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Asbestos at Anderson's Creek

BY

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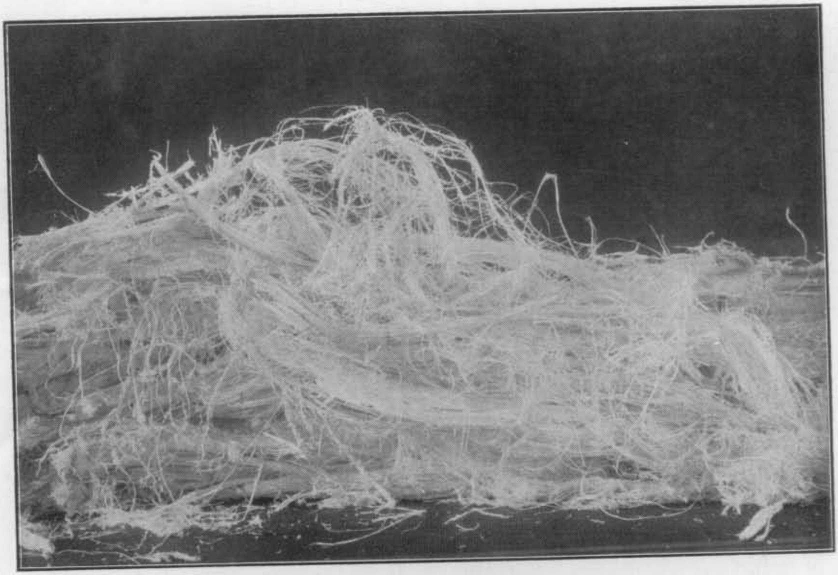

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1. AMPHIBOLE ASBESTOS.

$\frac{1}{2}$

2. CHRYSOTILE ASBESTOS.

$\frac{3}{4}$

Asbestos at Anderson's Creek

I.—Introduction.

The renewal of interest in the asbestos field at Anderson's Creek, together with the special demand for the mineral by reason of the fact that it has a new application as material of war, has led to a re-examination of the points where operations are now being carried on—which, by the way, have been the sites of prospecting work from time to time during a series of years.

The belt of serpentine rock in which asbestos occurs on each side of Anderson's Creek is about a couple of miles in length from north to south, and 1½ mile in width. Anderson's Creek, a perennial stream, flows through the belt, and empties into the West Arm at about 1½ mile north of the northern boundary of the fibre area. The township of Beaconsfield is situate 2½ miles east of it, and is connected with the field by means of a somewhat rough cart road.

The following official reports have been published dealing with the district:—

1. Geological Surveyor's Report of the Country near Ilfracombe, in the West Tamar District, by Charles Gould (Aug., 1866).
2. Report on the Asbestos Deposits, Anderson's Creek, near Beaconsfield, by W. H. Twelvetrees (20th November, 1899).
3. Report on the Mineral Deposits of the Districts of Beaconsfield and Salisbury, by W. H. Twelvetrees (13th March, 1903)

Although the deposits have received attention at intervals, the attempts at development do not seem to have attained profitable results. Recently, however, the Durabestos Company, of Sydney, and M. Paul Charriol, of Melbourne, have started work on them, and if the serious operations which are now in progress meet with success, the district will witness the birth of a new industry.

A growing demand for asbestos fibre for building and other construction work is springing up; it is being increasingly used for roofing. It is also stated to be of use as a material of war, being employed largely in the construction of new naval vessels, and as a protection against incendiary bombs.

The High Commissioner for the Commonwealth in London has brought the present great demand for, and value of, asbestos, under the notice of the Australian Government, with a view of stimulating the Australian output. It thus becomes of special importance to investigate the possible sources of supply in this State, and the present examination of the Anderson's Creek occurrences has been undertaken with this end in view.

II.—General Geology.

In this report, which is principally economic, the general geology of the field will be only lightly touched upon.

The country to the west of the asbestos field consists of a mountain range hemming in the fibre area in that direction, and terminating at Badger Head, in Bass Strait. This is known as the Asbestos Range, and probably owes its name merely to the proximity of the Anderson's Creek field, for neither serpentine nor asbestos is known to occur in it. The range is composed of schists and slates of Pre-Cambrian age. The probability is that these ancient strata at one time occupied the present area of the serpentine, and extended as far east as Anderson's Creek. On the Dan's Hill meridian on the eastern boundary of the serpentine, are sandstones and quartzites of the Beaconsfield series; these are of Silurian or Ordovician age. The country lying between them and the ancient strata referred to above is occupied by a serpentinised intrusion of ultra-basic rock, the home of the asbestos mineral. This intrusion is considered to be Post-Silurian and Pre-Permo-Carboniferous, *i.e.*, Devonian.

A linear hill ridge of dark granular igneous-looking rock traverses the serpentine in a mean north-and-south direction in the central part of the field. It is flanked on the east side by the chrysotile asbestos area, and on the west by serpentine, with bodies of hematite and magnetite, which at one time were worked for iron ore. It is ¾-mile long by 10 to 12 chains wide, and the crest of the ridge rises into three or four domes or rounded summits. Where it has been cut through by the creek, a massive cliff of bare rock is exposed. In the old days this ridge and its summits went by the name of the Settlers.

Though frequently very massive in aspect, the rock has in places a foliated appearance, and a directional arrangement of its constituent minerals is very marked under the microscope. Different opinions have prevailed as to the origin of the rock, some observers regarding it as a crushed aplitic or granitoid rock, while others interpret its character as denoting a crushed fragmentary rock of the greywacke or arkose type.

Dr. E. W. Skeats, who has kindly examined specimens of the rock, is of opinion that it was originally a rather coarse-grained sediment, containing quartz, aluminous or argillaceous material, and some partly decomposed felspars; *i.e.*, a rock approaching an arkose or felspathic and argillaceous sandstone, and that its present characters are due to contact-metamorphism.

The microscopic characters are those of a schist or gneiss; the constituent minerals are biotite, muscovite, quartz, felspar, with minute grains of apatite, and occasionally a crystal or two of tourmaline. Indications of strain and crushing are present.

A specimen was submitted to the late Professor Rosenbusch, who was unable to recognise in it the structure of an eruptive rock. For the present, therefore, the balance of probability is in favour of the rock having been a sediment, crushed and reconstructed as the result of its pressure by, and inclusion in, the serpentinised rock-mass.

There is also a small exposure of the same rock at the southern end of the old iron mines tramway, south-east of Scott's iron hill.

About ½-mile south of the southern end of the Settlers Range are signs of contact-metamorphic action, in the form of chloritic and vesuvianite rock. The eastern border of the serpentine is not marked by any alteration of the adjoining sandstones beyond their induration, and on Dan's Hill, by a little development of chalcedony. The latter is associated with some arsenical pyrites. Some pits have been sunk near the contact line in search of gold-bearing stone, and prospects are said to have been obtained at the time.

