. It is not clear from the surface outcrops just how this zone runs underground. The determination of this is a matter for underground prospecting. If the zone were found to dip steeply into the hill, which appears to be the most likely possibility, stoping methods could be used. A flat dip would require the normal methods of crosscutting and pillaring.

At the Mill Cut, it appears to the writer a strong possibility amounting almost to a certainty that the fibre-bearing zone continues at depth parallel to the slope of the hill down to the railway line and probably at no great distance beneath this sloping surface. As Knight pointed out, ore mined here would have to be hoisted but this must not be considered a serious disadvantage. In many mines, hoisting of the ore is part of the normal working methods. The lower extension of the Mill Cut is well worth investigating, either by driving as suggested by Knight or by diamond drilling on the hill slopes, the holes being normal to the hill surface. One scout bore 50 feet below the floor of the cut could, if successful, be followed by others placed on a square grid of, say, one chain side.

These holes would not exceed 100 feet in depth to prove ore. If ore were found as a stockwork, the area could quite well be mined by open-cut—if it were found to be in the form of one or more zones several feet in thickness (the more likely possibility) stoping methods would apply. Indications of fibre have been found west of the road between 100 and 200 feet north of the Mill Cut. It is not clear whether these constitute a northern extension of the Mill Cut orebody or are isolated patches as no direct connection was found on the surface. If, however, the Mill Cut orebody is proved by drilling to continue at depth, it would be advisable to trace it to its northern limit before deciding upon a plan of working.

The ridge extending south and south-west from the Mill Cut is composed of banded pyroxenite along the crest grading down to bronzitite kernels on each side. The eastern side is obscured by thick scrub but the western is fairly clear. At the southern end of the ridge, there are some excellent patches of fibre around the bronzitite kernels and similar patches appear along the western flank. It could not be determined, however, whether a continuous zone exists. It appears likely that this is the case and some preliminary prospecting in this area is to be recommended. This should take the form of clearing the outcrops. If a more or less continuous zone were proved, its extension at depth could be investigated by diamond drilling in a similar manner to that outlined for the Mill Cut. There appears to be little fibre along the eastern margin apart from two small patches just south of the mill site.

The most promising area in the field does not appear to have been prospected. From the east side of the road at a point $2\frac{1}{2}$ chains north of the southern lease boundary, a ridge of bronzitite kernels trends north-east towards the crest of Serpentine Hill. Along the north-west margin of this ridge, fibre-bearing serpentine has been traced for a distance of 400 feet. A small northern extension continues for a further 70 feet but is unconnected on the surface with the main zone. This zone is, as usual, irregular in width but averages between 4 and 6 feet. The content of fibre over this width is not less than 5 per cent and probably of the order of 7 to 8 per cent. No clear indication can be obtained on the surface of the dip but it probably dips under the bronzitite at a moderate angle. The eastern margin of the ridge, between the bronzitite and the gabbro is, unfortunately obscured by soil but there is a strong possibility that a further zone of fibre occurs on this eastern side of the ridge also. The area is well worth prospecting by driving along the apparent strike of the zone or by vertical diamond drilling through the bronzitite ridge. Clearing of the soil on the eastern margin is also to be recommended. This area of comparatively low relief is well suited to development by either open-cut or underground mining methods. The southern termination of the ridge is at road level and transportation of ore would present no difficulties.

Three possibilities present themselves:—

- (1) If one zone occurs dipping steeply east or two separated by a considerable thickness of barren rock, stoping methods would be indicated.
- (2) If two zones occur close together and dipping steeply, open-cutting along the strike would be preferable down to road level followed later by stoping.

- (3) If one zone occurs dipping flatly east, crosscutting and pillaring would have to be resorted to.

There is a small patch of fibre appearing at the southern end of the bronzitite mass near the south-western lease peg. This appears to be an isolated patch and not part of a continuous zone. The remaining patches marked on the map appear to be of similar type but may be worth investigating if production of fibre be undertaken.

As regards the average grade of fibre to be obtained from the areas just described, the length of fibre showing is similar to that showing in the areas which have previously been worked. It is reasonable to assume, therefore, that the grades of fibre which could be produced will not vary greatly from those actually produced during 1945. The manager's estimate of grades quoted above indicates that, with a mill efficiency of 100 per cent, two thirds of the finished fibre would be of grade 5D and one third of grade 7D or lower.

In considering the economics of the industry, the most remarkable feature of the Tasmanian Asbestos Pty. working is contained in the statement just referred to—"for every five tons of fibre of Grade 5D recovered, one ton of similar grade was lost and three tons of fibre of Grade 7D or lower was also lost". From the table of prices given on pages 17-18 of this report, it will be seen that the values of the above grades stated in round figures in Australian currency are:—

5D — £25 per ton.

7D — £15 per ton.

In these workings, therefore, for every £125 worth of fibre recovered, £70 worth was lost, i.e., only 64 per cent of the potential value of the fibre was realized or, in other words, if the mill efficiency had been raised to 100 per cent, the receipts would have increased by 56 per cent! The proportionate increase in operating costs would have been much lower—mining costs would have remained the same, the only increase being in milling costs. This increase, apart from capital cost, would have been of the order of 5 to 10 per cent. This appears to the writer to be the prime cause for the abandonment of the venture in 1946.

It is not, of course, possible to attain 100 per cent efficiency in any mill and, unfortunately figures on mill efficiency in established mills are unavailable. However, from published descriptions of Canadian milling practice describing the concentration of fine fibre in float chambers and by electrical precipitation, it appears that an efficiency close to 100 per cent is obtained. There is no reason why a plant of such efficiency cannot be erected in this State if the size of the deposits is deemed to warrant the establishment of a production plant. Indeed, if a plant were to be established, a high degree of efficiency must be considered essential.

As regards the utilization of the fines, no problem should present itself. These find a ready sale in Canada and overseas markets as constituents of asbestos plasters, pipe lagging and as fillers. Surely a market for such material could be created in this country if it does not already exist.

Summarizing, then, it may be stated that:—

- (1) The prospects for a revival of the asbestos production at the Argent Tunnel Prospect appear to be reasonably good.

- (2) All the information which can be obtained from the outcrops in their present state has been presented herewith.
- (3) The next step is for planned prospecting to be undertaken along the lines indicated by Knight and as detailed above.
- (4) The estimation of ore reserves. It is always difficult to give a figure for this without actual prospecting but the present writer believes the amount of fibre present to be of the order of 10,000 tons.
- (5) The final step will be the establishment of a mill of suitable size with a production efficiency of not less than 95 per cent.

The Razorback Prospect

The ultrabasics are exposed here in a saddle on the north-eastern ridge of Mount Razorback. The saddle is occupied by a sharp ridge of bronzitite. At a point six miles from Zeehan on the Renison Bell road Nevada Creek is met. Opposite a road metal quarry on the left of the road just before meeting the creek a timber track branches from the road and runs up the valley of the creek between Confidence Range and Mount Razorback. This is the access to the prospect which will be found three quarters of a mile from the road. The formation of the track, which continues past the Razorback Tin Mine to Dundas, is good but is now much overgrown. Half a mile from the road a track leads off the main track north along a branch of Nevada Creek to the now abandoned Grand Prize Tin Mine.

The ultrabasics appear from below thickly bedded Dundas "Red Rock" much impregnated with iron and weathering on the surface to a red-brown clay. The eastern slope away from the pyroxenite ridge is very precipitous for about 30 feet and then falls away to the stream and track in the valley below at about 25°. This slope and the valley floor are covered with a dense second growth of scrub, but serpentine appears here and there and in the stream bed. The ultrabasics continue to appear for a distance of 300 feet west of the crest of the ridge disappearing then below the sedimentaries.

The pyroxenites present are of two types. The crest of the ridge is occupied by banded pyroxenite exactly similar to that noted at the Argent Tunnel Prospect. This gives way at depth to bronzitite kernels which fringe the main mass and merge into the surrounding serpentine. The small mass of pyroxenite on the north-east is composed entirely of bronzitite. These pyroxenites maintain the normal rusty-brown weathered surface.

The serpentine is generally a pale to light-green waxy type, usually massive. On the eastern margin a rather bluish type is general. Magnetite is generally distributed throughout the serpentine along the line of bluffs south of the tunnel mouth but elsewhere it is only of sporadic occurrence. A small patch of limonite forming a veneer occurs on the north-western flank of the main pyroxenite mass.

The fibre occurrence follows the usual form. In the small area between the two pyroxenite masses the best development is seen. The serpentine here is a banded type and numerous strong veins of fibre parallel the bands making up 10 per cent of the rock. The system strikes at 15° and dips west at 35°. The average length of fibre is $\frac{3}{8}$ " and some veins occur up to $\frac{1}{2}$ " wide. The veins are mostly simple and any flaws are confined to a narrow zone on one

side of the vein. The quantity available is small. The normal type of occurrence with the fibres associated with bronzitite kernels continues around the north and west flank of the mass, the zones however, being only about one foot in width. They do not appear on the southern flank. On the east side of the small pyroxenite mass there is a remarkable development of the ribbon structure in the serpentine. A zone up to eight feet wide shows closely spaced narrow bands of dark-green serpentine alternating with similar narrow bands of fibre. Up to 50 per cent of the rock is fibrous but the veins are exceptionally narrow, all being under $1/32$ " in width. Accompanying the narrow bands, however, are wider veins up to $1/4$ " frequently distributed throughout. A little slip fibre also occurs. This type of material extends along the pyroxenite contact. Below the tunnel mouth and east of the magnetite zone, a zone of fibre appears intermittently striking south and disappearing beneath the sediments. The serpentine here is a somewhat crushed bluish-green type but the fibre contained is pale silky-green and of good quality. It is mainly developed along movement planes, is a cross-fibre type with veins averaging $1/4$ " wide but, as the veins are sporadic throughout the rock, the percentage of fibre available is low. The eastern limit of the fibre may be taken as 80 feet east of the tunnel mouth.

The tunnel has been driven along a crush zone. There is abundant evidence of movement showing in the serpentine exposed. All movement planes are characterized by one or more of the following—

- (1) Pale-green translucent, amorphous serpentine of the noble variety. This is a very pretty rock but is, unfortunately, rather brittle.
- (2) Picrolite grading locally to slip-fibre.
- (3) Patches of fibrous dolomite with delicate, pure white fibres disposed parallel to the movement planes. This material shows that the rare feature of triboluminescence, i.e., it glows momentarily in the dark when scratched or rubbed with a metal object.

The tunnel is in serpentine all the way and does not intersect the bronzitite mass. Mapping shows that, had it been driven a little further the mass would have been intersected giving valuable information as to the disposition of the pyroxenite and whether or not the association of fibre with the pyroxenite noted on the surface continues at depth. There is, however, a fair quantity of fibre showing throughout the length of the tunnel. It is mostly about $1/4$ " in length but the dump heap shows a pile of selected fibre taken from the tunnel. Many of the veins in this pile are up to an inch in width and the average length of fibre in the pile would be half an inch. It must be stressed, however, that this is selected material.

The total quantity of fibre available from this area is small and would be of the order of several hundred tons. On its own, therefore the deposit could not be considered as an economic proposition. It may be of value, however, as an additional source of material for a mill established in the district. It is not far from the main road and the present track could readily be improved if required. The value of the deposit lies in the longer fibre obtainable although in limited quantity—as far as length of fibre is concerned, it is the best showing that the writer has seen. A proportion of

this material which could be hand cobbled to save transportation costs could be blended with the Argent Tunnel material to improve the grade of the latter.

The Exe River Prospect

This is situated on the south side of the E.B.R. some two miles by rail south of Rosebery and a little further by road. Access to the area may be had either by rail or road.

The ultrabasics occur on the west flank of a steep hill which rises 150 feet above the railway and is the northern termination of the Colebrook Range. The eastern margin of the ultrabasics is composed of Dundas "Red Rock" identical with that described at the Razorback Prospect. These sedimentaries also continue to the south separating the outcrop from the main ultrabasic belt. The northern and western flanks of the ultrabasics are composed of fluvio-glacials which form swampy flats. The western slopes of the hill are precipitous and fairly free of vegetation. The flat area on top of the ridge is densely covered with second growth scrub.

