SOUTH AUSTRALIA

Department of Mines

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

BULLETIN No. 26

TALC DEPOSITS
IN SOUTH AUSTRALIA

BY

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Officers of the C.S.I.R.O.

Issued under the authority of
The Honourable A. Lyell McEwin, M.L.C., Minister of Mines

K. M. STEVENSON, GOVERNMENT PRINTER, ADELAIDE.
1951

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LETTER OF TRANSMITTAL

Geological Survey Office, Department of Mines,
Adelaide, 24th August, 1950.

Sir,

I have the honour to submit to you a report on the talc deposits of South Australia.

The investigations of the talc resources of the State were made by officers of the department in close co-operation with Dr. F. L. Stillwell and Dr. A. B. Edwards of the Commonwealth Scientific and Industrial Research Organization. They also included experiments on the beneficiation of low-grade material carried out by Mr. D. R. Blaskett of the C.S.I.R.O. and Mr. N. Jackson of the Department of Mines.

The demand for talc and other non-metallic minerals in South Australia increased markedly during the Second World-War when overseas sources of supply were severed. Australian manufacturers succeeded in using material from local deposits. In recent years the quality of the mine output has increased to a parity with that of the imported raw materials such that local supplies have continued to supply the Australian market. For the year ended 31st December, 1949, the output reached a record mark of 6,643 tons valued at £44,333.

The report gives a general review of the development of the industry in the State, and the uses, specifications, prices, and market for talc. The industry is changing rapidly and, with an increasing demand, the introduction of mechanical equipment in the mines and the establishment of beneficiation plants can be expected in the near future. South Australia supplies the greater proportion of Australian talc requirements. The publication of this report is aimed to encourage the largest possible use of these resources by acquainting consumers and other interests with the characteristics and potentialities of the known occurrences.

I have, etc.,

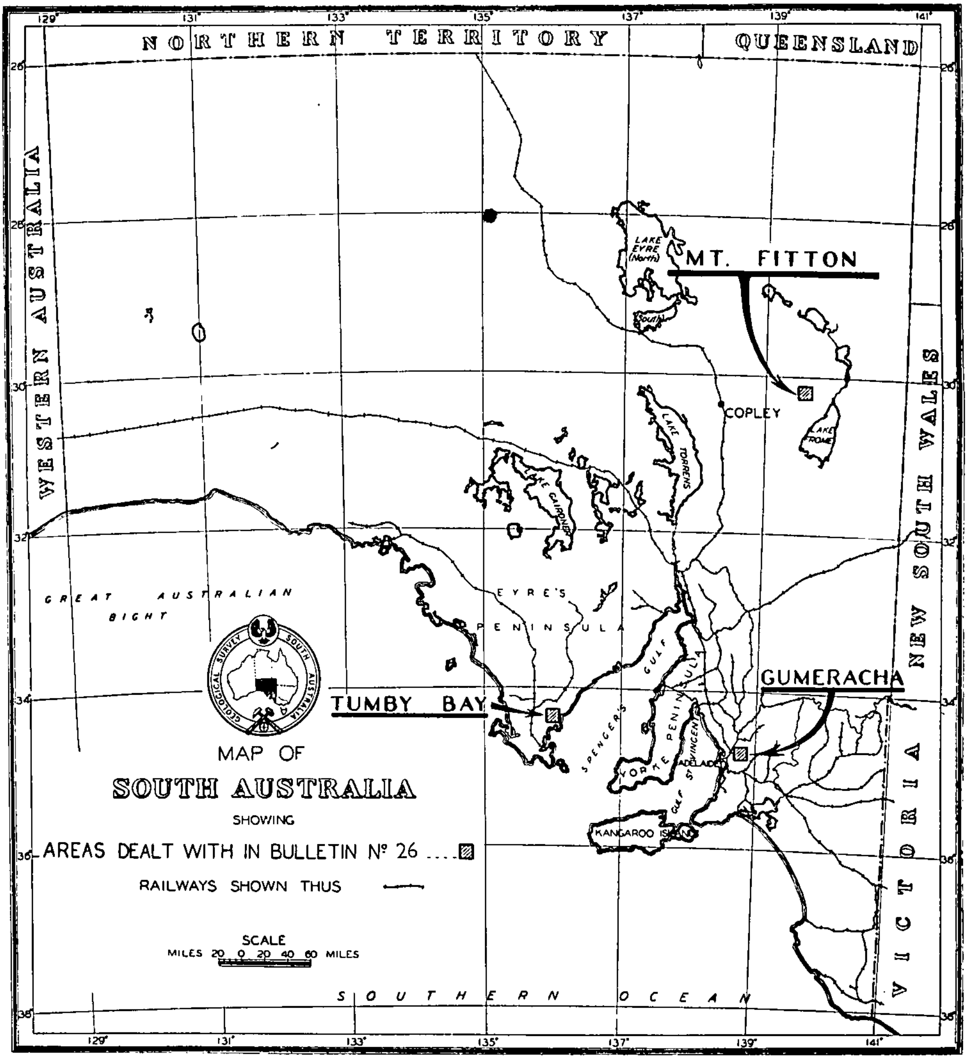
S. B. DICKINSON, *Government Geologist.*

The Hon. A. Lyell McEwin, M.L.C., Minister of Mines.

Submitted for approval to print as a Bulletin of the Geological Survey of South Australia.

Approved,

A. LYELL McEWIN, *Minister of Mines.*



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TALC DEPOSITS IN SOUTH AUSTRALIA

PART I

GENERAL INTRODUCTION

BY

S. B. Dickinson, M.Sc. (Director of Mines and Government Geologist)

South Australia has long been the chief source of talc in the Commonwealth, and production has increased notably over the last 10 years. In 1947 it amounted to 4,460 tons, and in 1948 to 3,874 tons. Production has been stimulated by the expansion of Australian industries and the difficulty of obtaining supplies from abroad. Investigations have revealed that all Australian demands for many years to come can be met from deposits in South Australia, and there are ample reserves to warrant the development of an export trade, in the higher grades of talc, with such countries as New Zealand.

The mineral occurs in bodies of irregular form within rocks having a notable content of magnesia, in the state of either complex silicates or carbonates, where these rocks have suffered metamorphism or attack by hydrothermal solutions. They are restricted to regions in which the older rocks have been subjected to those processes, and are especially common in dolomitic marble, and less so in ultra-basic igneous rocks, schists, and gneisses.

In South Australia two types of occurrence are found. The Tumby Bay and Mount Fitton deposits are associated with dolomite and dolomitic marble, whilst the deposits at Gumeracha occur in mica schist and quartzite. The Gumeracha occurrence is believed to be unique, and F. L. Stillwell and A. B. Edwards have concluded that the magnesian component of the talc was derived, most probably, from the magnesian-bearing biotite of the original schists. There are no known commercial deposits of talc in South Australia formed from the alteration of basic intrusives.

The three main mining centres—Gumeracha, Tumby Bay, and Mount Fitton—produce distinctive types of talc with properties which make them suitable for special uses. The nature and origin of the deposits are discussed elsewhere in this *Bulletin,* in addition to the detailed accounts of their mineralogy and petrology by Stillwell and Edwards of the Mineragraphic Section of the Council for Scientific and Industrial Research, who visited each field and collected typical specimens for their investigational work.