A noteworthy feature of this field is the appearance at various points of small intrusions of granitic rock in the serpentine. One of these occurs round the south-east corner of P. Charriol's Section 7232; another on the north side of the creek east of the tramway bridge; another a couple of hundred yards south-west of the bridge; another in the southern part of the field, on Lot 730 (W. Barnes, 640 acres), 2 chains south of what used to be Gale's gate, on the north boundary-line of the lot, and 5 or 6 chains east of Anderson's Creek. The gate and fence have now been destroyed by fire, and the exact spot is difficult to locate.

III.—Economic Geology.

(*a*)—Serpentinisation and the Formation of Asbestos.

The serpentine rock of Anderson's Creek is confined to an area which was previously occupied by the rocks known by the names of peridotite and pyroxenite. It is an alteration product of primary magnesian silicates, such as olivine and pyroxene.

A very common view has been that the metamorphism occurred in the zone of weathering, and that meteoric waters were the agents of the alteration. This opinion has, however, in recent years, given place to a new conception. Rosenbusch, in his "Elemente der Gesteinslehre" (1910), pointed out that serpentines strongly resist weathering, and adds that their high water content gives rise to the supposition that serpentinisation was effected in association with orogenic processes. Water is taken up from deep-seated thermal sources, the olivine of the fresh rock becomes replaced by serpentinous mineral, and finally the pyroxene follows suit; the specific gravity decreases, and the rock becomes a hydrous magnesian silicate. In the final stages of alteration, opaline silica and magnesia are common products. F. Weinschenk, in his "Grundzüge der Gesteinskunde," quotes a striking example from the Stubachthal of veins of perfectly fresh olivine intersecting completely serpentinised rock, which seems to show plainly that its serpentinisation was due to previous deep-seated causes.

The purely bronzitic rock or pyroxenite is intersected by veins of asbestos only infrequently, but wherever the olivine-bearing rock has been converted to serpentine, small veins of asbestos fibre traverse it in every direction. The minutely-fissured olivine crystals have been penetrated by magnesian silicate in solution, and this has resulted in the gradual formation of serpentine. The excess solution has found its way into, and remained in, the numerous joint-channels of the rock, where it has crystallised in the fibrous form as asbestos. Chrysotile-asbestos is practically identical in composition with serpentine, a hydrated silicate of magnesia. Amphibole-asbestos is an imperfectly hydrated fibrous hornblende.

(*b*) The Relation of the Igneous Rocks to the Asbestos Deposits.

As in Canada, the serpentine at Anderson's Creek is associated with varieties of granitic rock. Small isolated exposures of aplitic, graphic, and hornblendic granite arrest the attention, the more so as any normal granite massif is not known near the west bank of the Tamar. Perhaps the most reasonable explanation of the occurrence here is that both the serpentinised rock and the granitic varieties are the differentiated consolidation products of the same magma reservoir, the acidic intrusive material having remained fluid after the basic part had cooled. The consolidation of the different parts of the entire igneous complex was therefore not quite synchronous, though presumably in the Devonian period.

Somewhat similar phenomena are recorded in connection with the asbestos-serpentine of Quebec. Mr. J. A. Dresser writes*:—

> "Small bodies of granite, seldom exceeding a few hundred feet in length, are very numerous in the peridotite in the vicinity of the asbestos mines at Thetford and Black Lake, where they are generally believed to be essential to the good quality of a deposit of asbestos. They occur as dykes, much folded and broken, and in a great number of small irregular masses, whose relations to the serpentine are extremely difficult to determine. In composition they vary from an acid phase near aplite in the smaller dykes, to hornblende granite in larger masses, and in some of the largest to hornblende-biotite granite."

It may be assumed that heated waters set in circulation by the great granitic intrusion effected the serpeninisation of the cooling peripheral rock, and brought about the deposition of the asbestos. The whole process may be figured in the following broad outlines:—

1. There was the welling-up of the ultra-basic magma, probably the peripheral portion of the great granite magma. This consolidated as pyroxenite and peridotite.

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* On the asbestos deposits of the eastern townships of Quebec, by J. A. Dresser. Economic Geology, 1909, pp. 130-140.

2. The cooled rock was penetrated by protrusions of the granitic magma at various points.

3. The heated solutions set in movement by the above processes originated the serpentinisation of the rock-mass. Differential movements of the serpentine caused slickensided partings, and innumerable small channels and fissures were formed by shrinkage.

4. The wall-rock of the various channels and joints supplied the material, which crystallised as asbestos fibre. This operation was the end term of the entire alteration process. Investigators are not agreed as to exactly how the fibre was formed. Veins of magnetite intersect the serpentine, showing a fibrous crystallisation identical with that of chrysotile.

It must be concluded that the granite and its apophyses have a casual connection with the occurrences of asbestos, for, according to the views expressed here, if there had been no movements of the acidic magma, the basic rock would not have been serpentinised, and asbestos would have been absent.

(c) The Minerals of the Field.

Asbestos.—This has become a popular group name for some minerals differing from one another in constitution, but bearing a certain resemblance in habit. True asbestos is a fibrous variety of amphibole; while the Canadian commercial asbestos is chrysotile or fibrous serpentine. The group name is used in common parlance, and is applied by the trade to both varieties, distinguishing, however, amphibole-asbestos and chrysotile-asbestos.

Both of these varieties occur in the Anderson's Creek field, and both in serpentine rock. The amphibole variety, however, exists also in veinstone, consisting of aplitic granite. This is on P. Charriol's section. The fibre is mainly parallel with the partings in the serpentine in which it is contained. It is several inches in length, has a cottony feel, and can be easily separated with the fingers; cross-vein fibre also occurs. Some of it has a faint greenish tinge, but for the most part it is white, and resembles flax. When heated its hue is pure white. The original amphibole mineral has been partly hydrated, and in recrystallising, has assumed the fibrous structure. As might be expected, its composition differs somewhat from that of chrysotile asbestos. It has less magnesia and water, has more iron; and lime and manganese are constituents. Actinolite or tremolite, in minute colourless radiating tufts, is microscopically associated with the mineral.

Chrysotile asbestos is the fibrous form of serpentine. It is the silky, lustrous, greenish filling of narrow veins in serpentine rock. Its greatest development on the Anderson's Creek field is on the sections worked by the Durabestos Company. The chemical composition of the fibre is similar to that of the serpentinised wall-rock which encloses it. The strength and heat-resisting properties require to be determined by appropriate tests.

Normal veins of chrysotile show the fibres arranged transversely to the vein-walls; sometimes these veins have been displaced so as to cause the fibres to overlap and assume the appearance of long fibres parallel, or nearly so, with the walls. This is termed in the trade "slip fibre," the length of fibre being only apparent. Sometimes, however, without being slip fibre, the crystallisation is in long threads, parallel with joint planes. This is seen in one of the Durabestos trenches, which shows a silky fibre several inches in length. The chrysotile on this field runs through the whole gamut of varieties, from a superb silky quality of the highest excellence, to the stiff vitreous-looking fibre of inferior grade.