The outcrop is roughly oval in plan, the longer axis of the oval lying north-south. Along the whole of the eastern margin is a band of banded pyroxenite averaging one chain in width. This pyroxenite is similar to that described in the above two prospects but the banding is less pronounced. This appears to be due to a relatively gradual composition change between adjacent bands whereas in the other prospects the change is an abrupt one. Along the base of this belt, bronzitite kernels make their appearance and three well defined areas of bronzitite kernels are found on the western slopes of the hill. These kernels are similar in every way to those described above.

Fibre is sporadically distributed along the base of the main belt and there does not seem to be a continuous zone developed. Around the isolated kernels, well-developed zones of fibre averaging 1 to 2 feet in width have been found. The content of fibre in these zones would be of the order of 7 to 10 per cent. The fibre is of good physical quality and the grade would be similar to that found to exist at the Argent Tunnel Prospect. It may possibly be a little higher but no fibre above half an inch in length was seen.

The total quantity of fibre available is quite small and not over 100 tons is visible—probably much less than this. It is, of course, impossible to predict whether further bronzitite kernels would be found below the surface. If such were the case, the quantity of fibre available would be greater.

In this small area, underground mining methods would be unprofitable. If the deposit were to be developed, the ore could quite easily be extracted by open-cut methods. The situation of the ore-bodies on the side of a hill would make this method inexpensive and there is ample waste space on the fluvio-glacial flat to the west of the deposit to serve as a dumping ground for waste rock.

On its own, the deposit has no value. Its potential value lies in its comparative nearness to the Argent Tunnel Prospect. Both are alongside the E.B.R. and are about 12 miles apart. If the tunnel area were to be developed, this area could be considered as a supplier of additional ore for the mill.

No. 4 Prospect—From the southern termination of the old Exe Tram, a branch runs south-east to the base of the Colebrook Range. At the end of this branch are found the bins of the old Olympic Tin Mining Coy. From the bins, the haulage rises steeply to the east up the side of the range. This haulage cuts across the strike of the ultrabasic belt. The belt is composed almost exclusively of deep-green massive serpentine containing copious magnetite as disseminated particles and as fibrous bands. Patches of pyroxenite are rare and thus very little fibre is developed.

The No. 4 prospect occurs on the north and the south sides of the Olympic haulage. Small kernels of bronzitite averaging several feet in diameter are distributed over an area of several square chains. Around each, a small zone of fibre is developed. Although some good fibre up to half an inch in length was seen, the zones are only a few inches in width and the total quantity of fibre present is very small. Were the deposit more accessible, it could possibly be considered as an additional supplier to a mill at the Argent Tunnel. It would not be economic, however, to reconstruct the Exe Tram in order to obtain such a small quantity of ore.

No. 5 Prospect—This is situated on the north and south banks of Star Creek, a tributary of the Ring River east of Renison Bell. A track once connected the Boulder and the Exe trams. This track left the Boulder Tram east of the old battery, crossed the Ring River, followed up Star Creek to its head and then cut across the Colebrook Rivulet and the Exe River. It can now be followed only as far as the bridge across the Ring River which is still standing. From this point on the area is heavily covered by bauera and associated scrub.

The scrub makes progress most difficult and inspection of the rocks almost impossible. The writer was able, however, to find the approximate location of the fibre deposits mentioned by Hartwell Condor (G.S. Bull. No. 26, p. 18). As far as can be determined, there is no pyroxenite in this area and the serpentine present is a deep green type carrying only a minor proportion of magnetite. Fibre is certainly present but is rather sporadic through the serpentine mass. It is cross-fibre chrysotile but has a whitish appearance in the vein. The fibre is less flexible than that occurring elsewhere in this field and often grades to cross-fibre picrolite.

It is impossible to form an estimate of the quantity present. The absence of pyroxenite indicates that there will probably be very little fibre. On the other hand, it may be that there is a good development of fibre unassociated with pyroxenite. It is worthy of note that Hartwell Condor, who saw the deposit when the area was much clearer than it is now, states that the quantity seems "scattered and limited".

It must be stated, therefore, that the potentialities of this area have not been fully investigated. If production be undertaken in this field, further prospecting in this area may be worth while. It would be necessary first of all to burn off the scrub before any systematic work be undertaken.

Finally it must be noted that the area is comparatively isolated. Although the Boulder tram is within a mile of the outcrop, the cost of transporting material to the tram would be considerable.

No. 6 Prospect—This as the least accessible area on the field. It may be reached by following up the North-East Dundas Tram formation as far as the Confidence Saddle and then traversing the Confidence Track around the east side of Pine Hill. The eastern fall of Pine Hill has recently been burned off and the ultrabasics are well exposed. The greater part of the mass is gabbroid in character but near the base of the hill serpentine is seen. It is the usual deep-green massive type without pyroxenite kernels. However, the whole mass appears to have been under tension at some stage of its history and the serpentine is veined with very short and narrow veins of chrysotile. No veins of commercial size were seen and it is not likely that such will be found. It is possible, of course, that patches may have been missed and a further search may be justified if production be undertaken. Transport of material would be very expensive from this locality, however, and a very good deposit would have to be proved, before it could be considered economically workable.

No. 7 Prospect—This is the deposit mentioned by A. M. Reid (1925). The material is slip-fibre chrysotile, markedly high in iron and alumina. The distribution is very sporadic over a small area. Taking into account the above facts and also the location of the deposit in a flat swampy area which would make opencut methods almost impossible, it is considered that the deposit has no value either present or potential.

CONCLUSIONS AND RECOMMENDATIONS

Field work has shown that, while there is a large quantity of ultrabasic rock exposed in this area, it is very variable in composition and that chrysotile is only developed in serpentine associated with bronzitite kernels. The areas in which this association occurs are few and limited. It is considered that all deposits of potential value have been investigated. Further proving of these deposits requires prospecting either by driving or by diamond drilling. If this be undertaken, further geological advice should be sought as the work proceeds.

The general conclusions are as follows:—

- (1) That there is a potential source of cross-fibre chrysotile which, though comparatively small, could most probably be worked at a profit for a number of years.
- (2) At the present rate of consumption, the quantity available would supply the needs of this State.
- (3) Efficient mining and milling practice will be the major factor in the success or otherwise of the undertaking.
- (4) The Argent Tunnel Prospect is the only one large enough to warrant investigation at the present. It is the natural site for a mill.
- (5) If this prospect proves economically workable and a mill were erected, investigation of the Razorback and Exe River Prospects could be undertaken with a view to their utilization as additional suppliers of ore.
- (6) The other prospects are of doubtful value. They could be investigated at a later date.

Section VIII—Other Areas

INTRODUCTION

Five further areas have been investigated during the course of the present survey. They are:—

- (1) The Wilson River Osmiridium Field.
- (2) Part of the Heazlewood-Long Plains Osmiridium District.
- (3) The Trial Harbour Serpentine.
- (4) The Lynchford District.
- (5) The West Bank of the Pieman River, North of Rosebery.

In no case was asbestos seen in anything like commercial quantities and no plans were, therefore, prepared of the above areas. Some of the occurrences are interesting from an academic point of view and the following descriptions are included here for the sake of completeness.

THE WILSON RIVER OSMIRIDIUM FIELD

A plan of this area was prepared by A. M. Reid and published in "Osmiridium in Tasmania" (G.S. Bull. No. 32, Plate IX). This plan seems to be reasonably correct. Ultrabasics occur over an area of 8 miles by $1\frac{1}{2}$ miles, the area lying east of the Wilson River and north of the Pieman River. The area trends NW-SE and the northern portion lies to the west of the Wilson River.

Access to the area may be gained from Renison Bell along the old Wilson River "Digger's" track which has recently been cleared out. The track follows along the Argent River to the Pieman meeting the latter at its junction with the Huskisson. Two gages, one across the Pieman and one across the Huskisson give access to the area. On the northern side of the river, the track continues along open button grass plains for one mile then crosses two prominent ironstone ridges. The old Mount Ramsay track has been cleared from the north side of the second ironstone ridge a distance of two miles. From this point the track is very difficult to follow.

Topographically, the ultrabasics form a prominent ridge rising 500 feet above the old Pieman Plain. In the extreme south-east of the area a prominent steep-sided isolated hill known as Riley's Knob occurs flanked on the north by a smaller un-named hill. On the west side of the Wilson River, just above its junction with the Harman, Websterite Hill forms another prominent feature. The whole belt was kept burnt off when the osmiridium diggers were actively engaged in the area but, as it is 20 years since these activities ceased, the typical dense scrub of the serpentine country has now taken charge. The sedimentaries along either flank of the belt support a dense growth of myrtle and stringy-bark gum.

When plotted on a small scale plan, this ultrabasic belt is seen to be a continuation of the Pine Hill arc mentioned in Section VII. Along the valley of the Pieman, the connection is concealed beneath fluvio-glacial material. Petrologically, however, there is a distinct difference between the types of material occurring in the two portions of the arc—the difference being so striking as to suggest that they actually constitute two separate bodies. Not enough work was done, however, satisfactorily to decide this question. The main

mass of the ultrabasics from Riley's Knob to the Harman River consists of rather iron-rich serpentine. A number of different types occur, the chief being a massive type grey on weathered outcrops and a dark-grey veined with yellow when fresh. The veining is extremely fine and only imparts a mottled appearance to the rock on close inspection. A variant of this type, of fairly general distribution, is a distinctly yellow rock with a minor amount of fine greyish-black veins. The texture of these types is quite fine. Locally, however, it becomes coarse and the rock has the appearance of a medium grained brownish-yellow sandstone.

At Websterite Hill, and on both sides of the Wilson near the junction with the Harman, an exceptionally coarse pyroxenite occurs similar to that described near the Argent Tunnel. Petrological work by A. M. Reid shows that the rock contains enstatite and diallage and is, accordingly, a true websterite. Elsewhere, except at Riley's Knob, pyroxenite is conspicuous by its absence.

That the serpentine is iron-rich is evidenced by the segregations of iron ore forming the two prominent ridges in the southern portion of the field mentioned above and the general distribution of a deep-red soil as a veneer of varying thickness throughout the field.

The occurrence of asbestos on the field was first described by Waterhouse in "The Stanley River Tin Field" (G.S. Bull. No. 15, p. 21). He states:—"The serpentine is traversed by veinlets of chrysotile asbestos, generally in very short fibres, the greatest width of vein observed in situ being $\frac{1}{2}$ ", the average width about $\frac{1}{4}$ ". The chrysotile was noted first on the western bank of the Wilson River where it is joined by Jones' Track to Waratah, but afterwards at various other points between the Wilson and the Harman Rivers."

A. M. Reid following Waterhouse, states on page 24 of G.S. Bull. No. 32 "Chrysotile occurs in the Heazlewood and in the Wilson district, the latter deposits being of considerable size . . . It has been noted at various points between the Wilson and the Harman Rivers."

With the above conclusions the present author cannot agree. The area between the Wilson and the Harman Rivers has been carefully searched and, while it must be admitted that some asbestos veins do occur in the area, the distribution is so sporadic and the quality of the fibre so poor that the deposit must be considered as having no commercial value. The fibre occurs associated with coarse bronzitite masses (websterite?) mainly along the south bank of the Wilson east of the Harman. The veins are generally short and no suggestion of a vein system or zone of fibre-bearing material was seen. The average width of the veins would be less than $\frac{1}{4}$ " and fibre of greater length than this average is rare indeed. As is to be expected in an area of iron-rich serpentine, the fibre is high in iron. No analyses were performed, the material not being considered to warrant it, but the fibre in the vein is a deep golden-brown. This colour persists in specimens from fresh rock so that the colour is not due to secondary impregnation by circulating iron-rich solutions. By comparison with specimens from other areas which have been analysed it is considered that the Fe_2O_3 content of the fibre will not be below 10 per cent.