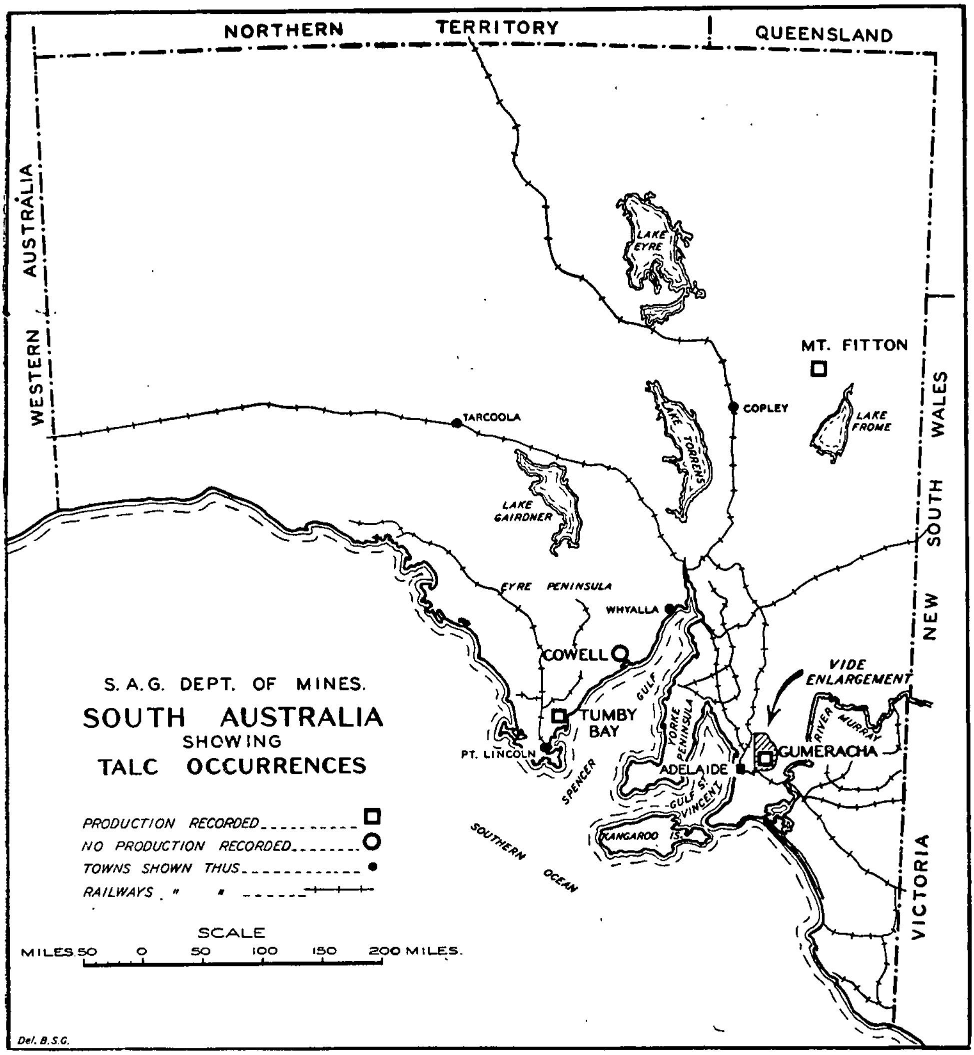
The field mapping was carried out by various officers of the Geological Survey of South Australia, and extended intermittently over a period of four years.

CHEMICAL AND PHYSICAL PROPERTIES OF TALC

Talc is an hydrous silicate of magnesium, and owes its importance as an industrial mineral to its physical properties rather than its chemical composition. It closely resembles pyrophyllite (a hydrous silicate of aluminium) both of which are recognized in the field by their extreme softness and greasy feel.

Steatite is the name given to compact massive talc without visible grain and free from visible impurities.

Soapstone is the name given to any talc-bearing rock that is readily cut and can be worked for the production of sawn blocks and bricks, which are used for oven and furnace linings.


NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
NEW SOUTH WALES
VICTORIA
LAKE EYRE
MT. FITTON
LAKE TORRENS
LAKE FROME
COPLEY
TARCOOLA
LAKE GAIRDNER
EYRE PENINSULA
WHYALLA
COWELL
TUMBY BAY
PT. LINCOLN
SPENCER GULF
YORKE PENINSULA
ADELAIDE
GULF ST. VINCENT
KANGAROO IS.
GUMERACHA
VIDE ENLARGEMENT
RIVER MURRAY
SOUTHERN OCEAN
S. A. G. DEPT. OF MINES.
SOUTH AUSTRALIA
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TALC OCCURRENCES
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Fig. 1

The chemical composition of pure talc is generally expressed as $3MgO.4SiO_2.H_2O$, but the actual proportions of SiO_2, MgO, and H_2O are known to vary within small limits. According to the above formula the theoretical composition of pure talc is given in the table below, which also contains analyses of the best grades of South Australian talc now being worked.

CHEMICAL COMPOSITION OF SOUTH AUSTRALIAN TALC

	Theoretical composition of pure talc	Tumby Bay talc*	Gumeracha talc*	Mt. Fitton (Flinders Range) talc*
Silica (SiO_2)	63·50	61·26	61·90	62·16
Magnesia (MgO)	31·70	30·53	28·23	32·06
Alumina (Al_2O_3)	—	1·76	1·88	0·61
Iron oxide (Fe_2O_3 and FeO)	—	0·37	2·31	0·58
Lime (CaO)	—	nil	nil	nil
Soda (Na_2O)	—	0·17	0·68	nil
Potash (K_2O)	—	0·10	nil	nil
Water at 100°C. (H_2O)	—	0·22	0·03	0·11
Water above 100°C. (H_2O)	4·80	4·90	4·66	4·51
Chlorine (Cl)	—	0·30	nil	—
	100·00	99·61	99·69	100·03

* Analysis by T. W. Dalwood, Departmental Analyst and Assayer.

The alumina, ferric and ferrous iron, lime, soda, potash, and chlorine are due to the presence of minute amounts of associated minerals invisible to the naked eye. The nature of these minerals is described by Stillwell and Edwards in their mineragraphic reports on the respective deposits.