Chromite.—A hard, black, isometric mineral, with the composition $FeCr_2O_4$, oxides of iron and chromium. It was formed at a very early stage of rock-consolidation, and is visible as minute granules or octahedra in the serpentine, though these do not appear to be profuse. At one time the mineral was believed to have crystallised during serpentinisation, but this is negatived by its occurrence in fresh peridotite, and it is more natural to suppose that owing to its refractory nature it has survived the alteration of the original peridotite to serpentine. It is evidently associated with the iron ores of the district, as analyses of the ironstone show a content of chromic oxide up to 6 per cent.

Magnesite.—$MgCO_3$, occurs as a white filling of joints in the serpentine rock, from which it is derivatory. It does not exist in sufficient quantity to be of commercial value.

Magnetite and Hematite.—These oxides, besides occurring as ordinary rock-forming minerals, exist in the form of beds or masses in the serpentine on Mt. Vulcan and Scott's Hill, which have been worked as ores of iron. A full account of these occurrences will be found in the Departmental report of March, 1903.* They are associated with asbestos-bearing serpentine. The slopes of the ironstone hills are strewn with nodular and concretionary boulders of brown hematite and magnetite, which below the surface are embedded in red ochreous drift. The latter seems to pass down into hematite and serpentinous clay, finally bottoming on hard serpentine, though doubtless this floor cannot be considered as the downward limit of the iron oxide. According to the old bores, alternations of iron ore and serpentine were met with (on Mt. Vulcan) to a depth of 176 feet. Pieces of fibrous magnetite or "needle ore" are common in the surface soil, liberated, no doubt, from veins in the serpentine. Fibrous magnetite, with cross vein fibres, simulating the habit of chrysotile, occurs in the asbestos belt in narrow veins. Its deposition in this form would seem to be coeval with the formation of asbestos.

Millerite.—NiS. Capillary nickel sulphide, occurs in the serpentine on the Durabestos leases, as tufts of delicate radiating fibres of a brassy colour and lustre.

Rhodonite.—$MnSiO_3$ This manganese metasilicate occurs in intimate association with scapolite in the old quarry on the hill. The scapolite stone shades off into pink rhodonite. Both of these minerals are to be regarded here as contact-metamorphic vein-products. Specimens of rhodonite are now difficult to obtain, the material broken out being buried under the tip.

Scapolite.—Calcium-aluminium silicate. This mineral is seen in the form of large white boulders lying at the entrance to the old hill quarry. At one time it could be seen that their source is a vein in the quarry face about a foot in width, but the face at this spot is now obscured by talus. Mr. G. W. Card, of the Mining Museum, Sydney, has more than once examined this veinstuff, and his latest report is as follows:—

> "Microscopically it is a granular rock, an aggregate of scapolite and felspar (plagioclase). The exact

* Report on the Mineral Resources of the Districts of Beaconsfield and Salisbury, by W. H. Twelvetrees, 13th March, 1903.

optical characters do not help me much; there is no trace of cleavage, but some of the grains seem to show broad twin lamellæ. Physical tests are fairly definite:—

Specific gravity (Walker's balance)—2·65.

Hardness—7, or slightly over.

Fuses quietly at a good heat to a blebby glass.

Na flame so strong it appears to indicate a sodium mineral.

Silver nitrate throws down copious AgCl; chlorine must be present.

The hardness I tested repeatedly; 6·5 is the highest quoted for scapolite, but your mineral seems to scratch quartz."

Tourmaline.—Borosilicate of aluminium and other bases. The ordinary black tourmaline occurs very rarely in the metamorphic schist of the Settlers' Hills. Its sporadic occurrence suggests some connection with the granitic intrusions in this field. It is not, however, any indication here of tin ore.

Serpentine.—Hydrated silicate of magnesium. As a mineral it forms microscopic veinlets in the constituents of the serpentinised rock and veins in the rock-mass, as well as constituting the bulk of the rock itself.

Picrolite.—A woody-looking magnesian splintery mineral is sometimes associated with the asbestos, showing a columnar or incipient fibrous structure, but of no apparent value. It is met with both as a cross-vein filling and parallel with the vein walls. It varies in appearance from that of a harsh asbestos to a flinty-looking veinstuff.

IV.—The Mining Properties.

C. B. Buxton's Leases—6479M, 70 Acres; 6340-M, 10 Acres; 6341M, 80 Acres.

These leases are situate 2½ miles west of Beaconsfield, on the east side of Anderson's Creek. The woodcarters' road from the timbered country on the creek passes through the sections and connects with roads to Beaconsfield and Beauty Point. In the north-east corner of Section 6479 the country is Ordovician or Silurian sandstone, and the dark gneissoid rock of the Settlers crosses its south-west corner; otherwise, the rock of the sections is everywhere serpentine.

The Durabestos Company of Sydney has been prospecting on the three leases as option-holders, Mr. Hartwell Conder, M.A., being the supervising engineer. Although prospecting work has been carried on here at intervals for many years, this may be said to be the first time that a serious attempt has been made under trained control to investigate and develop the resources of the area.

The ground was taken up in 1899 in five leases (1772M, 1773M, 1774M, 1775M, and 1935M), by the Australasian Asbestos Company, which worked the deposits for over a couple of years, and shipped 374 tons of stone to the mainland, with a view of establishing a market before going to any great outlay in developing the property. The material exported consisted of impure fibre, matted and interlaced with decomposed fibrous serpentine rock. The fibre was long, and associated with a good deal of picrolitic stone. A mineralogical feature of this quarry was the occurrence of a patch or vein of scapolite, a foot wide, associated with, and merging into, pink rhodonite. A few boulders of the white scapolite are still lying about the approach.

It was thought that the fibre might be found useful in making asbestic, an asbestos plaster in which the fibre is a substitute for hair. Laid over woodwork, this plaster renders the structure fireproof under ordinary conditions, and it was hoped that a strong Australasian demand would be created and fed by the Company's quarries. The market, however, did not eventuate, and the Company ultimately expended its capital, and died a natural death. The material broken out for use was found gradually to fall off in quality, the stone becoming harder and less fibrous. At the time, the price realised for it was £5 or £6 per ton after treatment in Melbourne, but as only the initial stage had been reached, permanent quotations could not be secured.

A little south-west of the above workings a new quarry was started two or three years ago, and some work has been done in it recently. The face was found by the present option holders to be practically barren when they came here, with the exception of a 10-ft. band of fibre-bearing rock in the north-west corner. A small prospecting shaft was started here, and has been sunk to 27 feet from the floor of the quarry. From 17 feet down to the bottom some good fibre appeared, with a maximum length of $1\frac{1}{4}$ inches, but the rock is poorer at bottom. From what can be seen on the ore-heap, the fibre seems a good cross-vein chrysotile, ranging mostly between $\frac{1}{4}$-inch and $\frac{1}{2}$-inch in length, and occasionally longer. The country-rock is greenish serpentine, somewhat decayed by weathering and intersected by slickensided partings at steep angles. This quarry faces south, and is situate just below the brow of the hill in a favourable position for working. It has been worked into the hill northwards 75 feet by 44 feet in its widest part, and with a face of 15 feet in height.