At Riley's Knob, a fair development of fibre was found. The Knob consists of the banded pyroxenite described above. The resemblance to the Spero River material is striking. The bands are most obvious

even from a distance of several chains, appear to be vertical and strike NW-SE. As at the Spero, the development of fibre is found along the junction of bands. In the vein the fibre is a greenish-brown, indicating a moderately high iron content. The veins are mostly simple and occur as vein zones up to an inch in width, the component members of the zones anastomosing in a most intricate way. The average width of veins is about $\frac{1}{4}$ ". There is a further development of fibre in a generation later than the above. The fibre is developed in tension cracks crossing the banded pyroxenite at high angles. These veins usually carry longer fibre but are less persistent than the type described above.

The total quantity of fibre available is small though prospecting work may reveal larger makes. On the surface, not more than a few hundred tons of fibre can be seen. The percentage extraction figure is difficult to estimate and would depend on the method of mining adopted. Opencutting would not give above 1 per cent.

The deposit has mainly academic interest at the present time. The showing is only fair, and the area, being on the north side of the Pieman, is isolated. Transportation of ore would involve heavy expense. However, the area is worth keeping in mind for a later date when perhaps an asbestos mill is erected in the district and the area north of the Pieman River is made more accessible.

HEAZLEWOOD-LONG PLAINS OSMIRIDIUM FIELD

Plans of this area prepared by A. M. Reid will be found in G.S. Bull. No. 32, Plates VI and VII. An extensive mass of ultrabasics extends on both sides of the Waratah-Corinna Road from the Thirteen Mile to the Nineteen Mile Creek. The petrology of this mass has been well dealt with by A. M. Reid in the above-mentioned Bulletin and the present writer has nothing to add to that description, except to remark on the striking similarity in the general aspects of this area as compared with the Wilson River Field.

The only references to asbestos in the area are that quoted from A. M. Reid above and a short sentence on page 10 of "Report on the Mineral Fields Between Waratah and Corinna" by W. H. Twelvetrees dated 1900. He says "These rocks and serpentine continue westwards all along the road cut in the side of the Bald Hill, as far as the 19-mile gully where the serpentine, slightly asbestiform, comes to an end . . .".

Along the Corinna Road from the Heazlewood Bridge to the 17-mile peg, the serpentine is a dark-green massive iron-rich variety. Here and there in the cuttings, moderately fine-grained bronzitite makes its appearance as kernels and a small development of fibre is associated with each. The showing is very small indeed and was not considered to warrant detailed investigation. The same type of occurrence continues along Fenton's Track up Roaring Meg Creek as far as the saddle on the divide between the watersheds of the Heazlewood River and Nineteen Mile Creek. A patch of bronzitite shown on Reid's petrological map of the area (Plate IV) is prominent and there may be a development of asbestos in this area.

The prominent "Bronzitite Hill" north of Jones Creek in the extreme north-east of the area proves to be identical with the Websterite Hill on the Wilson Field. The coarse grained pyroxenite

is very distinct. No development of asbestos was seen around it, however, nor elsewhere in the Bald Hill area. The patch of gabbro between the Roaring Meg Creek and the Heazlewood River was not inspected.

The showing of asbestos found is very poor and must be considered as having no commercial value at present. It is felt, however, that it may be worth while prospecting this area at a later date if economic conditions change.

The remainder of the field around Mt. Stewart and along the Savage River was not inspected. It is very difficult to penetrate to these areas at the present time. They appear from published descriptions to be similar to the Wilson and Heazlewood districts which have been shown to be very poor in asbestos fibre.

THE TRIAL HARBOUR SERPENTINE

This is shown on the geological plan accompanying G.S. Bull. No. 21. "The South Heemskirk Tin Field" by L. Lawry Waterhouse. A prominent ridge of serpentine rises from the sea coast and extends eastwards for one mile. A small nickel prospect, long since abandoned, is located on the north side of the ridge. The serpentine is a massive greyish-green type unassociated with original pyroxenite. An extensive patch of ironstone occurs on the crest of the ridge near the eastern termination. There has been no mention of asbestos occurring in this serpentine and the author was able to find no trace of fibre.

THE LYNCHFORD DISTRICT

From time to time, mention has been made of asbestos minerals occurring in the old Lynchford goldfield in the vicinity of the King gold mine. A short departmental report was made on this material by Mr. K. A. Rae in 1941.

The Lynch River flows into the Queen River some two miles south of Queenstown. The area drained by the Lynch is fairly open, there being a minimum of scrub and the area is one of moderate relief.

Past the site of the old King gold mine, on Section 5096/93M of the Queenstown Mineral Chart, there is a patch of iron rich clays on the bank of the river. A type of slip-fibre occurs in patches through this clay which is probably an alluvial deposit and the fibre derived from some pre-existing rock mass which was not seen. The fibre is slightly green-grey with a silky lustre. It is more or less fibrous but the fibres tend to break out in bunches rather than in individual fibres. Many blebs of limonitic material occur along the vein and interrupt the parallelism of the fibres. When separated from the vein, the fibres are brittle, have little flexibility and have a slightly talcose feel. When rubbed vigorously the fibres tend to break down to a powder.

On Section 717 of the Queenstown Mineral Chart another type of fibrous material was seen on the side of a hill overlooking a tributary of the Lynch. The host rock is a greenish-grey, very hard rock probably a member of the porphyroid group which has suffered silicification. Narrow veins of two types of fibrous material are contained in this rock.

- (1) Very narrow cross-fibre veins of fibrous quartz.

(2) Cross-fibre material in simple veins $\frac{1}{4}$ " to $\frac{1}{2}$ " wide. These veins are associated with quartz, fibrous and otherwise. Sometimes the material is a true fibre but more often it has a splintery fracture. Limonitic material is often associated with the fibre.

Analyses of these materials made by the Mines Department Laboratory, Launceston, are shown in the following Table VIII.

TABLE VIII

	(1)	(2)
Ignition Loss	6.33	3.50
SiO ₂	48.04	54.00
Al ₂ O ₃	13.20	10.71
Fe ₂ O ₃	4.79	12.50
FeO	10.32	N.D.
MnO	N.D.	N.D.
CaO	8.29	8.34
MgO	8.85	8.87
TiO ₂	Nil	Nil
P ₂ O ₅	N.D.	N.D.
Total	99.82	97.92

Column (1) Slip-fibre from Section 5096/93M.

Column (2) Cross-fibre from Section 717.

N.D. = "Not Determined".

The analyses show that the materials are definitely not chrysotile asbestos. They are most probably related to the actinolite-tremolite series with the alumina replacing part of the lime and magnesia. They appear to be more closely related to the actinolite end of the series though, in both cases the ignition loss is rather higher than the theoretical values. They can be classed as "mountain wood" or "wood asbestos".

The distribution of the deposits is extremely sporadic. This together with the poor quality of the fibre, makes the deposits of little commercial value either present or potential.

THE PIEMAN RIVER AREA

This last area is located along the west bank of the Pieman River west of the Bobadil Plains some two miles north of Rosebery. The Pieman River may be forded at this point in dry weather but the safest approach is across the button grass plains leaving the E.B.R. at the north end of the Pieman Bridge. The material is found on Sections 1921/93M and 1923/93M of the North Pieman and Huskisson Mineral Chart. From the bend in the Pieman River near its junction with Chester Creek southwards for three quarters of a mile, the bed of the river is occupied with light coloured poorly fissile slates striking meridionally and dipping east at angles of about 30°. Local variations occur. These slates are underlain by a uraltized dolerite which forms the west bank of the river along the

two sections noted above. Here and there the fibre is developed. It occurs in both the cross and the slip form, the former being the more usual type. The fibre is pale coloured, almost white at times, of very variable length and is usually associated with quartz. Sometimes veins of pure quartzite are seen. Physically the fibre bears a marked resemblance to the slip fibre described at Lynchford. It has a definite talcose feel but, in general is a somewhat better quality than the Lynchford material. Compared to chrysotile, however, it is poor. No analysis has been made of the material but it is most probably a member of the actinolite-tremolite series having closer affinity with the tremolite end of the series as it appears to be fairly low in iron.

The quantity available is very small though prospecting work may reveal larger makes. The distribution throughout the rock mass is very sporadic and in its present state, the outcrop gives little encouragement for further investigation. The location of the area is unfavourable for developmental work. Any material obtained would be very expensive to transport across the Pieman.

Summarizing, then, it may be stated that the material is a low grade fibre occurring sporadically in an isolated area. Its present commercial value is nil but its potential value may perhaps be realized at a later date. It may be worth investigating if an asbestos extraction plant be established nearby.

Section IX—Summary of Asbestos Prospects

Conclusions regarding each separate area have followed the descriptions. It remains now to compare and contrast the areas and to assess the asbestos potential of the State as a whole.

It must be stated at the outset that the results of the survey have not, on the whole, been promising. No large areas of fibre waiting to be mined have been discovered. The deposits that have been investigated are found to be small, some are definitely uneconomic, some can be classed as "marginal deposits". The economic question involved resolves itself into the solution of the problem "on which side of the economic margin can each deposit be placed?" The solution of this problem is difficult and cannot be answered fully here. It depends upon:—

- (1) The quantity of ore present.
- (2) Its percentage extractability.
- (3) The location of the deposit.
- (4) The efficiency of mining and milling methods.
- (5) The grades of fibre which can be produced.
- (6) The demand for the grades of fibre produced.
- (7) The price to be obtained for the finished product.

(1) **Quantity of Ore**—The Beaconsfield and the Argent Tunnel areas are the only ones showing anything like a reasonable quantity of ore. The quantities to be obtained from each are roughly equivalent, and are of the order of 10,000 tons of fibre. At Beaconsfield, the fibre is confined to one serpentine area. At the Argent Tunnel, however, there are other small deposits reasonably close at hand which may make this area a more attractive one than Beaconsfield.

(2) **Percentage Extractability**—This must be based on previous production and involves questions of efficiency. The overall extractability of the Beaconsfield ore on this basis was about 1 per cent. The Argent Tunnel material was also about the same figure. In the areas recommended at Beaconsfield it is considered that an extractability of 2 per cent can be obtained if the whole area is open cut. Selective mining methods would increase this figure probably to 3 per cent.

At the Argent Tunnel, the extractability based on a 55 per cent mill efficiency is estimated by Knight to be of the order of 1 per cent. By the use of selective mining methods and an efficient mill this could be raised to about 4 per cent. In some areas, stoping methods will give a higher percentage than this. No discussion of extractability in the Asbestos Point and Spero River areas can be undertaken. The Ulverstone area is quite uneconomic.

(3) **Location of Deposits**—This has an important bearing on the transportation costs of finished material and the supply of labour. Beaconsfield and Argent Tunnel are quite well located from this point of view. Access would have to be provided for the subsidiary areas in the Dundas-Rosebery area. The deposits south of the Macquarie Harbour must be ruled out because of their location at the present time.

(4) **Efficiency of Mining and Milling Methods**—This has been fairly fully dealt with in the discussion of the Argent Tunnel area. No details of production methods are available for Beaconsfield. It must be stressed at this point that efficient production methods will be a necessity. The deposits being of comparatively poor grade, the methods of working must be of correspondingly high grade.

(5) **Grades of Fibre**—The figures for the Argent Tunnel area give a good indication. The bulk of fibre will be around the 5D grade. The utilization of areas of longer fibre could probably bring this up into Group 4. It is improbable that fibre of Group 3 standard could be produced. No figures are available for Beaconsfield and accurate data could only be obtained by milling bulk parcels. It may be possible to have this done by arrangement with Mainland firms. In the writer's opinion, the Beaconsfield deposits should produce fibre of Group 4 and possibly some of the lower grades of Group 3.

(6) **Demand for Fibre**—This is more a question for a production engineer. From the fact that Canadian asbestos is imported into this State under great difficulty at the present time, it appears to the writer that there is a good demand for fibre of grade suitable for the manufacture of asbestos cement products. What the demand for the lower grades is and what the total demand is likely to be over a period of years are questions that the writer is unable to answer.