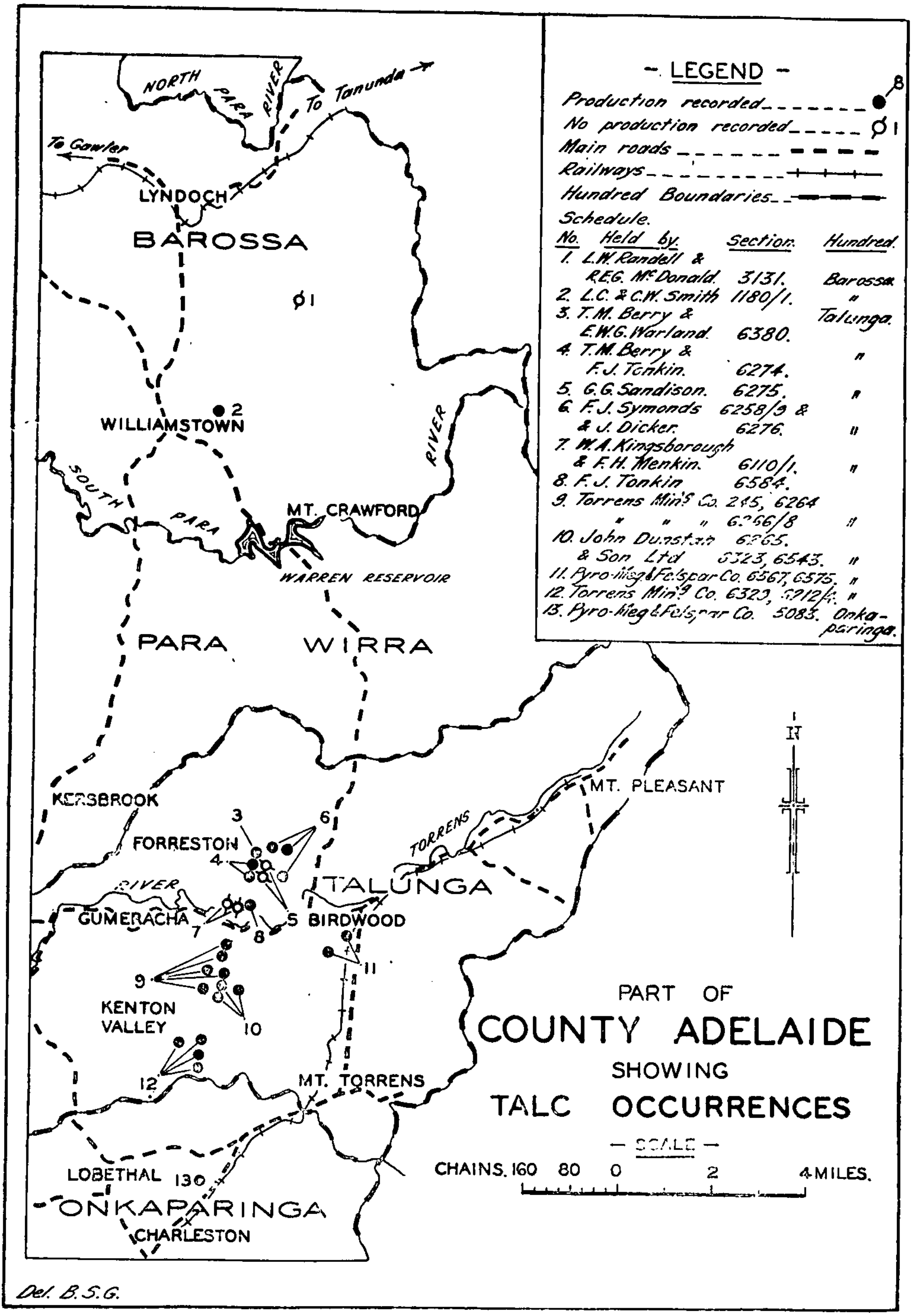
Generally speaking the value of talc for commercial use is dependent, in the first place, on its purity. Best quality talc is free from, or contains only traces of, lime, iron-bearing minerals, and gritty material. Lower grades may contain appreciable amounts of these impurities, and are sold at lower prices. The presence of impurities causes marked variation in the physical properties of talc and, as the suitability of a talc for a particular industry depends largely on its physical properties, the determination of these is important before the output from a particular talc deposit is acceptable to a consumer. Chemical analysis is generally of secondary importance.

The more important physical properties of talc are its softness and ready tendency to cleave into thin flakes which are responsible for its greasy feel. In addition its resistance to both physical and chemical change, and its low electrical and heat conductivity, afford it wide application industrially, and its range of use is continually increasing. Unfortunately no universal standard testing methods or specifications for talc are generally recognized, and at the present time its value is largely a matter of individual opinion. Its range of use and value to industry depends to some extent on its relative abundance and cost of mining and preparation, as substitutes can be found for many of its uses. The properties of talc are dealt with further in the following outline of the main uses of talc.

USES OF TALC

Talc is supplied to industry either in the powdered form or in blocks.

Powdered talc is by far the more important and is valued and used chiefly on the basis of colour, on the hardness and shape of grain, and grain size. At the deposits the talc is generally carefully hand-picked into two grades, for dispatch to milling plants in Adelaide, Melbourne, and Sydney. First grade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Production recorded
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Main roads
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Schedule.
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1. L.W. Randell & R.E.G. McDonald. 3131. Barossa.
2. L.C. & C.W. Smith 1180/1. "
3. T.M. Berry & E.W.G. Warland. 6380. Talunga.
4. T.M. Berry & F.J. Tonkin. 6274. "
5. G.G. Sandison. 6275. "
6. F.J. Symonds & J. Dicker. 6258/9 & 6276. "
7. W.A. Kingsborough & F.H. Menkin. 6110/1. "
8. F.J. Tonkin 6584.
9. Torrens Min.g Co. 6264
10. John Dunstan & Son Ltd 6543. "
11. Pyro-Meg & Felspar Co. 6567, 6575. "
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PARA WIRRA
KERSBROOK
MT. PLEASANT
FORRESTON
TORRENS
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TALUNGA
GUMERACHA
BIRDWOOD
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N
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SHOWING
TALC OCCURRENCES
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Del. B.S.G.

Fig. 2

comprises material specially selected for its whiteness and freedom from visible gritty impurity. Second grade comprises slightly off-colour talc with little visible impurity. At the milling plant, both first- and second-grade talc are ground to particle sizings required by the various trades. No serious attempt has yet been made to improve the quality of the ground product by ore-dressing methods, which would remove or reduce the content of mineral impurity in the run-of-mine material before or during the grinding process.

Block talc is more commonly referred to as steatite or soapstone. It has a limited range of use, and the consumption is exceedingly small compared with that of powdered talc. The deposits from which block talc is produced are worked only at infrequent intervals, whilst the mines producing talc for subsequent use in the powdered form are in continual operation.

USES OF POWDERED TALC

Paint Industry

Talc is now recognized as one of the important constituents of a large number of paints. It is used in their manufacture, both as a filler and as a pigment.

Its value as a filler is due to the tendency of the flat flake-like grains of talc, in ready-mixed paints, to remain in suspension and prevent the settling of pigments. Also, paints containing talc as a filler are found to have a superior covering power per unit weight of filler. In oil paints the quantity used usually does not exceed 5 per cent of the total pigment.

As a pigment, its whiteness gives a strong binding power to complex colouring agents, and is used largely in cold-water paints for covering interior plaster-work. During the war talc was used extensively in special non-reflecting paints. When mixed in greater proportion with other paint constituents its chemical stability is extremely important, and if its content is increased sufficiently, that is, to about 50 per cent of the total solid constituents, it produces fire-resisting qualities in certain paints. Being a poor absorber of moisture it contributes to the waterproofing properties of certain enamels and roofing paints.

For satisfactory use in all types of paint it should be ground to pass a 200-mesh screen—preferably a 350-mesh screen—and be free from gritty impurities, moisture, and any material causing discoloration.

Powdered talc is generally sold to the paint industry under the name of "asbestine", which is very misleading, as besides giving the erroneous impression that asbestine is ground asbestos, the name is not restricted, as originally intended, to fibrous talc or a mixture of talc and tremolite which make a good paint-filler with strong bonding properties. This name (asbestine) is now equally applied to granular or platy talc containing carbonate or clay impurity, which lacks distinctive bonding properties of true asbestine. It is desirable, therefore, that paint manufacturers should know the origin of the talc they are consuming, and the properties of the naturally occurring material. For example, the Tumby Bay talc contains a white clay impurity and occurs in a pulverulent form; it lacks the high slip and platy texture of Gumeracha talc and Mount Fitton talc.

In Canada and America the paint industry has long been the principal consumer of talc; but in Australia the paint industry is a very minor consumer.

Paper Manufacturing Industry

Talc is used as a filler in paper of all grades because of its good retention and flaky character. The retention of talc is superior to that of clay and, provided it is procurable at a price equal to, or slightly more than, that of white clay of good quality, it has wide application in this industry. For white paper the talc must have a pure-white colour, a fine grain-size (200 mesh or finer) and be free of gritty impurities. It is used for newsprint as well as the finest grades of paper. Its other physical properties are utilized in the numerous special papers. For example, on account of its moisture- and air-resisting properties it is employed for paper used for preserving purposes; grease-proof paper depends on the low oil and grease absorption property of talc; and tissue paper gets its silky opaque appearance through the use of talc. Generally speaking, talc gives to paper a flatness, smooth appearance, and soft feel unequalled by any other known mineral filler.

Coarser and off-colour talcs find wide application in the preparation of weather-resisting and fire-proof roofing papers. For this purpose it really forms a coating on a paper background. Grain size or colour are not important, but talc for this purpose must be cheap to compete with scrap mica and other cheap by-product materials which have low-moisture absorption properties.

Overseas, the paper industry follows paint in extent of the consumption of talc; but in Australia it is relatively unimportant.