Over the top of the hill are the north-west quarries, which show narrow repeated ribbon-veins of chrysotile one-tenth to one-twelfth of an inch wide. These veins are, in places, no more than $\frac{1}{8}$-inch apart, and the formation has the appearance of being good milling rock, which would yield a fair percentage of short fibre. Its present value depends upon whether mainland dealers have more than a limited range of requirements.

In the flat country south of the hill quarries, a series of trenches has been opened, all of which expose bands or patches of chrysotile-bearing rock. These trenches yield a nice silky cross-vein fibre usually between $\frac{1}{4}$-inch and $\frac{1}{2}$-inch long, and sometimes some fibre of superb quality 6 inches or 7 inches in length. The trenches may be distinguished by the letters A, B, C, D, E, and F.

A is a set of double trenches east to west, 330 feet and 80 feet respectively, situate in the southern part of Section 6479-M. There are two belts of good fibre rock in the long trench, separated by about 20 feet of lean rock. Some of the fibre from this trench is the best that has been yet seen on the field.

B trench is 160 feet long, situate 200 feet further south, and is in pale-green serpentine rock, showing fibre from one-sixteenth to one-fourth inch in length.

C trench is 100 feet south of the preceding, on the boundary-line between Sections 6340 and 6341. It has been driven a chain east and west. The serpentine is a little harder and the fibre not quite so plentiful as in the northern trenches. Some picrolitic fibre is noticeable on the gliding-planes of the rock.

D trench, with an old shaft, is 100 feet south; and 116 feet further south of this is E trench.

About 200 feet south of the above is an old tunnel which has been driven east, with a long approach. Some good fibre has apparently been obtained from this point, as evidenced by the existence of an old knapping-floor. South of the tunnel are some knobs of hard bronzitic rock, and no further prospecting has been done in this direction. The asbestos area, however, continues, for fair chrysotile fibre occurs 200 feet south-east of the tunnel; and ¼-mile south-east are surface exposures of excellent fibre, ¼-inch and ¾-inch in length. This goes to show that almost anywhere in this field prospecting would disclose fibre. A complete scheme of prospecting would mean the extension of the present plan of work to the whole of the ground, so as to make sure of locating all the important patches.

The present plan has, no doubt, been to carry out as much prospecting as possible, with a fixed limited outlay. As far as operations have proceeded, the indications are that the patches of fibre-bearing rock will be found to be numerous, but of small size. Their number, if they are in close juxtaposition, may possibly compensate for their size. If prospecting results are good, it may possibly pay for a time to break out and ship the fibre-rock to Sydney for the purpose of testing the market; but to restrict export permanently to hand-cobbed fibre or to small parcels of selected stone would be prejudicial to the future of the property. The ultimate realisation of the asbestos resources here involves treatment on the spot, so as to turn to account all lengths and classes of fibre. However, it would be premature to erect crushing and fiberising plant at the present time, before the leases are prospected throughout, and a better idea gained of their capabilities of supplying the demands of a mill, as well as of meeting the requirements of the Australian market generally.

The fibre on these leases is, on the whole, chrysotile-asbestos of varying character, identical in appearance with that usually met with on the market. Some of it is the pale-green variety, separating when rubbed into very minute fibre; other varieties are white and more fluffy; another variety is the well-known slip fibre, several inches long, teasing out into lengths of 2 and 3 inches of soft, silky thread. The flexibility, softness, and length of the fibre at present being extracted appear to be satisfactory though perhaps not quite comparable with the finer Canadian varieties. The analysis of a sample in the Geological Survey Laboratory by Mr. W. D. Reid, Government Assayer, gave the following results:—

	Per cent.
SiO_2	42·80
MgO	41·86
CaO	0·00
Fe_2O_3	5·04
Al_2O_3	2·24
H_2O	8·46
	100·40

The iron oxide content, 5·04 per cent., is considerably higher than in the analyses of Canadian chrysotile fibre, as given by Cirkel. He quotes fibre from Thetford as containing only 0·87 per cent. iron protoxide, and 3·05 per cent. iron sesquioxide. The general run of Canadian fibre seems to be between 1 per cent. and 3 per cent. iron oxide. The remaining constituents in the Anderson's Creek analysis are in normal proportions. The adjacent iron ore deposit is suggestive of an exceptionally high percentage of that metal being present in the serpentine of the field. The presence of iron in asbestos increases its fusibility and diminishes its heat resistance.

The veins, as a rule, do not show the parting in the middle which characterises many chrysotile veins in other parts of the world, so that the width of the vein corresponds with the length of fibre. Some of the veins are accompanied by parallel veins of magnesite, talc, and serpentine mineral.

Occurrences of hard and splintery picrolite, harsh to the feel, are frequent. White veins of this fibrous rock traverse the serpentine, looking like veins of dehydrated chrysotile, but their minute structure does not support the inference. They may, perhaps, be interpreted as being veins of anhydrous asbestiform rock material, but exactly what process has originated them is at present uncertain. They seem to affect the bronzitic and imperfectly serpentinised rock, in preference to rock which has fallen a complete prey to serpentinisation.

The width of the serpentine belt is so narrow that conclusions cannot be drawn as to the relative fibre values of its central and marginal portions respectively. At present good fibre is being found towards both margins, as well as in the centre of the belt. The probability is that the whole of it has come strongly within the range of influence of under-lying cooling granite, which has been favourable for the asbestos-forming process. Perhaps the only qualification is that fibre is most likely to be met with where the serpentinisation is most complete, and in this connection a favourable feature is that the mass of igneous rock is, comparatively speaking, so small that its serpentinisation is almost universal.

SECTION 7232M (80 ACRES—P. CHARRIOL).

This is situate a little over a mile from the preceding property in a north-westerly direction, 1½ mile from the mouth of Anderson's Creek, and ½-mile west of the latter. Two roads give access to the lease—one, the Leonardsburgh-road, from Beaconsfield, and the other, a longer but better one, round by York Town, at the head of the West Arm. A short cut may be taken across the creek on E. Dally's 48 acres, by means of a log. The country-rock between the creek and the quarry is serpentine, interrupted on the south-east boundary of the section by one of the intrusions of granitoid rock so characteristic of this asbestos field.

A quarry has been opened in the west part of the lease in rotten and fissured serpentine rock. Partings in the decayed rock, several inches wide, have a general dip towards the north, and are filled in places with long asbestos fibre, between 6 inches and 1 foot in length.