(7) **Prices of Fibre**—The Canadian and American prices quoted on pages 17-18 of this report are a sufficient guide.

It may be stated in conclusion that, of all the deposits investigated, only the Beaconsfield and the Argent Tunnel Prospects show any promise at the present time. No large scale production can be expected in either area, but both are capable of supporting a small enterprise sufficient for the needs of this State. There is little difference in the potentialities of the two areas but, all things being considered, the writer considers the Argent Tunnel area to be a slightly better proposition than the Beaconsfield area.

Again it must be stressed that, with these marginal deposits, thorough investigation of all factors must precede any decision on the erection of a production plant.

Section X—Serpentinization & the Genesis of Chrysotile Asbestos

INTRODUCTION

This difficult and complicated problem has been the subject of much discussion. Agreement has been reached on some points but not on others. It is not possible critically to review all the theories here but it is hoped that the following observations will assist in the solution of the problem.

Turning first to facts capable of verification by direct observation we may note the common association of ultrabasic, basic and acid plutonic rocks in the field. Hatch and Wells (1933) state (page 243) "The close association of these ultrabasic rocks with gabbros and norites and the perfect gradation in mineral composition from norite through increasingly mafic norite-pyroxenites into bronzitites; and from norite and gabbro through olivine-rich feldspar-poor types into peridotites within the limits of one rock body, proves derivation by differentiation from normal basaltic magma". In Tasmania, this is especially evident in the Dundas-Rosebery, Heazlewood and Asbestos Point areas though it is not observable at Beaconsfield, Ulverstone and the Spero River. The general association of ultrabasics with acidics has been remarked on numerous occasions and all the Tasmanian occurrences with the exception of those at Ulverstone and south of the Macquarie Harbour show this feature. Acid plutonics occur fairly near Macquarie Harbour ultrabasics, as, for instance, at Mount Darwin and it is likely that further masses occur concealed not far below the surface.

Further, the general association of serpentine with pyroxenites and peridotites is so well known as to need no emphasis.

Exponents of the theory of granitization would apparently deny the existence of a stock magma and thus also the theory of differentiation. The work of N. L. Bowen shows, however, that differentiation can occur though by what means is not so certain. It appears to the present writer, from a study of the literature combined with his own field observations, that the theory of differentiation is substantiated in this State and he thus agrees with the view put forward by Ward in G.S. Bull. No. 6 and subsequent workers, that the ultrabasics and acidics represent differentiates of the one stock magma, the ultrabasics representing the earlier injection but the whole igneous complex being completed during the one orogenic period. The evidence for the ultrabasics being the earlier is conclusive at Beaconsfield where the acidic types invade the serpentine, and at Pine Hill where the quartz-porphry dyke cuts across the ultrabasics. The evidence for the age of the ultrabasics is not so conclusive. At Beaconsfield they intrude a series "tentatively ascribed to the Siluro-Ordovician" (A. M. Reid, G.S. Report No. 8, p. 4). The most that can be said for the age of the ultrabasics here is that they are post Precambrian. At Ulverstone the intruded rocks are Precambrian schists. In the Dundas-Rosebery area the intruded rocks are the Dundas Group shown to be at least Mid Cambrian and later. Assuming that all the ultrabasics belong to the one period, therefore it can only be said on the evidence of the rocks themselves that they are later than the Middle Cambrian. It

has been shown by Ward, however, that the acidics are definitely Devonian (G.S. Bull. No. 3). Accepting the theory that the ultrabasics and the acidics are differentiates of the one stock magma, it follows that the ultrabasics also are Devonian and probably early Devonian.

The ultrabasics appear to be composite rather than simple intrusions and consist of three types of injection.

- (1) Successive small injections of varying composition forming the banded pyroxenites. The time interval between successive injections was probably quite short.
- (2) Sheetlike masses of bronzitite composition from a few inches to many feet in thickness.
- (3) The final injection of gabbro.

These injections occurred in the order indicated although field evidence indicates that the first two stages may have alternated. In all cases the gabbro was the latest injection. It will be noted that the above series indicates a decrease in basicity up to the gabbro which may be considered as the connecting link between the ultrabasics and the acidics. This is in accord with the theory of differentiation. As highly basic portions of the magma are drawn off, the portion remaining must become increasingly acidic.

SERPENTINIZATION

The ultrabasic rocks can be considered as consisting of the essential molecules MgO , FeO and SiO_2 with subsidiary amounts of CaO and Al_2O_3 . In the serpentines the above molecules are present and, in addition H_2O and CO_2 . That the serpentine have been derived from the ultrabasics can be taken as axiomatic. The problem of serpentinization, then, resolves itself into the solution of the questions—

- (1) What is the source of the H_2O and CO_2 ?
- (2) Under what conditions do the chemical changes occur?
- (3) What physical changes do these chemical changes produce in the mass?

(1) **Source of H_2O and CO_2 .**—This question has been well dealt with by W. N. Benson (1918) who states after a consideration of all possible sources (p. 727) "in some cases at least the hydration was brought about by the agency of water emanating from the same magma that produced the peridotite, though not generally until a considerable amount of further differentiation has taken place. The change was, however, completed by the end of the one orogenic period of vulcanicity", i.e., from a magma of granitic composition. The question of the source of CO_2 has, in the author's opinion, been overstressed. In Tasmania at least, although carbonate minerals do occur they are generally quite subordinate. It is considered that only a minor proportion of CO_2 is involved in the reaction and its source may well be the granitic magma. In connection with the source of H_2O , Lindgren (1933) states (p. 387) "All these result from the action of water, in most cases doubtless of atmospheric origin on peridotites, pyroxenites, or gabbros, either near the surface, or with the co-operation of stress, at great depths." This does not apply to the Tasmanian deposits which are of the types described by Benson.

pyroxene the increase would be less but of the same order. Thus the newly-formed mass is subject to intense internal stresses which are relieved by slipping of portions of the mass one over the other producing slickensided surfaces. These are of general distribution in the Tasmanian serpentines and have been fully described above.

Summarizing, therefore, it may be stated that the process is viewed as either metasomatic or pneumatolytic depending upon whether the water is in the liquid or the gaseous phase. In modern terminology it may be characterized as "deuteric" which has been defined by J. L. Gillson (1929), pp. 100-102 as covering those metasomatic changes in igneous rocks resulting from the reactions between the minerals already formed and the gaseous or liquid emanations persolating through the solid or nearly solid rock and derived from the same magma as which the rock itself had been derived.

GENESIS OF CHRYSOTILE ASBESTOS

In this discussion only cross-fibre forms of chrysotile will be considered as they are the only ones likely to prove of economic importance in Tasmania. The chief facts to be borne in mind are:—

- (1) The chrysotile is of essentially the same chemical composition as the enclosing serpentine.
- (2) The S.G. of serpentine is 2.5-2.65 and that of chrysotile 2.219.

From these it is deduced that the chrysotile is a crystalline form of serpentine with a lower density. Thus, in the formation of chrysotile, no additional matter is introduced into the serpentine and the problem becomes one of explaining the change in physical form of the amorphous substance $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. S. Taber critically reviews all the theories and concludes (page 74) "all cross-fibre veins are formed through a process of lateral secretion, the growing veins making room for themselves by pushing apart the enclosing walls; and that the fibrous structure is to be attributed largely to the physical conditions which have limited growth to a single direction. In the case of the asbestiform minerals, the fibrous structure is accentuated by the normal prismatic habit and cleavage. In individual occurrences it may be difficult or impossible to determine why the fibrous mineral was taken into solution, the cause of its redeposition and the other details of origin; but, in the case of serpentine, pressure due to the expansion of volume is probably the controlling factor".

With this theory the present author is in general agreement and the following notes can be considered as additions to Taber's theory rather than criticisms of it.

The development of cracks in the serpentine is the first step in the alteration to chrysotile. This can only be the result of tensional stresses set up in the mass and probably occurs during the last phases of serpentinization. Compressional stresses have been relieved in the mass in the manner described above. The kernels of bronzitite and other parent rocks, being competent, remain passive throughout the process but serve as local centres from which the serpentine tends to be drawn away by the movements going on within itself. Thus a series of parallel tension cracks develops in the zone around the pyroxenite. These may be likened to the parallel cracks developed at right angles to the direction of the

tension in a semiplastic material such as putty which has been stretched out. In completely serpentized masses such as the Dundas arc there are no centres of competent material and thus no cracks produced. It may be noted at this point that on the plan of the Bajenova District (Urals) Russia figured by Lilley (page 29) all the pits are located at the junction of masses of peridotite and serpentine and the inference is that the fibre in this area also is located along the contact zone.

The development of fibre along the tension cracks is initiated by small quantities of heated waters remaining from the serpentization process tending to gather in the cracks and to commence solution of the walls. The exact process which occurs may be well complicated and is properly a study for the physical chemist. It probably involves solution by a comparatively small amount of water, supersaturation, and the consequent redeposition of material, the small amount of water "working over" the rock. It is logical to assume that this process operates on both sides of the tension crack. In the resulting slow deposition, the serpentine molecules tend to assume a regular pattern, i.e., to crystallize. Being restricted on both sides by similar crystals the tendency is for the crystals to assume the prismatic or needle-shaped form.

Taber points to the known power of growing crystals to exert considerable pressure in pushing aside the enclosing walls. This process most certainly operates but it is not necessary to assume it in all cases. Another explanation is that the walls may have been pulled apart gradually by the tensional stresses still operating during the deposition of the chrysotile. A combination of these factors has probably operated in most cases. That movement has taken place during deposition is evidenced by the curved nature of the fibres in many veins. This shows that the walls have moved relative to one another while deposition was taking place.

The above theory then, postulates that the fibre is formed by lateral secretion in tension cracks developed around centres of competent material, the medium of solution being heated water left over from the process of serpentization and that the fibre development commences in the final phases of serpentization and probably continues for a short time after this process has ceased to operate.

Addendum

STRUCTURAL RELATIONSHIPS OF WEST COAST ULTRABASIC ROCKS

Since the completion of the investigation of asbestos deposits in 1949, the author has spent several years studying the regional geology of the West Coast area, in particular the North Pieman Mineral area and its extension south to Zeehan and Dundas. Also other investigations by members of the University of Tasmania Geology Department have been carried out over nearby areas. From these investigations further facts have been gained and it is considered that these should be included as an addendum to the main report.

It is now clear that three major belts of ultrabasic rocks occur as follows:—

(1) **The Western Belt**—This commences at Keenan Creek north of Parson's Hood, and runs south-east almost in a straight line to the Pieman River. There is continuity of surface outcrop over this portion except for a few hundred yards between the Huskisson and Pieman Rivers. The belt averages one to one and a half miles in width over this section. South of the Pieman River, the belt swings sharply to south along the Exe River and then continues SSW and SW being observed in Colebrook and Stor Creeks. It continues SW as far as Pine Hill at which point it curves again to run nearly west following the course of Melba Creek to Serpentine Hill and continues west of the Renison Bell Road to the Copper-Nickel Field. In the area between the Pieman River and Stor Creek, the outcrops are discontinuous being partially obscured by glacial debris. The total length of this belt is 18 miles and its structural relationships have been studied by the author over the greater part of this length.

In general, it may be stated that there is a parallelism between the trend of the belt and the enclosing rocks. This has been observed along the Wilson, Huskisson, and Pieman Rivers, near Pine Hill, at Serpentine Hill and in the Copper-Nickel Field. The most detailed studies have been carried out along the Huskisson River where it was observed that successively older formations of the Huskisson Group of sediments (defined in unpublished work by the author and equivalent to the Dundas Group as defined by J. N. Elliston) overlap the eastern margin of the belt, the difference of strikes being of the order of 15° . It is therefore concluded that, while the belt in general is concordant with the bedding of the enclosing sediments, it locally shows discordant relationships and must therefore be considered as an accordant intrusion.