Hitherto, in Australia, talc has been used chiefly as a corrective agent in the preparation of sulphite pulps prior to milling, and partly as a filler for a few special products, such as grease-proof paper. At a reasonable price the consumption of talc in the paper industry in Australia can be expected to gradually rise, now that the major teething problems of the industry have been overcome and more time can be devoted to the study of raw materials. As in the case of the paint industry, the properties of the naturally occurring talcs—such as texture and colour—should be compared with those sought in the paper products, in addition to the routine study of the properties of the milled material accepted for use.

The production of bituminous roofing papers containing coarser ground inferior talc and ground soapstone is increasing, and provides a market for low-grade talc. Scrap mica is equally, if not better, suited for this industry, and is therefore a strong competitor.

Cosmetic Industry

The cosmetic industry is at present the largest consumer of talc in Australia. Only the highest-grade white talcs are employed for the manufacture of a wide variety of goods, principally talcum powders, soaps, creams, lotions, lipstick, and many other toilet and pharmaceutical preparations.

Prior to the war supplies were obtained almost exclusively from India, Italy, and Manchuria; but with the severance of communications it was found necessary to find sources of supply. The extensive testing of Australian talcs proved that suitable material was available locally, and that Australia could be self-sufficient in respect to high-grade talc for cosmetics and to most other grades of ground talc for industrial purposes.

No generally recognized specifications are applied to the purchase of cosmetic talc, but individual consumers insist on it having a good white colour, a good slip, freedom from grit, and fineness of grain size. Apart from fineness—which is determined by a sizing test—these characteristics are determined qualitatively by comparison with standard talc powders whose commercial value has been established. Other properties—which are usually specified and determined chemically—include maximum allowable percentages of moisture, acid-soluble material, water-soluble material, loss on ignition, and iron content, all of which are a guide to the impurities which may be present in tolerable amounts. For example, the acid soluble material is commonly a carbonate impurity.

The constant supply of high-grade talc for the cosmetic industry requires special care in selection during mining and milling operations. As the talc production in South Australia is at present chiefly concerned with the cosmetic industry, the maintenance of quality of output must be regarded by producers as being of prime importance to their successful competition with foreign cosmetic-grade talcs, which can be expected to become again available in Australian markets.

Roofing Industry

Coarse low-grade talc, in some cases produced from the grinding of soapstone, is used in the roofing industry for the manufacture of roofing paper. It imparts weather-resisting and fire-proofing properties to the paper, and is applied both as a filler and as a surfacing agent. Ground scrap mica is generally preferred by manufacturers of roofing products on account of its more pronounced flaky character and greater covering power; but if available at a low cost, talc finds ready use. The extensive post-war building programmes are likely to increase the use of low-grade talc in this industry.

Ceramic Industry

Talc is used in ceramics chiefly for the manufacture of electrical porcelain, wall tiles, and dinner ware. The developments in radio and high-frequency electricity increased the demand for talc during the war. Its chief uses in these fields were for insulators in communication equipment such as radio transmitters, radar, and other electronic devices, and for certain types of spark plugs and other electrical and heat-insulating products. Initially these articles were made from blocks of naturally occurring steatite (or compact massive talc) by machining and drilling to the required shapes which were then fired. The finished product, after firing, possesses remarkable properties. Like talc it is very resistant to chemical and physical changes, and has a very high di-electric strength, but in contrast to raw talc, it is extremely hard with a high compressive strength. Steatite used in this way is sometimes called "lava", which is merely a trade name introduced by one of the pioneer manufacturing companies. Due to the shortage of supplies of pure block talc or steatite, and the high cost which is accentuated by firing losses, intensive research has led to the successful manufacture of steatite insulators from die-pressing powdered talc. Besides being more readily obtainable this method eliminates waste in the fabrication process, and has made possible the addition of other ingredients such as silicate of soda, alumina, and fluxes for the purpose of imparting special properties to the steatite bodies. Although this synthetic lava has largely replaced natural lava for most purposes, the latter is superior where high precision and intricacy of shape is involved.

Generally speaking, talc for ceramic use must contain less than 1 per cent of iron oxide and 1 per cent of lime. By itself, or mixed with certain types of clay, it is finding a wide range of use as a substitute for clay in kitchen-ware and dinner-ware. In America this trend is clearly evident from consumption statistics, which show the ceramic industry in 1939 ranking third on the list of major consumers, having risen from an unimportant position in 1929. In Australia it is reasonable to expect a similar development once the characteristics of local talcs are understood, and adequate supplies at reasonable cost are available.

Rubber Industry

Powdered talc is used extensively in the rubber industry for the dusting of moulds and finished products. Its value lies in its high slip and lubricating power. A good second-grade or off-colour grey talc is generally acceptable to consumers, provided it is free from metallic mineral impurities such as manganese, copper, and zinc. Manufacturers usually require it to be ground to a fineness of less than 200 mesh, and to be grit and moisture free. Besides being used in the manufacture of rubber, talc is also used on the rubber plantations for dusting the sheets of crude rubber prior to shipment. From the tonnage point of view the rubber industry in Australia is of minor importance, but with the probable establishment of tyre factories in South Australia an increased local consumption may be anticipated.

Foundry Industry

Iron and steel foundries use low-grade off-colour talc for facings and the coating of moulds. It is either mixed with or used instead of graphite. In Australia, production for this purpose has been chiefly iron-stained talc from the Wallenbein deposits of New South Wales, but second-grade South Australian talc has also been used.

Miscellaneous Uses

Talc finds minor application as a filler, absorber, or polishing agent in a vast number of manufacturing processes. Probably of most importance is its increasing use in the manufacture of insecticides, which could almost be classed separately as a major consumer of talc. As a filler it is also used in linoleum and oilcloth; in seals for food containers; in textiles; in polishes; in composition floorings; and in wall plasters. As a polishing, lubricating, and dusting agent it is used in fertilizers to render the product free running; in rice, barley, corn, and other cereals for polishing purposes; in leather goods of all kinds to give a smooth finish; and in moulds of various types to prevent sticking. It is further used, with a suitable binder, for the manufacture of talc crayons for marking steel or glass—talc being the one substance that will mark these materials whether their surfaces are hot or cold. These are a few of the minor uses which talc can serve, particularly if it is available to these trades at prices which are competitive with those of substitute materials.

USES OF STEATITE

The term steatite has already been defined as applying only to massive compact pure talc without visible grain. In South Australia the only naturally occurring material to which this definition can be applied is the Flinders Range talc or steatite. Steatite is ground like ordinary talc for the production of powdered talc, the uses of which have already been considered. Reference has already been made to the declining use of steatite in block form for ceramic ware. In Australia steatite bodies are made almost exclusively from powdered talc, whilst most of the precision lava ware is imported from overseas.

There are no other uses—other than those for which soapstone is used—which would equally be served by steatite.

USES OF SOAPSTONE

Whereas steatite is the term given to a pure dense talc rock, soapstone is any soft impure talcose rock which can be readily sawn. Talc forms the greater proportion of a soapstone, but other minerals are generally conspicuous and may influence the range of its use. When it is ground it is classed as powdered talc and finds use in roofing products and in the foundry and rubber trades to which reference has been made.

Soapstone finds a limited use in the form of sawn blocks and bricks for furnace and oven linings. It is used in the kilns of kraft-paper mills, and on account of its resistance to chemical attack and refractoriness it is ideal for their alkali recovery furnaces. It is also used in bakers' ovens, for brick and slab liners, for fireboxes and stoves, and for fireless-cooker plates, etc. Its suitability for furnace work is generally determined under full-scale working conditions by comparison with "standard stone".

Its acid-resisting properties make it a desirable material for laboratory benches, sinks, tanks, and fume cupboard hoods. Because of its good electrical insulating properties it is used for switchboard panels. There is considerable scope for the expansion of soapstone mining in Australia as, to date, soapstone has only found small application to the above uses, and there are others—notably for building purposes—to which it can also be applied.