A couple of tons of fibre have been broken out and selected from a formation width of 10 to 15 feet; other formations also appear in the face. The rock partings are open, and have admitted much surface water; in addition to which the quarry has been filled with water for a considerable time, so that the fibre, as taken from the face, is clammy, and somewhat discoloured.

The analysis of the fibre, made by Mr. W. D. Reid, Government Assayer, is as follows:—

	Per cent.
SiO_2	54·88
MgO	18·94
CaO	12·15
Fe_2O_3	10'04
Al_2O_3	2·60
H_2O	1·20
	99·81

The analysis of the amphibole-asbestos is a typical one of that variety, though the iron content here too is above normal.

It is plainly different from the fibre worked on the Durabestos sections. The lime content, and its nearly anhydrous nature, indicates that it belongs to the amphibole division, or asbestos proper. The trade name asbestos, however, includes also chrysotile, the hydrated fibre, which is asbestiform, and known as chrysotile-asbestos. The asbestos of this quarry resembles in appearance the hornblende asbestos of Gundagai, New South Wales. It has a cottony feel, and is easily separated by the fingers. Though the colour is greatly improved in drying by artificial heat, the heating will have to be carefully watched, and its effect on the strength of the fibre determined, for heating has an invariable tendency to weaken asbestos fibre. It will be well not to push the process too far. With more cover it may be anticipated that the fibre will be stronger, and of a purer white.

Besides this long form, a cross-vein white fibre occurs, ½-inch to ¾-inch in length, with the habit of chrysotile, but with the constitution of amphibole-asbestos.

A rather peculiar feature in this quarry is the association with the asbestos of hard felspathic rock, which is found even in the heart of bunches of fibre, and is itself sometimes traversed by veinlets of asbestos. In the present wet and disintegrated condition of the face of the quarry, it is difficult to determine the exact nature of this association, but from appearances the rock is in the form of a vein or dyke, some inches to a foot in width, which has penetrated the serpentine; possibly from somewhat allied rocks, which are seen on the eastern boundary of the lease.

This vein-rock is preponderatingly felspathic, or again quartzo-felspathic, with the microscopic structure of aplite.* The only other rock-forming mineral in it, besides the introduced asbestos, is a little actinolite or tremolite. It is very hard and tough. At the south-east angle of the section, surface stones are seen of a rock consisting entirely of felspar and long-bladed sections of hornblende. Some years ago samples of this rock were sent to Professor Rosenbusch, who recognised that it was an abnormal rock variety, but was unable at the time to assign to it a position in any of the accepted schemes of classification.

* The felspar has the low extinction angles of the oligoclase-and-esine group.

Evidently the formation of asbestos took place during a late phase, for veins of it traverse both the serpentine and the aplite.

In the upper part of the quarry, large splintery fragments of the asbestiform serpentine, known as picrolite, were found. The large pieces bear some resemblance to petrified wood. As is well known, varieties of picrolite are common in the serpentine of most asbestos mines.

In Italy hornblende-asbestos occurs also in serpentine rock, and the experience there is stated to be that as the workings attain greater depth the fibre becomes softer and better. The descriptions of the lumpy bundles of long flax-like fibre in those mines read curiously like the occurrence on Charriol's section. Cirkel, contrasting the Italian hornblende-asbestos with the Canadian chrysotile, says:—

> "Both the Canadian and Italian varieties possess some fine qualities and characteristics, and each finds its special application. Manufacturers even say that in some cases a mixture of both gives better result, and is superior to the best quality of either of them used separately."

Hornblende-asbestos is used for mill-board, and a fluffy variety of it for gas stoves. For engine and similar packing it should find a ready demand. Most of it is too brittle for spinning purposes.

Not much can be said about the present deposit till it is opened up more. More than one band of fibre rock is exposed in the working face, and a fair quantity of material should be available. The conditions indicate the necessity for continuing the face into the hill and freeing the workings from the influence of surface water.

Without incurring the expense of erection of a treatment plant, which at the present stage would be premature, a small drying arrangement seems to be necessary in order to get rid of the superabundant moisture, but, as said above, it must be used with caution.

An important task of the lessee is to assure himself of a market for his output. In this instance it is the prime condition of success. The work can then be laid out and the ground developed with some degree of confidence. The present quarry is apparently situated in a fibre-bearing belt, but for any continuous work, prospecting in advance is essential, for in this class of mining, formations of fibre are notoriously discontinuous and patchy, and success often depends upon keeping work going at one time on several patches.

V. General Methods of Asbestos Treatment.

Treatment methods vary in different countries and in different localities and mines in the same country, so that no particular practice can be quoted as typical. Differences of occurrence, nature of fibre, width of veins, hardness of rock, &c., make it impossible to adopt uniform working schemes. Still, general principles have to be followed. The process involves:—

1. The extraction of the stone from the quarry.
2. Where possible, handpicking the best fibre.
3. Drying and milling the short fibre rock.

A perfectly satisfactory milling treatment has not yet been evolved, but improvements are continually being brought forward and old drawbacks remedied.

Canada sets the milling practice for the rest of the world, producing over 80 per cent. of the world's fibre, and the best information regarding the principles of extraction and treatment must be gleaned from Canadian practice. Mr. F. Cirkel, of the Canadian Department of Mines, has collected much valuable information on this subject, and issued it in his admirable work on "Chrysotile-Asbestos: Its Occurrence, Exploitation, Milling, and Uses" (1910). Older information may be gathered from Mr. R. H. Jones' book on "Asbestos and Asbestic: Their Properties, Occurrence, and Use" (1897). A paper on "Asbestos and its Production in Canada," by W. Mollmann, in the "Journal of the Canadian Mining Institstute" (1902), may also be consulted; likewise "Notes on Plant in the Mining Districts of Canada," by R. E. Commans, in the "Transactions of the Institution of Mining and Metallurgy, Vol. XVIII., 1908-9).

Cobbing.

The rock broken down in the quarry is sorted, and the best pieces go to the cobbing-sheds. The fibre is there separated as far as possible from the rock with hammers, and then with screens. The fibre so obtained is bagged for market and sold as "crude." The separation of the fibre, however, is still very incomplete, and the stone is not entirely eliminated. If there is not much crude fibre obtainable in this way, it answers better to pass all through the mill. Fibre $\frac{3}{8}$-inch and upwards is generally bagged, while shorter lengths are milled.