(2) **The Eastern Belt**—North of the Pieman River from its junction with the Exe River there occur two sizeable masses of ultrabasic rocks over a distance of seven miles. Similar rock occurs in the Pieman itself upstream from the Exe junction, and the belt is almost continuous on the surface south of the Pieman, being exposed along the western flank of the Colebrook Range for three miles almost to Ringville. This belt trends slightly west of north and is slightly convex towards the west, the apex of the curve occurring near the

Exe River. This point is also the apex of the easterly-convex western belt described above. Only a few hundred yards separate the two belts at this point and the author is of the opinion that there may be physical connection between the two belts at about the Exe River.

(3) **The Southern Belt**—This commences at the saddle north of Razorback Hill between Nevada Creek and an un-named tributary of the Dundas Rivulet, trends east forming the Dundas Flats and then curves south towards South Comet Creek. The length of the belt is five to six miles and its forms a complementary curve to that of the eastern belt described above, being convex towards the north-east.

It is considered that the distribution of ultrabasic rocks as observed provides a key to the understanding of the regional structure of this portion of the West Coast. Consider a series of horizontal beds. Fold this series along two axes at right angles to each other, the folding to be symmetrical. This produces a structural "high" at the centre. Then erode the series to base-level, and consider the trace of any one bed. It will be found that it forms four rectangular hyperbolic curves, one in each quadrant, the axes being the original fold axes. This is an ideal case which would never occur in nature. However, skew the axes a few degrees, make the folding asymmetrical, and consider the situation at a youthful stage in the geomorphic cycle. It will then be found that the four rectangular hyperbolic curves are still present but distorted.

In the area under discussion, it was a consideration of the above theory which first gave the author a clue to the regional structure of the area. Much detailed work on the sedimentary rocks has served to prove the basic thesis but the details of this work cannot be given here. It is assumed in the above theory that the ultrabasic rock is at least an accordant intrusion. This is considered to be beyond doubt. Details of the reasons for this statement are given in the Section VII of the main report under the heading "Relationship Between Ultrabasics and Enclosing Rocks". Later work has only served to confirm this thesis.

An interesting corollary of the theory of structure above outlined is the question of the location of the fourth curve of the group. It will be noted that only three belts (or curves) have been described. This fourth curve should occur in the wild and inaccessible country east of Mt. Dundas and the author has never had the opportunity to search for it. However, he is convinced of its existence and of the certainty that it will ultimately be discovered.

17th November, 1955.

B.L. TAYLOR, B.Sc. (N.Z.), A.M. (Aust.), I.M.M.

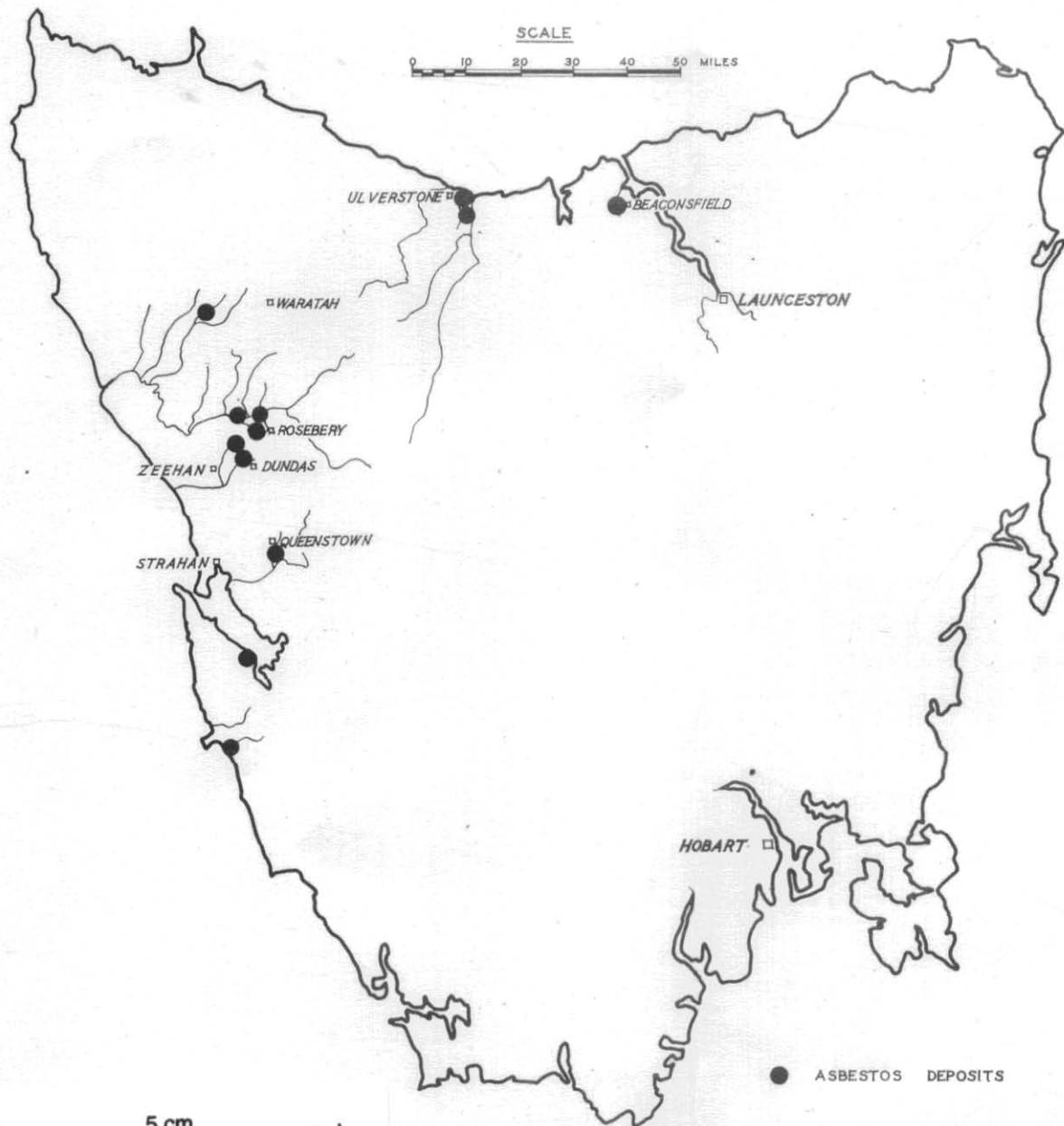
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ASBESTOS IN TASMANIA