PRICES

Powdered talc has a wide range of prices, depending on its purity, physical properties, and fineness of grinding, the specifications for which vary in the different consuming industries.

Roofing and foundry talcs are the cheapest and sell at £6 to £7 per ton f.o.r. Off-colour talcs, fairly free from grit and suitable for the rubber industry, sell at about £8 to £10 per ton f.o.r. White talc for paint, paper, and ceramic use sells at £10 to £12 per ton f.o.r.; while the highest grade of Australian talc—used chiefly for cosmetics—ranges from £19 per ton f.o.r., according to the particular product concerned.

The cost to consumers of best grade imported Indian talc, which is no better than the Flinders Range talc, ranged from £27 10s. to £36 per ton during 1945. It enters Australia under the British preferential tariff of 30 per cent, *ad valorem.* Imports are restricted as long as adequate and suitable supplies can be obtained from local sources at reasonable cost.

Prices of crude talc from the various deposits range from £4 to £10 per ton f.o.r. or f.o.b. for first and special grades at the nearest rail siding or shipping port, and £3 to £5 for second grades. First and second grades at different deposits are not comparable, and the prices are determined by agreement between individual producers and consumers, depending on the purpose for which the talcs are used. The prices generally include an allowance for road transport between the mine and the nearest point of shipment.

PRODUCTION

The total recorded production of talc and soapstone in South Australia since the inception of mining in 1900 to 31st December, 1949, amounted to 51,806 tons, valued at £204,862.

A maximum annual production of 3,868 tons, more than treble the pre-war output, was reached in 1944 as a result of substantial wartime demands for talc from local sources, resulting from drastic curtailment of imports from India, Manchuria, and France, and the development of new uses for war-purposes. The tables and graph, printed herein, show the contributions from the three main producing centres, Gumeracha, Tumby Bay, and Mount Fitton, both prior to and during the war. Small outputs from prospecting activities are recorded from deposits near Cowell on Eyre Peninsula, and from Lyndoch which is about 35 miles by rail from Adelaide.

The material is sold by producers in the crude form. The talc is purchased chiefly by mineral-milling firms which rail or ship it to their grinding plants in the eastern States. The small intermittent output of furnace soapstone blocks for bricks is purchased directly by consumers.

AUSTRALIAN CONSUMPTION

The Australian consumption of powdered talc in 1943, as reported by users, totalled 4,860 tons. The distribution by industries was as follows: cosmetics 2,650 tons (54 per cent); rubber 820 tons (17 per cent); paint 480 tons (10 per cent); foundry 480 tons (10 per cent); miscellaneous 430 tons (9 per cent). These figures include 300 tons of high-grade imported talc. In 1944 and 1945 the quantity of talc used decreased to 4,450 tons and 3,740 tons respectively. This decrease was due to declining war-time activities. In 1946 the consumption increased slightly to 3,760 tons, which suggests an early revival of the pre-war upward trend with the increasing application of talc in peace-time industry.

Undoubtedly the main features of Australian consumption are the large proportion used by the cosmetic industry and the relative unimportance of talc in

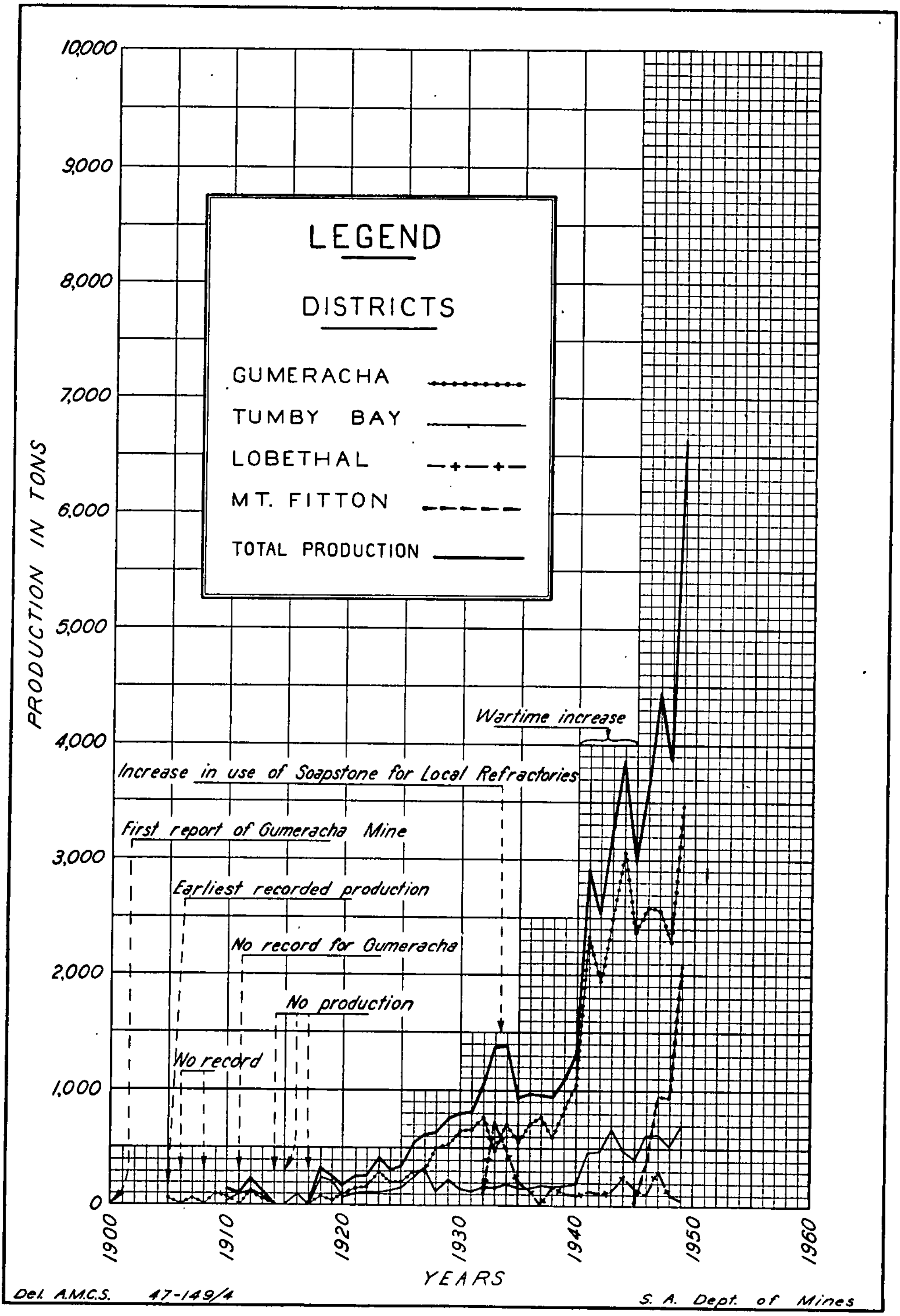

Fig. 3—Talc and soapstone production in South Australia

other industrial trades. In contrast, in America and Canada, where talc mining has progressed much farther than in any other country, conditions are found to be entirely the reverse. The cosmetic industry ranks last instead of first amongst principal talc consumers, and absorbs only about 5 per cent of the total output. It is superseded by paint, ceramic, roofing, paper, and rubber industries, which collectively take about 80 per cent of the total consumption. This contrast shows that there is considerable scope for an increased consumption of talc in secondary industries in Australia, which have expanded considerably during the war. Generally speaking, however, for widespread use except for cosmetics, talc must be regarded as a low-priced commodity and, therefore, with most of the markets at present situated in the eastern States, low costs of production and freight rates are of great importance for the future development of the industry.