As an example of a quarry where cobbing has to be carried on, the Takaha quarry, in New Zealand*, may be quoted:—

"The mining—or more correctly speaking, the quarrying—is carried on from open-cuts or benches on the hillside. Hand and machine drilling is practised for the breaking of the rock *in situ*, and the explosives used are dynamite and gelignite. The dark-green serpentine is easily drilled; holes 8 to 10 feet deep are placed, and loaded in such a manner as to break out the rock in masses, as much as 4 tons in weight, with a minimum amount of fines. Heavy blocks beyond the capacity of the derricks are block-holed. Considerable skill is exhibited in the work of drilling and loading the holes, as it demands a thorough knowledge of the direction of the various fissures and cracks. These blocks are lifted by crane on to trucks, and run to the dump; the fines are shovelled and the smaller blocks rolled into shallow wooden boxes (capacity, 10 cubic feet) placed on the ground. When filled these pit-boxes are hoisted on to truck-frames, built to tip their load in any direction, and sent to the dump. When this work is sufficiently advanced, operations commence on the asbestos-bearing rock, enough powder being used to shatter without scattering the material. A rough sorting takes place; slabs and pieces of fibre more or less free of rock are picked up, thrown into hand-barrows, and sent to the cobbing-shed, together with blocks containing inch-fibre, or longer, which is easily separable from the rock; whilst the balance is paddocked for future mill treatment. The derricks consist of a mast stepped in a cast-iron plate, and held in position by six or eight galvanised iron guys. The 30 to 50 feet booms are so arranged that they can be raised or lowered at will; the hoisting-rope leads over a sheave at the outer end of the boom, thence two sheaves placed above and below the hollow pivot of the mast, through which it passes to the winch or horse-whim. This arrangement permits the derrick to swing a complete circle.

At the cobbing-shed the fibre is freed from the adhering rock, $1\frac{1}{2}$ lb. hammers being used for the

* See "The Mining and Engineering Review," September, 1911.

purpose. The work is done on any piece of scrap-iron, steel, or even stones, offering a level surface about a foot square. The fibre is then graded, according to its length, colour, and purity; usually material 1-inch long and over is graded No. 1, and put up in 100-lb. bags for the market. Some operators include fibre of less length, which is one reason for the wide variation in the price of this grade. All the waste is retained for mechanical concentration. Cobbing is a very troublesome and expensive process. It is done in a rough and ready fashion, and the loss is enormous, as the adherent rock is firmly frozen to the asbestos; but so far it gives better results, both as regards the extraction and cost, than any other known method."

Drying.

The next step is to dry the rock, which, as it comes from the quarry, generally contains much moisture. Any steam-pipe or furnace arrangement as commonly used for drying ores will answer the requirements, but the rotary drying cylinder is the appliance used in most works of any size, although it has certain disadvantages in heat losses and excessive fuel consumption, which are, however, counterbalanced to some extent by its continuous action and its capacity for dealing with a large output. It is essentially a hollow steel tube, 30 feet long and 3 or 4 feet in diameter, rotating 6 to 8 times per minute. It is surrounded by the fire, and the stone gradually loses its moisture as it works its way slowly down the inclined rotating tube.

Crushing.

To crush the rock before drying is considered correct practice, as it greatly assists the subsequent drying. It is, however, only done in some mills. It is usually accomplished by a mill of the jaw stonebreaker type. The details of the process vary, a rough classification sometimes being effected, and the coarser rock recrushed in a second stonebreaker.

Generally a jaw stonebreaker effects the first crushing, after which the stone passes in some mills to a rotary crusher of the Gates type. A still finer crushing is then achieved by rolls. The stone, as it goes to the rolls is in pieces not exceeding the size of a nut. It is further reduced, and is then ready for separation into fibre and waste respectively.

Fiberising.

This part of the process of separation is known under the term "fiberising." The machines for effecting the separation are the so-called "cyclones," which consist of enclosed blades of the screw-propeller type revolving in opposite directions at a high rate of speed (2000 to 2500 revolutions per minute). The air movement caused by the revolution of these blades reduces the material by mutual concussion of the constituent grains to the size of small particles, $\frac{1}{8}$-inch and under. Cirkel says that hard and tough rock can be treated in a cyclone at the rate of 25 or 30 tons a shift, while soft rock can be dealt with at the rate of 40 or 50, or even 60, tons.

The pulverised material is discharged on to shaking screens, one-sixteenth-inch mesh, in an air-tight box, from which an exhaust or suction fan draws the fibre off into collectors and settling chambers. The shaking screens separate the sand and small particles of rock from the fibre, which, having worked its way to the surface of the layer of material, is ready to be drawn off by fans into settling chambers.

In the collecting or settling chambers the fibre is graded by means of revolving screens, the dust going off through escape holes. The dust carries extremely fine particles of fibre, and is sometimes collected for asbestic plaster.

The above is an abstract of the general principles of asbestos milling, as gathered principally from Cirkel's exhaustive treatise, but the application of them varies in nearly every mill, according to conditions and requirements.

VI.—Cost of Erection of Mills.

The factors which govern cost are so variable that an estimate for any particular mill can be framed only by the engineer consulted in the matter of erection. As an illustration of the approximate cost of a typical mill, Cirkel gives £10,000 for mill with two cyclone units and a capacity of 240 tons per day of 24 hours, plus about £4000 for mine equipment and £3000 working capital. This is stated to be a moderate estimate, some plants having cost a great deal more. The same authority states that the number of cyclones governs the milling capacity, a cyclone treating 120 tons per double shift. Most mills have two or three cyclones. One to $1\frac{1}{4}$ horsepower per ton of rock treated is given by Cirkel as the power requirements for asbestos mills. Commans says the larger mills have a capacity of 500 tons per day, and require one to one and three-quarter horsepower per ton of rock, 75 per cent. of which is absorbed by the crushers.*

VII.—Cost of Asbestos Production at Anderson's Creek.

At the present stage only an approximate forecast can be made, the percentage of fibre in the rock not being yet established, and very little guidance available for forming a proper idea of milling costs. Part of the output of stone being derived from the hill quarries and part from excavations in the flat country, the quarrying cost will be affected by the proportion of work carried out at the respective points. It looks as if fully one-half, if not more, of the rock broken will go to the spoil heap, perhaps a very small proportion be cobbed, and the rest milled. Some patches of rock would go straight to the mill, while intervening barren blocks of ground would have to be excluded. The rock milled might yield 5 per cent. of fibre, or possibly somewhat over that percentage. In Canada the extraction runs from 6 per cent. to 10 per cent. for ordinary cross fibre, and from 7 per cent. to 12 per cent. for slip fibre. Individual examples vary considerably Thus, in some Canadian mines, nearly the entire output of rock is milled, and yields 8 per cent. of fibre. Other mills are quoted as giving an extraction of 5 per cent.; in another proposition 35 per cent. waste rock is rejected, and the balance gives 8 per cent. At another (a slip fibre quarry) all the rock goes through the mill, and the extraction exceeds 7 per cent., and sometimes even attains 12 per cent. The general extraction in asbestos mills in different parts of the world appears to conform practically to these figures; thus, in Cyprus, the rock quarried contains from 8 per cent. to 10 per cent. of fibre; in Rhodesia, 6 per cent. to 10 per cent.; in Wyoming, the milling rock runs

* "Notes on Plant in the Mining Districts of Canada," by R. E. Commans. Trans: Inst. of Mining and Metallurgy, Vol. XVIII., 1908-9, p. 185.

from 5 per cent. to 10 per cent. As a whole, it may be said that the asbestos production of the world is from rock containing between 5 per cent. and 10 per cent. marketable fibre.