LOCALITY MAP



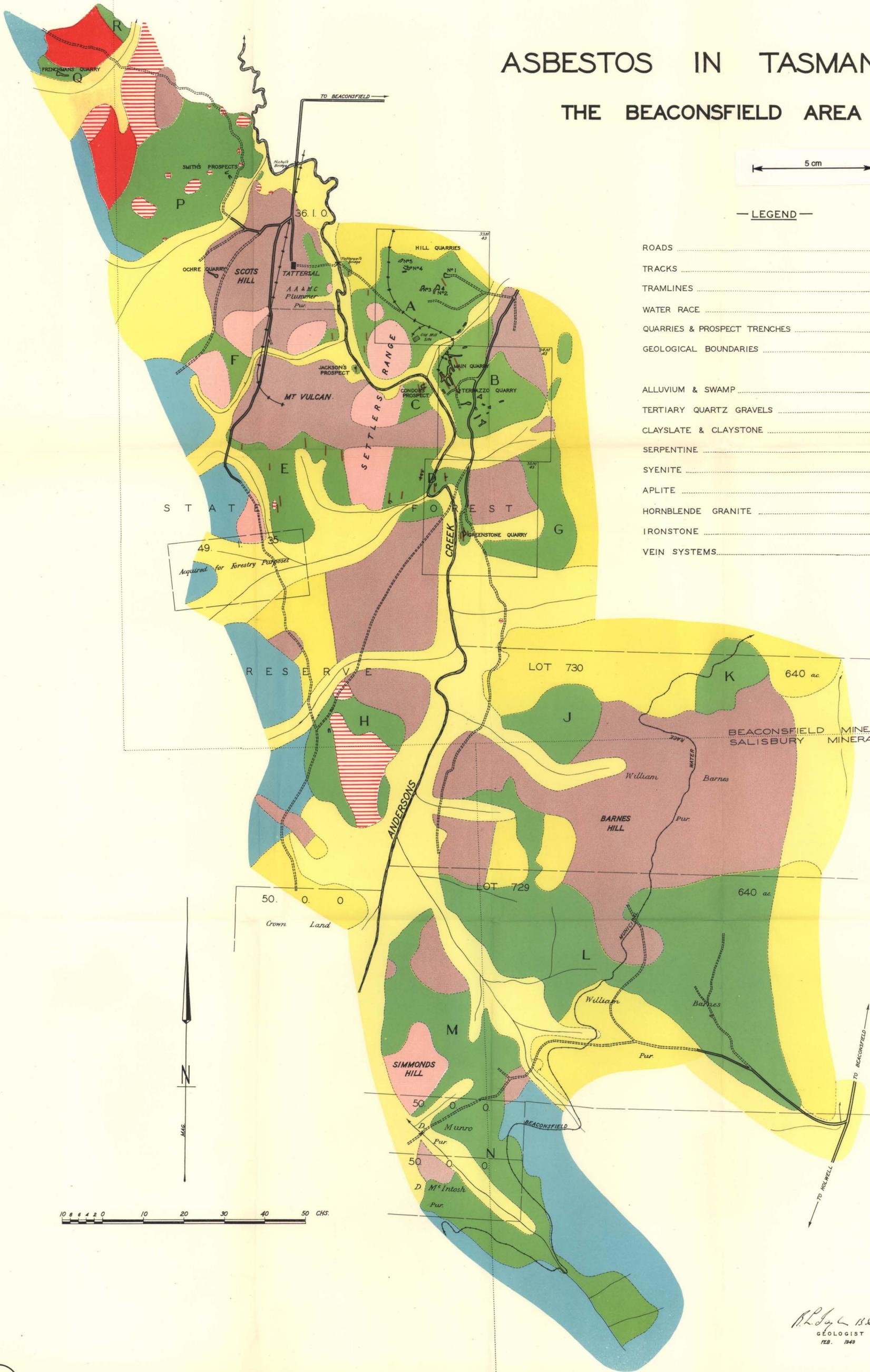
ASBESTOS IN TASMANIA

THE BEACONSFIELD AREA

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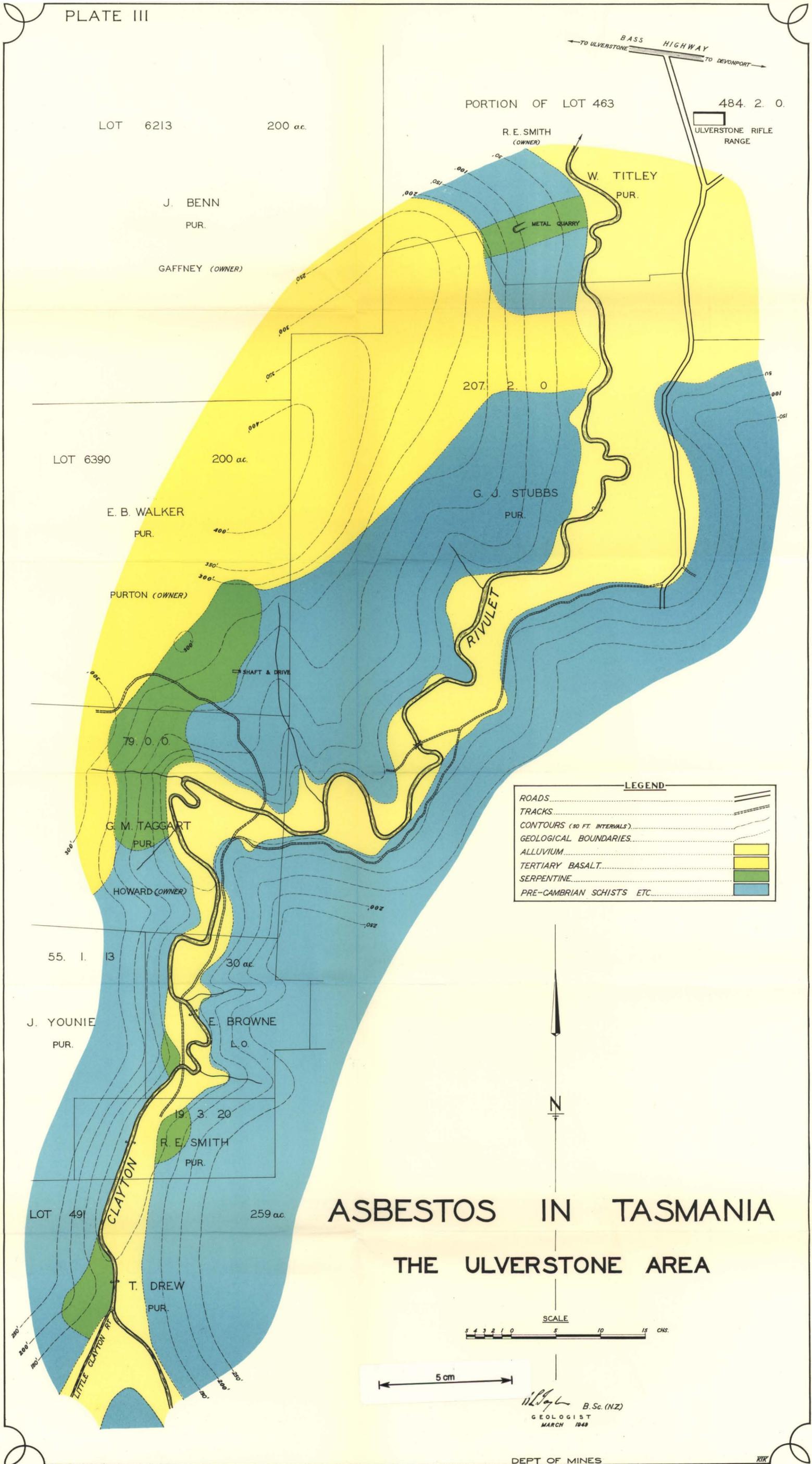
— LEGEND —

- ROADS 
- TRACKS 
- TRAMLINES 
- WATER RACE 
- QUARRIES & PROSPECT TRENCHES 
- GEOLOGICAL BOUNDARIES 
- ALLUVIUM & SWAMP 
- TERTIARY QUARTZ GRAVELS 
- CLAYSLATE & CLAYSTONE 
- SERPENTINE 
- SYENITE 
- APLITE 
- HORNBLende GRANITE 
- IRONSTONE 
- VEIN SYSTEMS 



BEACONSFIELD MINERAL CHART
SALISBURY MINERAL CHART

B. J. G. B. G. G.
GEOLOGIST
FEB. 1949



PORTION OF LOT 463
 484. 2. 0.
 ULVERSTONE RIFLE RANGE

LEGEND

ROADS	— — — — —
TRACKS	— · — · — · —
CONTOURS (50 FT. INTERVALS)	— — — — —
GEOLOGICAL BOUNDARIES	— — — — —
ALLUVIUM	Yellow
TERTIARY BASALT	Light Blue
SERPENTINE	Green
PRE-CAMBRIAN SCHISTS ETC.	Dark Blue

ASBESTOS IN TASMANIA

THE ULVERSTONE AREA

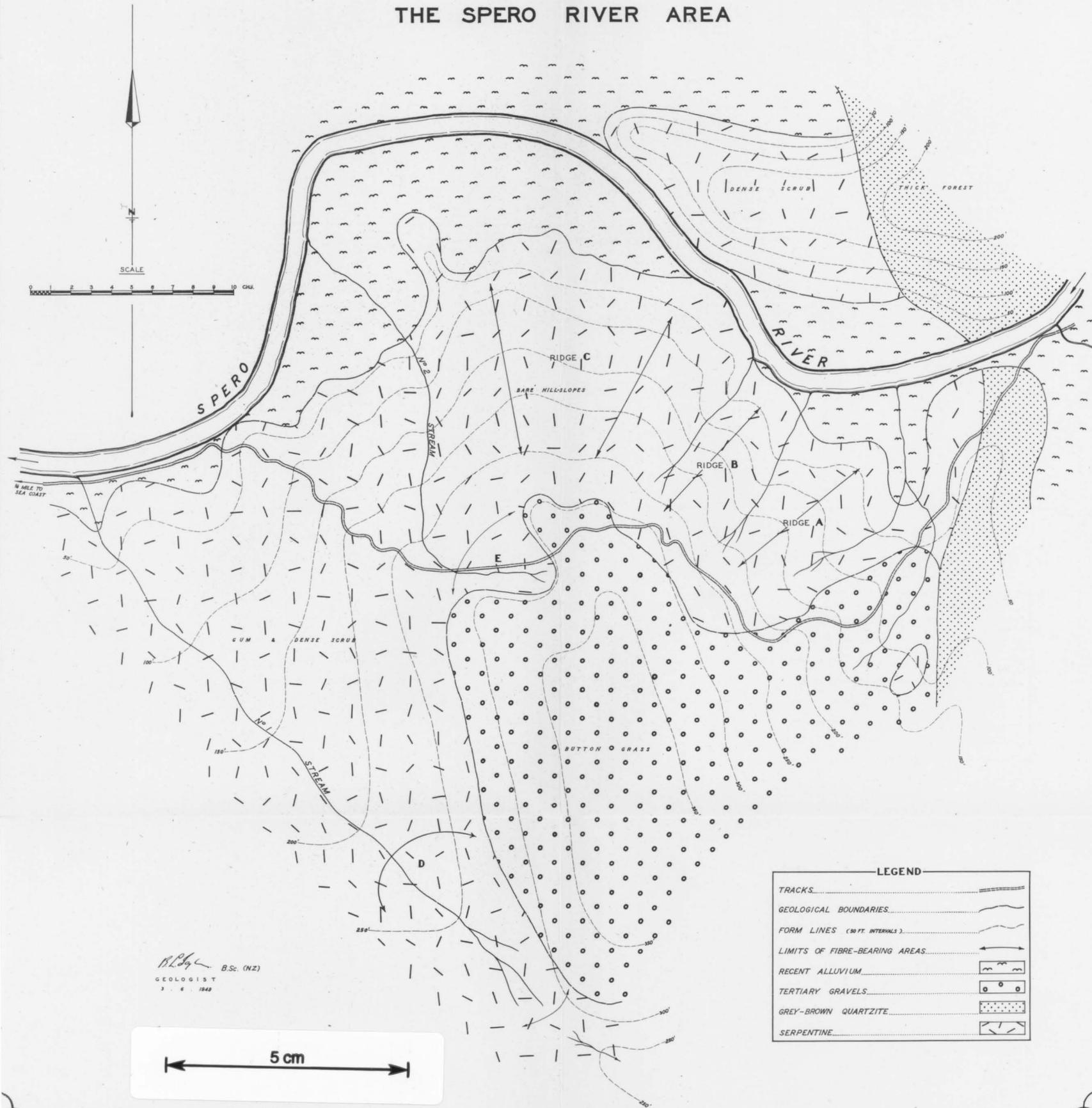
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W. J. Bayly
 B.Sc. (N.Z.)
 GEOLOGIST
 MARCH 1948

ASBESTOS IN TASMANIA

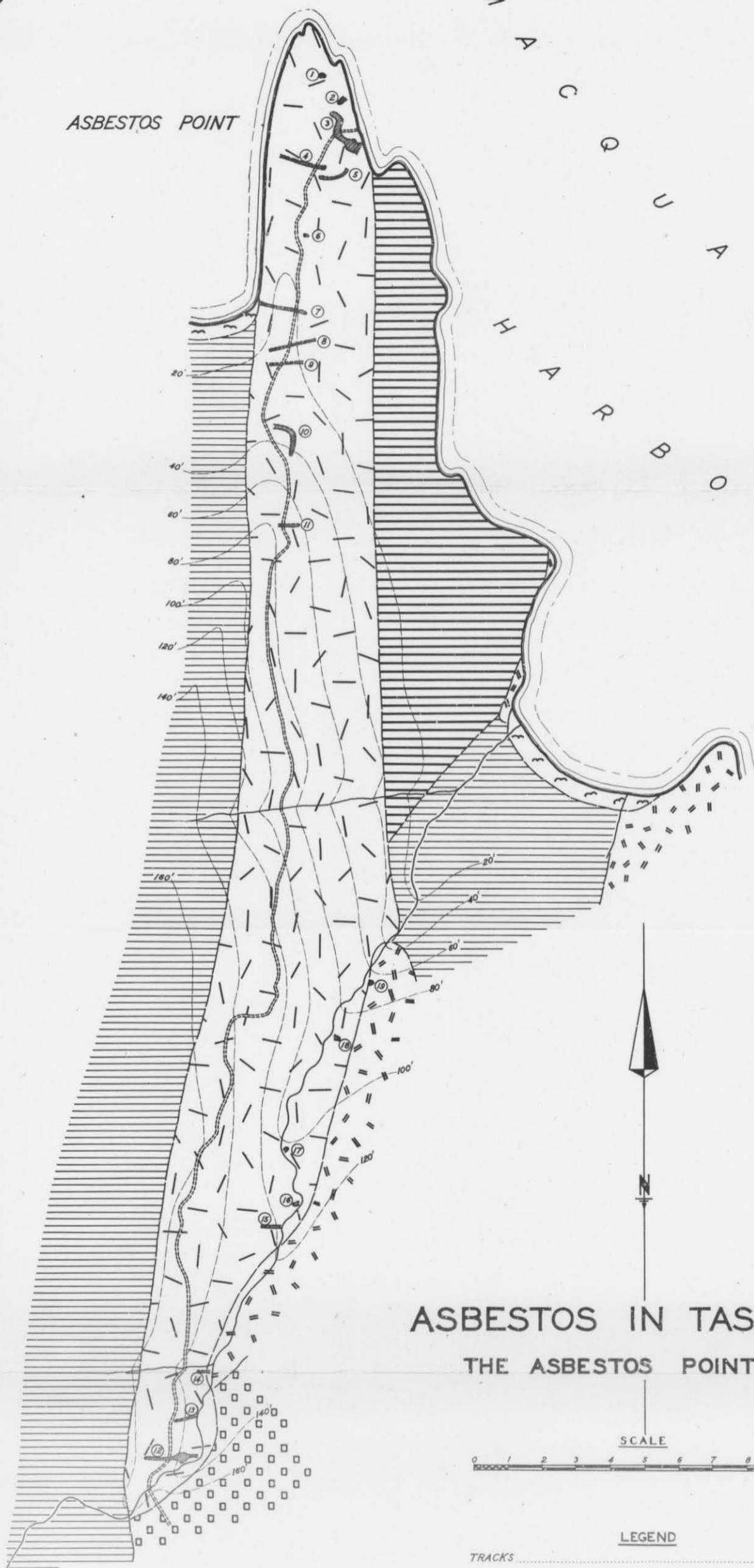
THE SPERO RIVER AREA



B.L. G. B.Sc. (NZ)
GEOLOGIST
3. 6. 1942

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ASBESTOS POINT



ASBESTOS IN TASMANIA
THE ASBESTOS POINT AREA

SCALE



LEGEND

- TRACKS.....
- GEOLOGICAL BOUNDARIES.....
- FORM LINES (20 FT INTERVALS).....
- TRENCHES.....
- BEACH SANDS.....
- SLATES.....
- SOFT SCHISTOSE ROCK.....
- SERPENTINE & PYROXENITE.....
- GABBRO.....
- IRONSTONE.....