MINING OF TALC

Talc deposits in South Australia are developed by means of quarries and underground workings, the manner of these being dependent on their shape, the quality of near-surface talc, and the character of the terrain. Because of the small outputs from these workings capital expenditure on mining plant and on development work has not been justified. Producers now find that they are unable to supply the considerable demands of consumers, and the introduction of more effective mining methods is essential to future development of the industry.

The deposits at Gumeracha are situated in hilly country and are worked chiefly from shafts and adits at various levels. As it is customary to find the near-surface talc stained with iron, it is usual to find the stopes of outcropping deposits beginning at 30ft. to 40ft. below surface. These stopes are small and extremely irregular with no semblance of design as part of a permanent mine structure. In most cases they have no common level and merely follow the talc as it pinches and swells, both vertically and horizontally. The stopes are kept open by pillars which are often composed of huge masses of schist and quartzite, weighing many tons, left in the talc and too costly to shift. When worked out, an abandoned stope often becomes a travelling way to the working faces farther ahead or below, where the talc is bagged and carried, or wheeled in a barrow, to the surface. The presence of these masses or boulders of hard rock in the soft talc must always be largely responsible for irregular-shaped stopes, but it is no reason to neglect the provision of level haulage ways and vertical shafts for easy handling of talc or mullock. The results of the geological study of the nature of these deposits should assist development along more systematic lines.

At Tumby Bay the same mining methods as at Gumeracha have been employed, except that the ground is soft and does not need explosives. A large number of small shallow shafts, rarely more than 30ft. to 40ft. deep, occur along the outcrop, and those being worked are equipped with windlasses. At varying shallow depths, levels for stoping are commenced in which the talc is dislodged from the back or the floor with a pick; that for market is bagged and the waste either cast aside in the level or hauled to surface and dumped. These stopes are exceedingly small and rarely accommodate more than two men. They generally collapse in a relatively short time because of the pulverulent nature of the talc. Because of this, also, they rarely extend more than 40ft. or 50ft. from the shaft and, therefore, to fully exploit the deposit by this method a series of shafts has to be sunk. Hence the large number of shafts in a very small area. This method of mining must eventually be succeeded by the development of the deeper talc from crosscuts and drives on a series of levels from a vertical shaft, or possibly, in the first place, by quarrying operations designed to salvage that which has been left in and adjacent to the shallow-shaft workings and near the surface. As nearly all the known shallow ground has been worked, a choice must be made in the next few years, particularly if it is to be exploited on a much larger scale.

The Flinders Range deposits are being worked by open cuts, ordinary quarrying methods being used. The talc is massive and requires blasting. Reserves of shallow talc are large.

The mining of soapstone is confined to open quarry work. The soapstone is cut from the walls of the quarry—into rough blocks—by toothed steel saws, and the rough blocks are lifted on to motor trucks for dispatch to consumers.

MILLING OF TALC

The talc is usually graded at the mine, before transport to the mill. The grade may be improved by simple hand-sorting with rejection of coarse impurities. Lime or clay skins on the cleavage surfaces may be removed by brushing, if the resultant product is up-graded enough to pay for the increased costs.

Transport of talc from the mines to the grinding mills is either in truck lots, or in bags holding approximately 1cwt. Bags are sometimes necessary with high-grade material to prevent contamination with dirt, soot, etc., in transit. Storage at the mills is best done in separate bags under cover. Many mills still use stockpiles on the ground in an open yard. This method must lead to either losses of talc or admixture with impurities.

Three types of mill are available in Australian plants grinding non-metallic minerals:

1. Hammer mill.
2. Roller mill.
3. Ball mill.

The latter two are high-capacity mills, so that talc is usually treated in hammer mills. Even these are often used only intermittently, requiring careful cleaning with each change of material treated.

The talc is spalled and fed by hand to a small jaw-crusher, which reduces the material to approximately 1in. in diameter. This product is fed by hand to the hopper of the pulverizing unit. The hammer mill may have a fan incorporated in its design, or may have auxiliary draft, to remove the ground product to a separating cyclone. The collected powder is bagged by hand. The excess air is vented through flannel bags to prevent fine dust being exhausted to the atmosphere. All sections of the plant where dusting occurs with the handling of the talc should be serviced with suction hoods to minimize the dust hazard.

It is difficult for millers to maintain a close control of the ground product when small lots only—of varying composition—are available from the mines.

TALC AND SOAPSTONE PRODUCTION IN SOUTH AUSTRALIA

Year	Talc												Soapstone (Steatite)								Grand Total	
	Hundred Yaranyacka		Hundred Talunga		Hundred Barossa		Hundred Para Wirra		Mt. Fitton		Total for Year		Hundred Talunga		Hundred Onkaparinga		Hundred Minbrie		Total for Year			
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
1905...	—	—	—	—	—	—	—	—	—	—	—	—	50	85	—	—	—	—	50	85	50	85
1906...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1907...	—	—	—	—	—	—	—	—	—	—	—	—	50	65	—	—	—	—	50	65	50	65
1908...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1909...	—	—	—	—	—	—	—	—	—	—	—	—	100	121	—	—	—	—	100	121	100	121
1910...	40	100	—	—	—	—	—	—	—	—	40	100	90	116	—	—	—	—	90	116	130	216
1911...	100	200	—	—	—	—	—	—	—	—	100	200	—	—	—	—	—	—	—	—	100	200
1912...	110	500	—	—	—	—	—	—	—	—	110	500	120	100	—	—	—	—	120	100	230	600
1913...	80	340	—	—	—	—	—	—	—	—	80	340	50	64	—	—	—	—	50	64	130	404
1914...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1915...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1916...	103	309	—	—	—	—	—	—	—	—	103	309	—	—	—	—	—	—	—	—	103	309
1917...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1918...	235	453	—	—	—	—	—	—	—	—	235	453	75	150	—	—	—	—	75	150	310	603
1919...	224	785	—	—	—	—	—	—	—	—	224	785	40	80	—	—	—	—	40	80	264	865
1920...	98	714	—	—	—	—	—	—	—	—	98	714	100	100	—	—	—	—	100	100	198	814
1921...	108	560	—	—	—	—	—	—	—	—	108	560	150	150	—	—	—	—	150	150	258	710
1922...	118	845	—	—	—	—	—	—	—	—	118	845	150	225	—	—	—	—	150	225	268	1,070
1923...	118	119	—	—	—	—	—	—	—	—	118	119	300	300	—	—	—	—	300	300	418	419
1924...	125	750	—	—	—	—	—	—	—	—	125	750	200	250	—		—	—	200	250	325	1,000
1925...	152	912	—	—	—	—	—	—	—	—	152	912	200	250	—	—	—	—	200	250	352	1,162
1926...	251	1,443	—	—	—	—	—	—	—	—	251	1,443	300	375	—	—	—	—	300	375	551	1,818
1927...	319	1,515	—	—	—	—	—	—	—	—	319	1,515	300	450	—	—	—	—	300	450	619	1,965
1928...	131	557	—	—	—	—	—	—	—	—	131	557	500	750	—	—	—	—	500	750	631	1,307
1929...	229	916	120	225	—	—	—	—	—	—	349	1,141	400	600	—	—	15	45	415	645	764	1,786
1930...	155	465	237	419	—	—	—	—	—	—	392	884	406	609	—	—	—	—	406	609	798	1,493
1931...	143	500	454	1,589	—	—	—	—	—	—	597	2,089	207	311	—	—	—	—	207	311	804	2,400
1932...	173	444	463	804	—	—	—	—	—	—	636	1,248	311	488	107	368	—	—	418	856	1,054	2,104
1933...	159	797	382	682	—	—	—	—	—	—	541	1,479	112	273	724	2,209	—	—	836	2,482	1,377	3,961
1934...	198	905	488	853	—	—	—	—	—	—	686	1,758	220	428	491	1,274	—	—	711	1,702	1,397	3,460
1935...	159	675	333	658	—	—	—	—	—	—	492	1,333	231	462	216	566	—	—	447	1,028	939	2,361
1936...	145	621	392	858	—	—	—	—	—	—	537	1,479	310	552	140	368	—	—	450	920	987	2,399
1937...	188	797	393	843	—	—	—	—	—	—	581	1,640	390	780	5	10	—	—	395	790	976	2,430
1938...	175	726	356	899	—	—	—	—	—	—	531	1,625	251	528	171	342	—	—	422	870	953	2,495
1939...	179	763	550	1,107	—	—	—	—	—	—	729	1,870	262	574	106	212	—	—	368	786	1,097	2,656
1940...	197	837	740	1,829	—	—	—	—	—	—	937	2,666	301	657	90	135	—	—	391	792	1,328	3,458
1941...	470	1,973	2,076	6,076	—	—	—	—	—	—	2,546	8,049	258	473	120	180	—	—	378	653	2,924	8,702
1942...	479	2,113	1,785	6,176	—	—	—	—	—	—	2,264	8,289	164	253	108	162	—	—	272	415	2,536	8,704
1943...	682	2,672	2,447	7,318	—	—	—	—	—	—	3,129	9,990	27	67	127	76	—	—	154	143	3,283	10,133
1944...	495	2,977	3,016	10,352	56	160	—	—	—	—	3,567	13,489	46	177	255	510	—	—	301	687	3,868	14,176
1945...	414	1,761	2,365	8,923	—	—	—	—	27	102	2,806	10,786	19	33	164	98	—	—	183	131	2,989	10,917
1946...	608	2,892	2,565	8,964	—	—	4	20	361	3,328	3,538	15,204	30	30	100	100	—	—	130	130	3,668	15,334
1947...	618	2,934	2,567	10,721	—	—	4	49	967	9,283	4,156	22,987	—	—	304	792	—	—	304	792	4,460	23,779
1948...	520	2,861	2,229	11,319	—	—	—	—	940	9,417	3,689	23,597	66	136	119	315	—	—	185	451	3,874	24,048
1949...	682	4,371	3,285	17,911	358	1,532	—	—	2,073	20,138	6,398	43,952	177	203	68	178	—	—	245	381	6,643	44,333
Total .	9,380	43,102	27,243	98,526	414	1,692	8	69	4,368	42,268	41,413	185,657	6,963	11,265	3,415	7,895	15	45	10,393	19,205	51,806	204,862