As regards Anderson's Creek, supposing that half of the rock goes to the dump, and only a negligible proportion is cobbed, as mentioned above, the milling-rock might very well contain anything between 5 per cent. and 10 per cent. of fibre. Some samplings have given more than this, and in certain patches the whole rock seems to consist of fibre, but this is ascertainable only by crushing the material. Mr. W. B. Smith reported in 1910 that four samples of rock taken by him and crushed yielded 16 per cent., 17 per cent., 23 per cent., and 24 per cent. respectively, and that he considered that most of the asbestos-bearing rock contained between 15 and 30 per cent. of fibre. This estimate is probably excessive if applied to the formation in its entirety. On the other hand, there are belts of rock which are quite barren, and while these would be avoided in working as much as possible, some of them would have to be taken out in developing the quarries. If a 10 per cent. extraction could be obtained, it would seem possible to produce the fibre at works site on the spot for something like £8 or £10 per ton. If a lower rate of extraction ruled, the cost would be correspondingly higher. In Canada the cost seems to range between £4 and £7 per ton; and the average fibre content of the rock milled in 1915 was 5·71 per cent., as against 6·03 per cent. in 1914.

VIII.—Realisation of the Product.

A difficulty met with in forming a satisfactory opinion with regard to the returns is that the grades of fibre in the asbestos trade are not standardised, and are different at different mines, so that little information can be gleaned from mere general quotations. In some cases the grades are regulated by the length of fibre, in others by its quality; but for the most part by length and quality combined.

Thus, Cirkel states that No. 1 crude is a fibre about 1 inch long, and No. 2 from ½-inch to 1-inch. Other market grades comprise No. 1, of 1-inch length, and No. 2, averaging ¼-inch. "Mill stock" (*i.e.*, fibre from milled rock), is classed in three grades; and besides this there is the dump sand "asbestic."

The crude fibre obtained by hand-picking commands the highest price. In 1915, the prices realised in the Quebec province of Canada, which produces practically all the asbestos of the Dominion, were for No. 1 crude long-fibre £55 per ton; and for No. 2 crude, £24 10s. per ton; for the mill stock Nos. 1, 2, and 3, £13, £5 7s., and £2 10s. respectively. The asbestic was valued at 3s. 6d. per ton. These prices did not vary more than a pound or two from those ruling for three years previously. It should be mentioned here that the mill products in the above statement are classed arbitrarily for statistical purposes in three qualities, namely £9 per ton and upwards; between £9 and £4; and less than £4 per ton respectively. (Mill stock Nos. 1., II., and III.) The hand picked crude is classed according to its value of £40 per ton, and upwards; or less than £40 per ton (Nos. 1 and II.). It is of interest to observe that the mean value of the total rock broken is 6s. per ton, and this seems to be a pretty constant figure.

The crude fibre is stated to command startling prices in Australia, but reliable information about Australian prices is in the possession only of the firms who control the local market. The bulk of the chrysotile which would be won from the Anderson's Creek field would probably range between ¼ and ½ inch lengths.

The production of fibre in Quebec from 1911 has been:—1911, 102,224 tons; 1912, 111,175 tons; 1913, 136,609 tons; 1914, 107,401 tons; 1915, 113,115 tons.

In the annual report for 1915 of the Minister for Mines for Quebec, it is stated that.—

> "In the earlier part of the year the Jacobs and British-Canadian Mines suspended operations, most of the other mines only working half or one-third time. This temporary suspension dated from the beginning of the European conflict, and was the result of the closing of the German markets and difficulty in obtaining the necessary cargo space in vessels between America and Europe. The difficulty was diminished only when asbestos began to be employed for war purposes. On the other hand, since last spring the great demand for it on the part of American manufacturers has eliminated the disease which threatened to paralyse this industry . . . . It is interesting to note that the demand for the higher grades of asbestos was greater in 1915 than in any previous year; while 1913, a year in which there was the maximum activity in constructional work, witnessed the greatest consumption of all the lower grades."

General confidence in the future of the trade prevails in Canada amongst those interested. At most of the mines the reorganisation of quarries and mills is under way; improvements in haulage, in motive power, and in the concentrating machinery are being effected, which it is anticipated will reduce the cost of the output and put the mine-owners in a position to cope with the increased demand which they believe they will have to face in the near future.

IX.—Extraction of Ornamental Stone.

Section 7414-m (80 Acres—H. Conder).

This section is south of and adjoining the 80-acres lease 6341-m, and has recently been taken up for prospecting the extension of the asbestos belt existing on the northern properties. It is in serpentine rock, and with search, no doubt, fibre rock will be found on it.

On it is a little bridge crossing over Anderson's Creek, and 400 feet south of the bridge, though still east of the creek, is a quarry which was worked for a time by the Tasmanian Greenstone Company for ornamental building stone. The quarry has been opened in serpentine rock for a depth of from 15 to 20 feet. The derrick for lifting the stone is still there, and some blocks of hewn and squared stone 3 or 4 feet by 1½ and 2 feet are lying about the quarry ready for shipment. The attempt to establish an industry was a laudable one, and it is to be regretted that it did not meet with greater success.

The stone is a dark-green mottled serpentine, and would take a good polish. Unfortunately, it is traversed by innumerable parallel partings, not more than an inch or two apart, which, while enhancing the beauty of the prepared stone, will inevitably cause the rock when sawn to break away into thin slabs, and it is probable that the same tendency will develop in the solid blocks if left exposed to the weather long enough. This feature is common in serpentine rocks all over the world, and they are notorious for bad joints. This drawback makes it difficult to obtain good-sized slabs of serpentine rock for building purposes. Its weathering also is too irregular to make it reliable for exterior work; but where it is sufficiently massive it can be used for decorative and other interior work, for which it is highly prized.

From the above it will be gathered that the quarry rock is none too good for the object which was in view; and in any case, on account of the want of uniformity in the physical characters of the stone in this field, it will be necessary to open up and test more than one quarry. With a greater population and an increased demand for decorative work and articles de luxe, a profitable trade of modest dimensions could probably be developed. At present the market has to be created, and care must be taken not to put the stone to a wrong use, which will militate against success later on.

X.—Conclusion.

The field is in that condition that it may develop into the source of a profitable industry. Present prices of asbestos and asbestos productions are encouraging. Information from the Commonwealth offices in London is to the effect that every particle of asbestos is now worth £20 per ton. In this case the market prices in Australia should be such as will enable the Anderson's Creek deposits to be worked at a profit, if workable patches of any size can be exposed.

Preliminary prospecting work on a large scale seems necessary in order to establish the tonnages available, and this must be done before the installation of a treatment plant can be thought of.