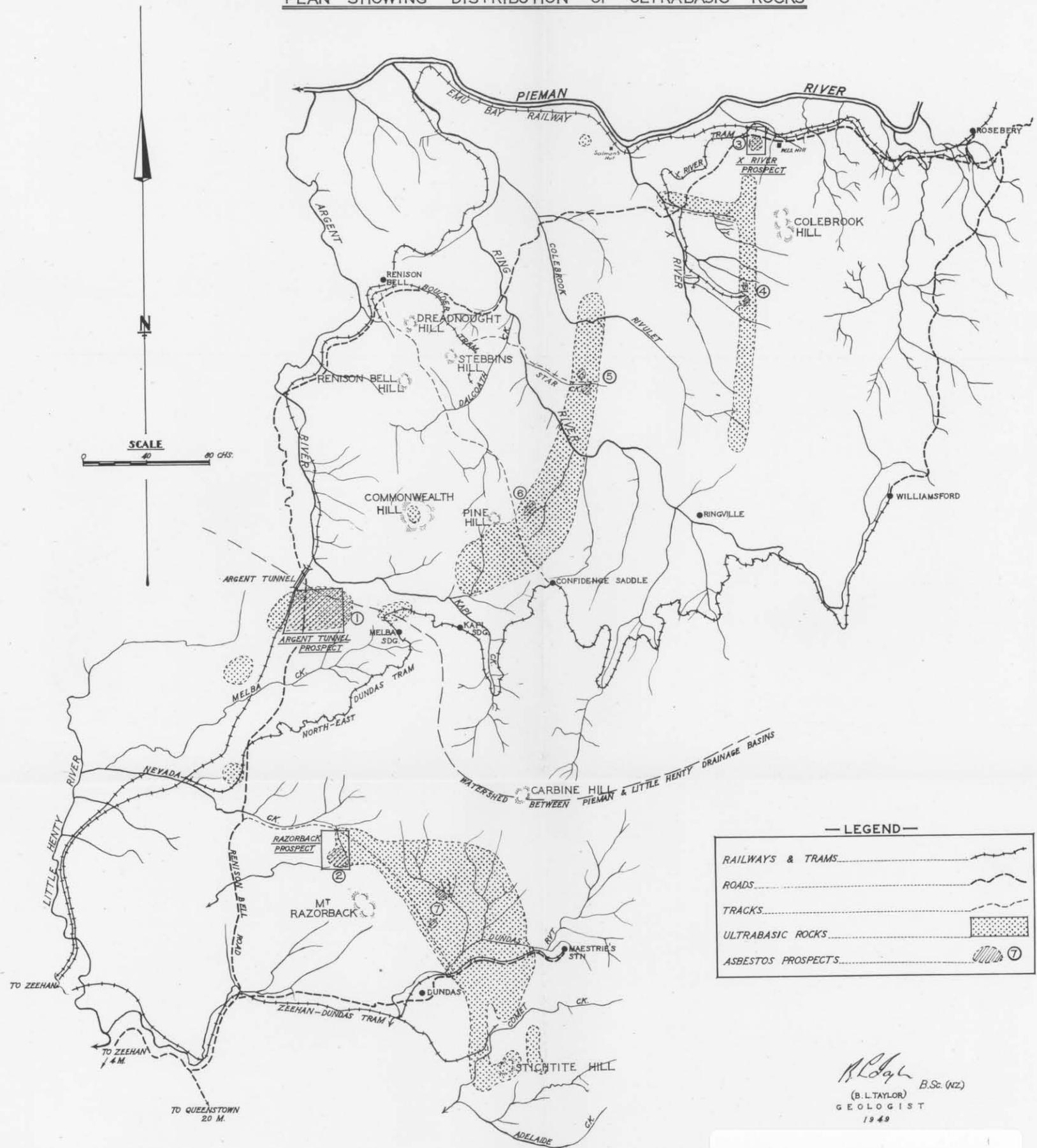
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7 . 6 . 1949

ASBESTOS IN TASMANIA

THE DUNDAS — ROSEBERY AREA

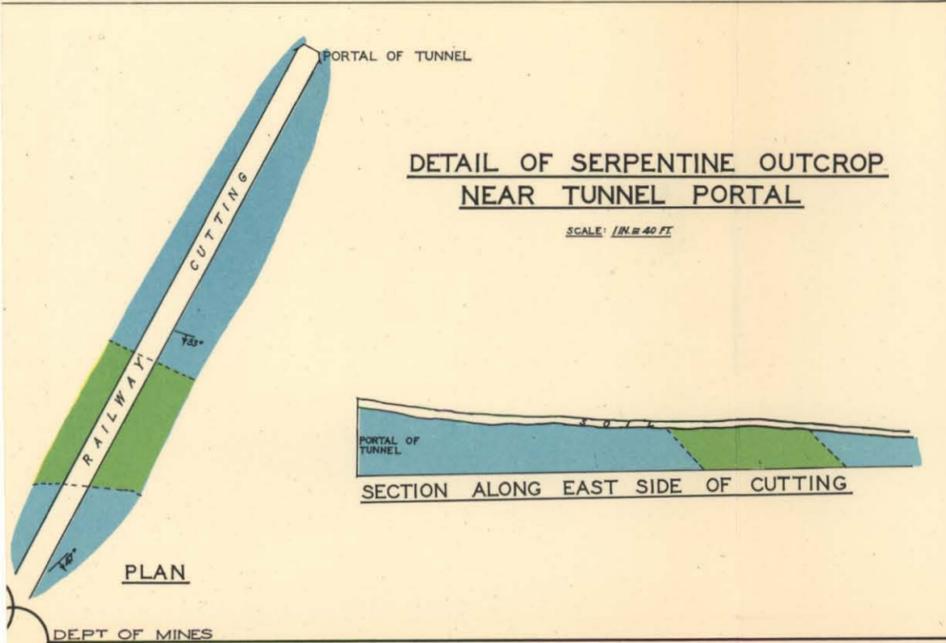
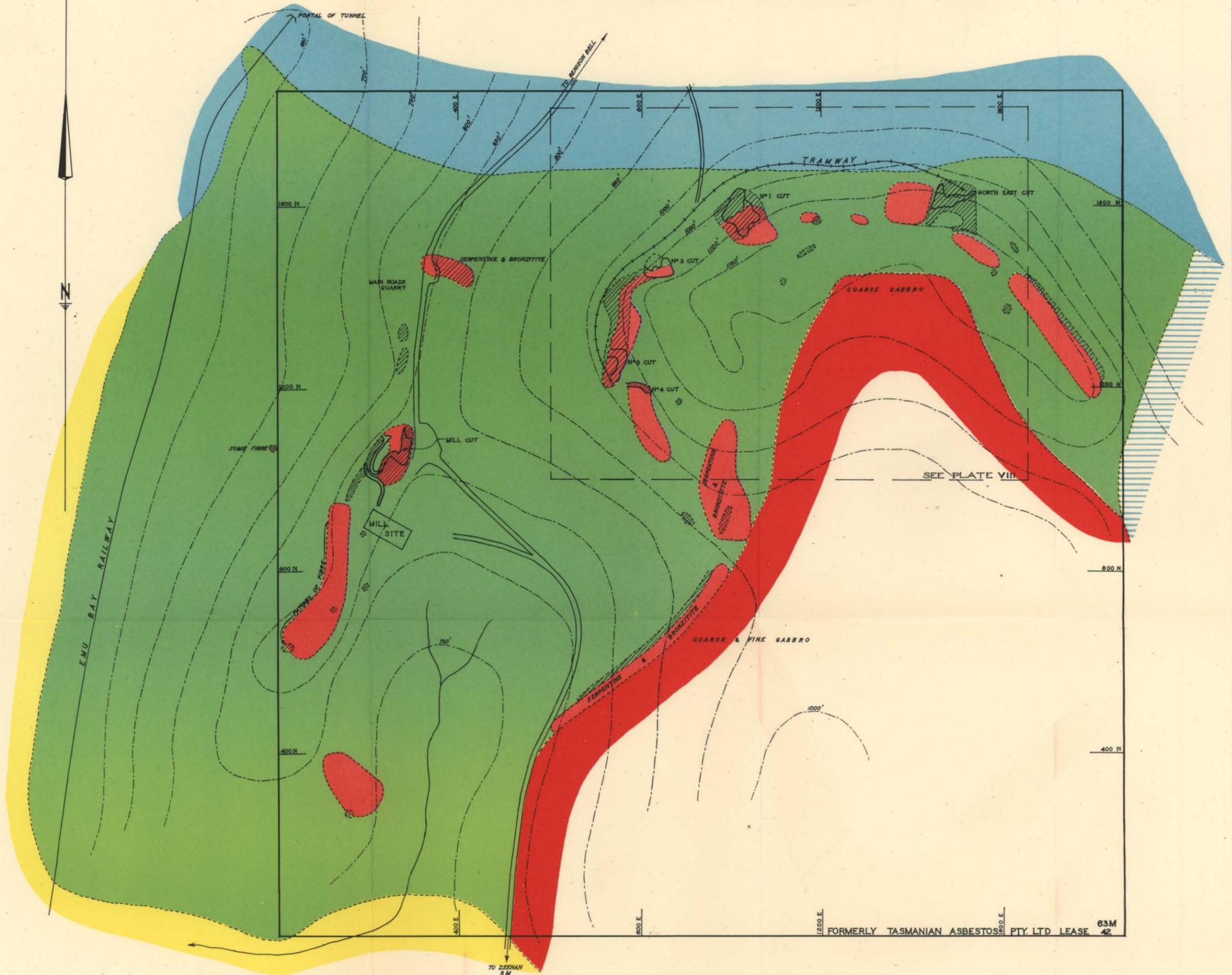
PLAN SHOWING DISTRIBUTION OF ULTRABASIC ROCKS



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ASBESTOS IN TASMANIA

THE DUNDAS — ROSEBERY AREA



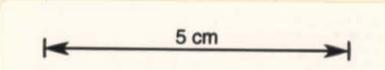
THE ARGENT TUNNEL PROSPECT

(BASED ON BUREAU OF MINERAL RESOURCES PLAN N° 1339)



— LEGEND —

GEOLOGICAL BOUNDARIES	---
FORM LINES (50' INTERVALS)	--- 750' ---
FIBRE-BEARING AREAS	Green
SERPENTINE	Red
BRONZITITE KERNELS	Red with diagonal lines
GABBRO	Red with horizontal lines
DUKAS SERIES	Blue
KERATOPHYRE TUFFS	Blue with diagonal lines
ALLUVIUM & SWAMP	Yellow



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PLAN
SHOWING
UNDERGROUND WORKINGS & EFFECTIVE GRADES
MAIN ASBESTOS-BEARING AREA

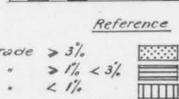
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ASBESTOS IN TASMANIA
THE DUNDAS - ROSEBERY AREA