PART II

GUMERACHA DISTRICT

Chapter 1

THE GUMERACHA TALC DEPOSITS

BY

S. B. DICKINSON, M.Sc. (DIRECTOR OF MINES AND GOVERNMENT GEOLOGIST)

AND

A. W. G. WHITTLE, M.Sc. (PETROLOGIST)

INTRODUCTION

The Gumeracha district was first worked for talc in 1900, but mining operations were small and intermittent until 1918 when it became a consistent producer. The curtailment of imports of Indian talc during the second World-War materially further increased the output which has been sustained in post-war years.

Mining is conducted by two companies—John Dunstan & Son (W.A.) Ltd., and The Torrens Mining Co. Ltd.—which sell chiefly to mineral-milling firms in the eastern States. The product finds a wide market for general industrial use, but is not suitable for special purposes, such as high-grade cosmetics, because of the presence of albite felspar in the original ore, which cannot be entirely eliminated by hand-picking mining methods as practised at present. Beneficiation will undoubtedly improve the product, but considerable experimental work is necessary before its advantages can be accurately assessed.

This report covers the more essential features of the geology of the deposits and their likely reserves.

LOCATION

The main deposits are located in an area of about 12 sq. miles in the hundred of Talunga, near Gumeracha, a small township 25 miles from Adelaide in the heart of the Mount Lofty Range. Isolated occurrences are known as far north as Lyndoch, and near Lobethal in the south, about 21 miles apart, and are generally aligned with the outcrops of a favourable formation of schists containing thin interbedded quartzites.

The topography in the immediate vicinity of Gumeracha is somewhat mature, with the talc mines and prospects chiefly confined to hilly quartzite country which is thickly wooded and which stands out in strong contrast to the surrounding valleys intensely cultivated and supporting a rich farming community. The average annual rainfall is 32·99in., mostly falling in the winter and early spring. It is sufficiently high to discourage open-cut mining operations. Streams flow intermittently, and only during the rainy season. The summers are dry, without excessive heat; whilst winter temperatures rarely fall below 39°F.

HISTORY AND PRODUCTION

According to the *Record of Mines**, mining commenced about 1900 on section 6265, hundred of Talunga (Skinner's claim). A mineral claim was taken out by M. H. Mead who produced chiefly soapstone for furnace linings and other refractory uses. He worked the deposits on a small scale for approximately 30 years.

* *Record of the Mines of South Aust.*, 4th ed., p. 355, 1908.

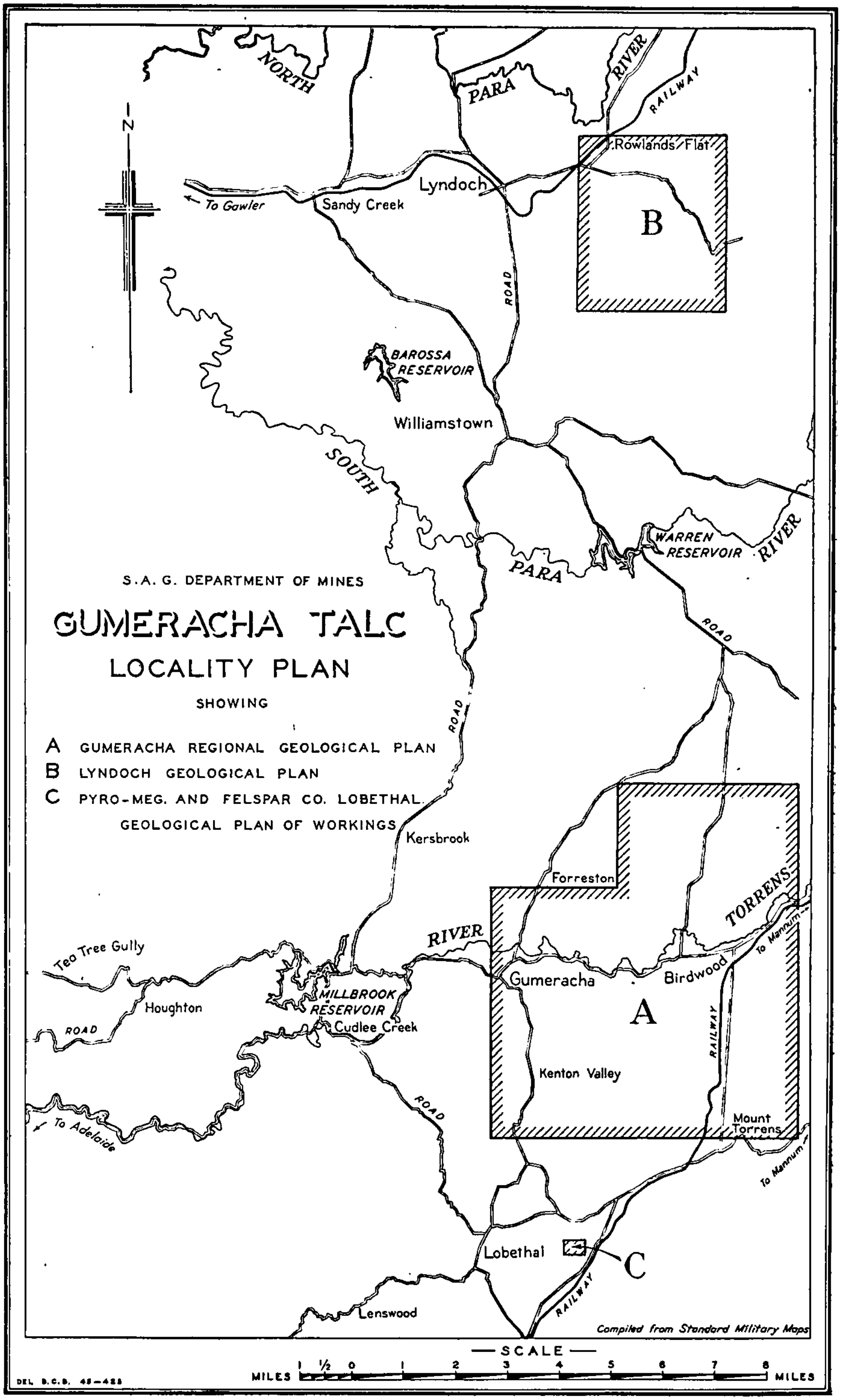
S.A.G. DEPARTMENT OF MINES
GUMERACHA TALC
LOCALITY PLAN
SHOWING
A GUMERACHA REGIONAL GEOLOGICAL PLAN
B LYNDOCH GEOLOGICAL PLAN
C PYRO-MEG. AND FELSPAR CO. LOBETHAL. GEOLOGICAL PLAN OF WORKINGS
NORTH PARA RIVER
RAILWAY
Rowlands Flat
Lyndoch
To Gawler
Sandy Creek
ROAD
BAROSSA RESERVOIR
Williamstown
SOUTH PARA
WARREN RESERVOIR
RIVER
ROAD
Kersbrook
Forreston
TORRENS
RIVER
To Mannum
Tea Tree Gully
Houghton
ROAD
MILLBROOK RESERVOIR
Cudlee Creek
Gumeracha
Birdwood
Kenton Valley
Mount Torrens
To Adelaide
Lobethal
Lenswood
Compiled from Standard Military Maps
SCALE
MILES 1 ½ 0 1 2 3 4 5 6 7 8 MILES
DEL. B.C.B. 45-425