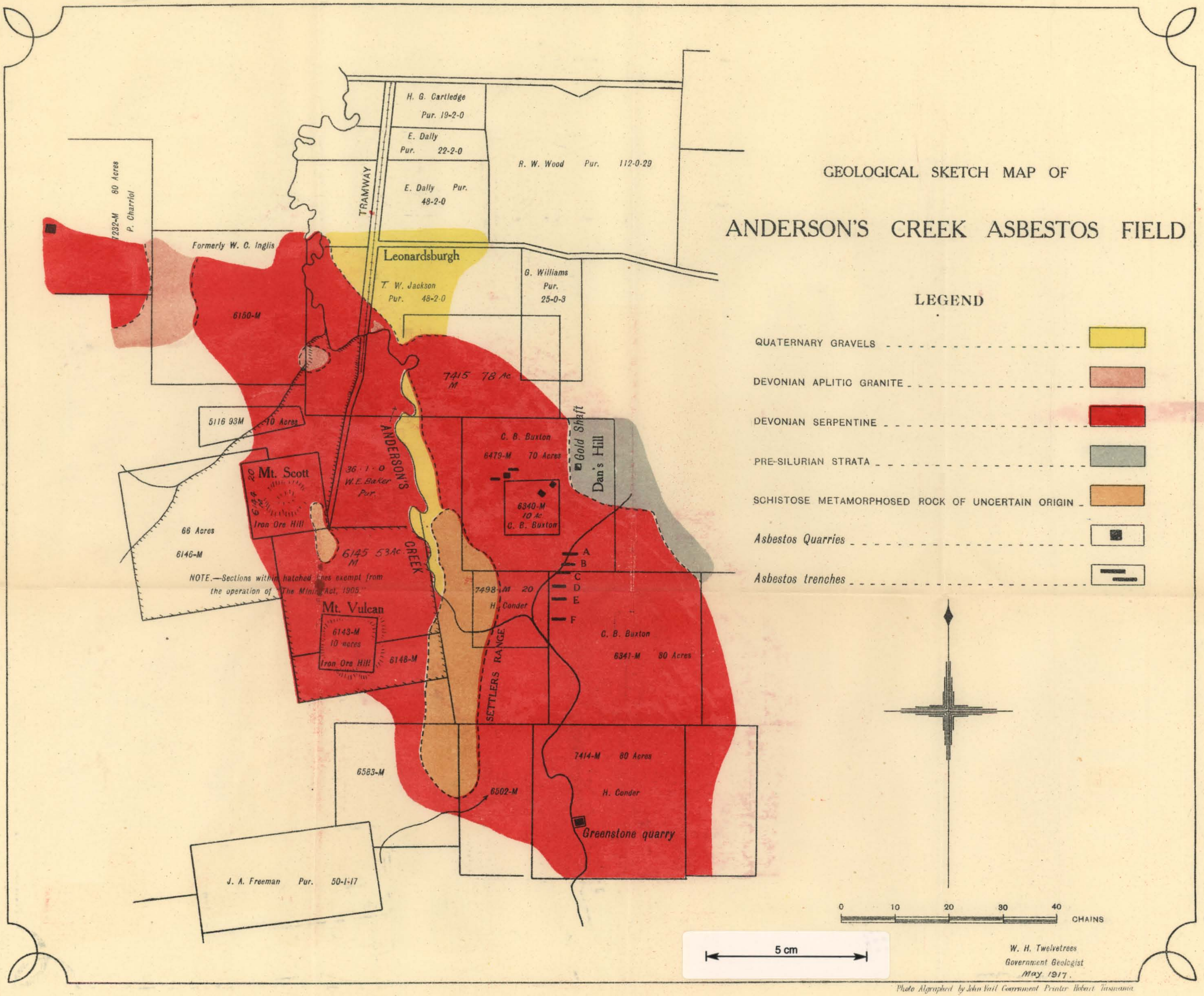
The question of providing Government assistance in establishing a new industry of this kind deserves attention. The policy of the Government has been to assist mining by grants-in-aid and advances on the £ for £ principle, and it is to be presumed that the operators of asbestos properties will enjoy their share of whatever votes may be passed by Parliament. In addition to this, the industry might be fostered by payment of a bonus of so many pounds sterling per ton upon the first 500 or 1000 tons of marketable fibre produced.

Some fear has been expressed lest the asbestos veins should prove to be merely superficial phenomena, and cut out in depth. Against this may be set the fact that the formation of asbestos was a deep-seated process. In Canada, asbestos has been met with at a depth of 400 feet. The question of depth, however, need not disturb leaseholders, for the patches of fibre-bearing rock are so irregular that they will not be followed to any great depth.

Quarrying may be expected to be the extraction method employed, as sinking is hardly likely to be remunerative except where the orebody is large and continuous, and the fibre of high grade. If prospecting discloses any broad zones of fibre rock, the outlook for the field will be bright. Present developments show the area in question to possess potentialities which it is possible that the work which is now proceeding may convert to payable actualities.

W. H. TWELVETREES, Government Geologist.

Launceston, 18th May, 1917.


GEOLOGICAL SKETCH MAP OF
ANDERSON'S CREEK ASBESTOS FIELD
LEGEND
QUATERNARY GRAVELS
DEVONIAN APLITIC GRANITE
DEVONIAN SERPENTINE
PRE-SILURIAN STRATA
SCHISTOSE METAMORPHOSED ROCK OF UNCERTAIN ORIGIN
Asbestos Quarries
Asbestos trenches
H. G. Cartledge Pur. 19-2-0
E. Dally Pur. 22-2-0
E. Dally Pur. 48-2-0
R. W. Wood Pur. 112-0-29
TRAMWAY
7232-M 80 Acres P. Charriol
Formerly W. C. Inglis
Leonardsburgh
T. W. Jackson Pur. 48-2-0
G. Williams Pur. 25-0-3
6150-M
7415 78 Ac. M
5116 93M 10 Acres
ANDERSON'S CREEK
C. B. Buxton 6479-M 70 Acres
Gold Shaft
Dan's Hill
Mt. Scott
Iron Ore Hill
36 : 1 : 0 W. E. Baker Pur.
6340-M 10 Ac. C. B. Buxton
66 Acres
6146-M
6145 53Ac. M
NOTE.—Sections within hatched lines exempt from the operation of "The Mining Act, 1905."
A
B
C
D
E
F
7498-M 20 H. Conder
Mt. Vulcan
6143-M 10 acres Iron Ore Hill
6148-M
SETTLERS RANGE
C. B. Buxton 6341-M 80 Acres
6583-M
6502-M
7414-M 80 Acres H. Conder
Greenstone quarry
J. A. Freeman Pur. 50-1-17
0 10 20 30 40 CHAINS
W. H. Twelvetrees Government Geologist May 1917.
Photo Algraphed by John Vail Government Printer Hobart Tasmania