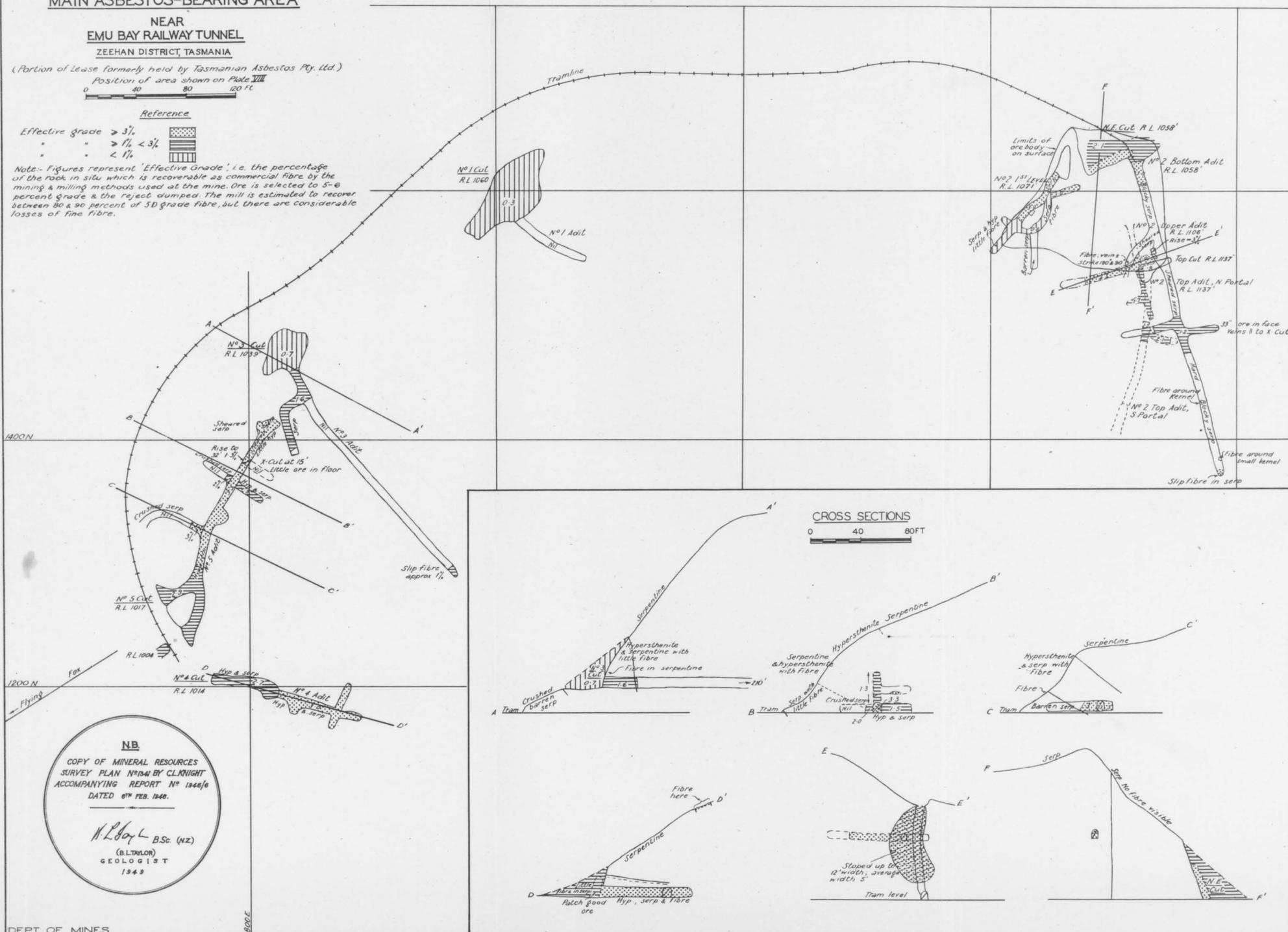
NEAR
EMU BAY RAILWAY TUNNEL
ZEEHAN DISTRICT, TASMANIA

(Portion of Lease formerly held by Tasmanian Asbestos Pty. Ltd.)

Position of area shown on Plate VII

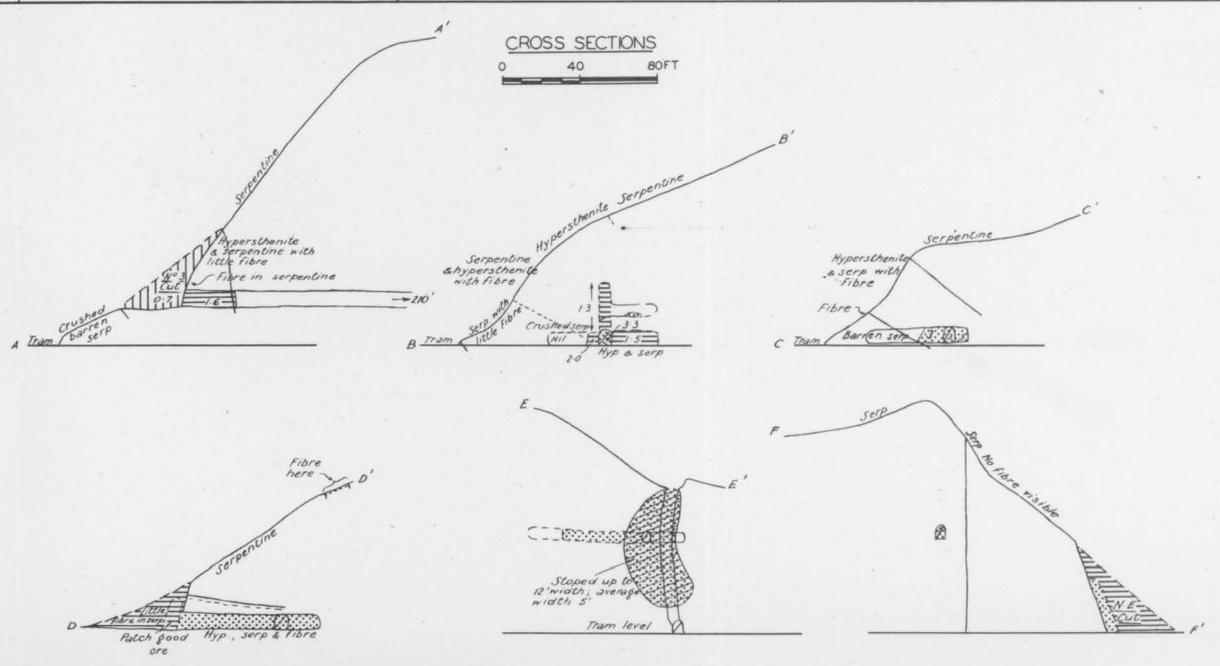


Note: Figures represent 'Effective Grade', i.e. the percentage of the rock in situ which is recoverable as commercial fibre by the mining & milling methods used at the mine. Ore is selected to 5-6 percent grade & the reject dumped. The mill is estimated to recover between 80 & 90 percent of 5D grade fibre, but there are considerable losses of fine fibre.



CROSS SECTIONS

0 40 80 FT

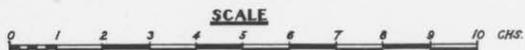


NB
COPY OF MINERAL RESOURCES
SURVEY PLAN N° 104 BY CLK NIGHT
ACCOMPANYING REPORT N° 1944/6
DATED 6th FEB. 1948.

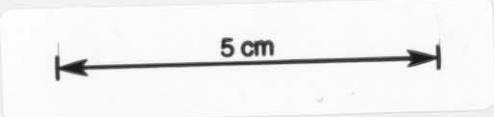
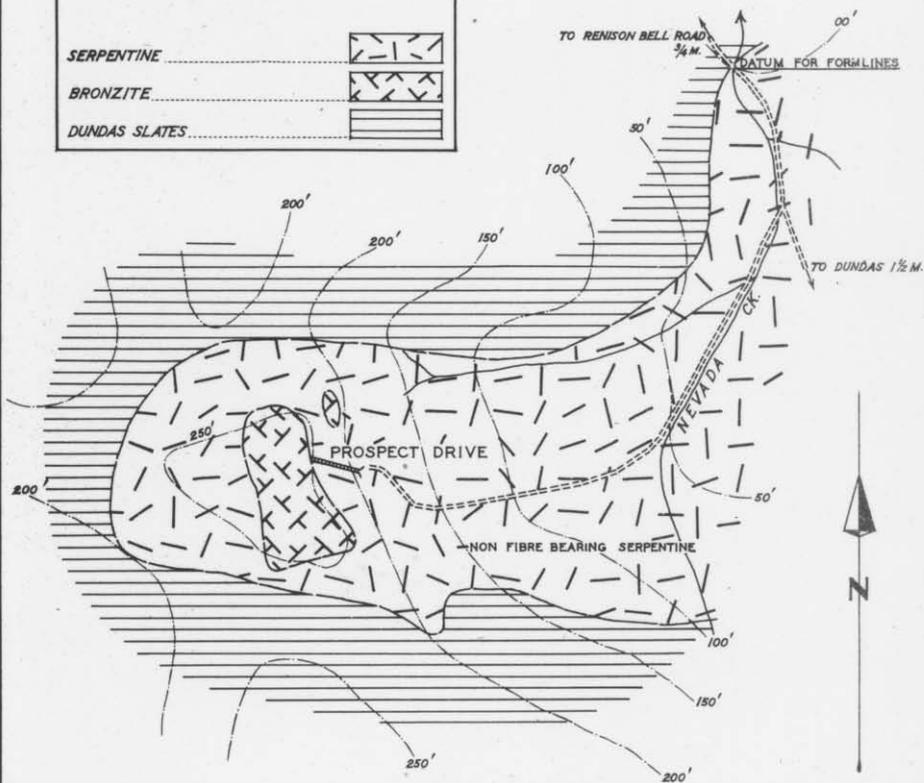
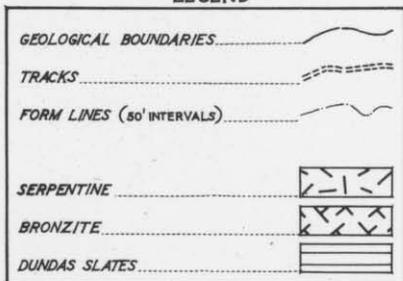
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ASBESTOS IN TASMANIA

THE RAZORBACK PROSPECT



— LEGEND —

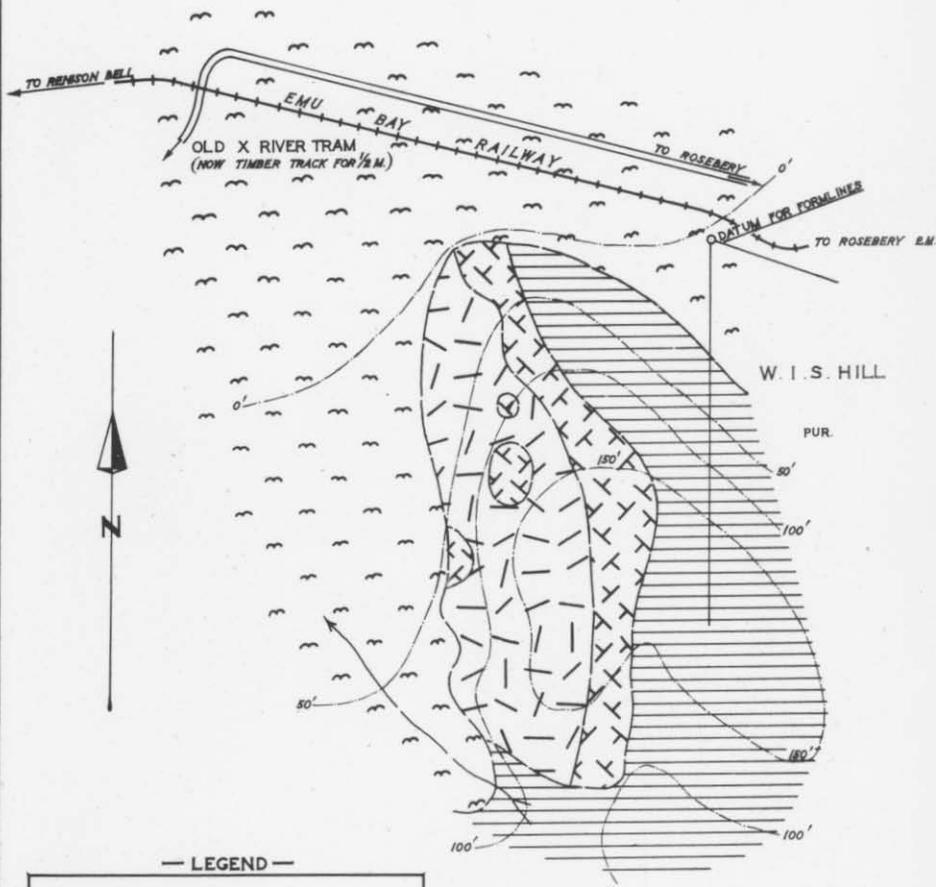


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ASBESTOS IN TASMANIA

THE EXE RIVER PROSPECT

SCALE



— LEGEND —

GEOLOGICAL BOUNDARIES.....	
TRACKS.....	
FORM LINES (50' INTERVALS).....	
FLUVIO-GLACIAL.....	
SERPENTINE.....	
BRONZITE.....	
DUNDAS SLATES.....	

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1949