Plate I

In 1905, this claim is reported to have produced "5 tons of french chalk and 277 cut stones" valued at £85. (*Mining Review* 4, p. 18, 1905.) In 1907, 50 tons of soapstone were produced; in 1909, 100 tons; and in 1910, 90 tons. Then production lapsed for a year, but for the next two years, 1912 and 1913, 120 tons and 50 tons of soapstone were sold, respectively. Output again ceased but recommenced in 1918, since when it has been continuous. The recorded output to 1932 is 5,373 tons of soapstone at an average price of approximately £1 to £1 10s. per ton.

From 1933-1941, G. Forrester carried on small-scale production in the same area. He produced 1,717 tons of block talc valued at £2 per ton.

John Dunstan & Son (W.A.) Ltd. took out leases in 1941, over the area previously held by G. Forrester, and commenced operations on a much larger scale. The Torrens Mining Co. Ltd. began in 1929, and has worked continuously since that date. Its activities have extended over sections 245, 6212-4, 6264, 6266, 6267, 6268, and 6329, hundred of Talunga. Both these companies concentrated on talc for use in the ground form in the rubber, paint, textile, cosmetic, ceramic, and other industries.

The total recorded production is set out in the following table:

PRODUCTION OF TALC AND SOAPSTONE—HUNDRED OF TALUNGA

Year	Quantity	Value	Year	Quantity	Value
	tons	£		tons	£
1905	50	85	1927	300	450
1906	—	—	1928	500	750
1907	50	65	1929	520	825
1908	—	—	1930	643	1,028
1909	100	121	1931	661	1,900
1910	90	116	1932	774	1,292
1911	—	—	1933	494	955
1912	120	100	1934	708	1,281
1913	50	64	1935	564	1,120
1914	No production		1936	702	1,410
1915			1937	783	1,623
1916			1938	607	1,427
1917			1939	812	1,681
1918	75	150	1940	1,041	2,486
1919	40	80	1941	2,334	6,549
1920	100	100	1942	1,949	6,429
1921	150	150	1943	2,474	7,385
1922	150	225	1944	3,062	10,529
1923	300	300	1945	2,384	8,956
1924	200	250	1946	2,595	8,994
1925	200	250	1947	2,567	10,721
1926	300	375	1948	2,295	11,455
			Total	30,744	£91,677

SCOPE OF INVESTIGATION

This report is primarily concerned with the geological features of the Gumeracha talc deposits. The investigations have extended over a period of three years and several geologists of the Survey have participated, including E. Broadhurst, former Assistant Government Geologist, and S. B. Dickinson, Government Geologist, who initiated the detailed geological examination of the mines, and A. W. G. Whittle, Petrologist, who subsequently carried out the comprehensive regional survey of the district (approximately 65 sq. miles in area) and completed the detailed study of deposits with the Government Geologist. Dr. F. L. Stillwell and Dr. A. B. Edwards of the C.S.I.R. made a detailed petrological and mineragraphic study of the talc minerals and associated rock types, and their findings proved invaluable for the field mapping. Their report is published in this *Bulletin*. Acknowledgment is also made of the help afforded by the producers, and L. L. Mansfield, Inspector of Mines, in the course of mine inspections.

The Geological Survey had done no systematic mapping in the Gumeracha district previously, and the only information available is a report by P. S. Hossfeld.* This report being purely of a general reconnaissance character, provided little information. It was therefore necessary to start at the beginning and make detailed maps of the deposits as well as a general map of the district. Additional petrological work was carried out by one of the writers (Whittle) chiefly in connexion with the regional geological work.

PLANS

The following plans illustrate this report:

(1) Locality plan showing talc occurrences.
(2) Regional geological plan and section of the Gumeracha district.
(3) Detailed geological plan of the Gumeracha talc-mining area.
(4) Underground and surface working of the mine of John Dunstan & Son (W.A.) Ltd.
(5) Eastern end of open cut in the southern workings of the property of John Dunstan & Son (W.A.) Ltd. Showing detail of contact of talc against schist.
(6) Underground workings of the mine of The Torrens Mining Co. Ltd.

GENERAL GEOLOGY

Introduction

The rocks exposed in the Gumeracha district comprise chiefly schists of variable composition derived from shales and sandstones, with thin quartzites interbedded with the schists. In all probability they belong to the Adelaide Series of late pre-Cambrian age, and rest unconformably on gneisses and schists of an older pre-Cambrian formation locally known as the Barossian Series. The prevailing strike is north with dips to the east, excluding those in the talc-bearing area where the beds are heavily folded, but nevertheless form part of the north-south regional schist belt. The schistosity is very variable in strike and dip and was probably developed by the diastrophic forces which caused the crumpling of the beds, it being much accentuated in the closely folded areas.

Numerous small pegmatite intrusives are scattered over the whole area, the largest about 150ft. in width and 1 mile in length. These seem to be related to the talc mineralization which was largely affected by metasomatic processes resulting in a widespread development of rock rich in albite felspar, the host rock of the talc occurrences. A major Tertiary fault, striking N.35°E., in the north-west corner of the area is the only evidence of major diastrophism after the ore deposition. These geological features are described in greater detail in the following sections of the report.

Rock Sequence

The rock sequence from the oldest to the youngest is as follows (*see* plate II)†:

(1) *A series of gneisses and schists*—Known locally as the Barossian Series of pre-Cambrian age (not shown on the map) outcropping to the west of the area. The thickness is not known, but is considerable. A fault separates the Barossian Series from (2) which does not include the basal beds of the Adelaide Series.

* Hossfeld, P. S., *Roy. Soc. South Aust. Trans.* 59, pp. 16-67, "The Geology of Part of the North Mount Lofty Ranges", 1935.

† Plates II and III in pocket at end of *Bulletin.*

(2) *A formation of brown slates and phyllites*—The upper portion is shown on the extreme western part of the map. Slates and phyllites are the dominant rock types, and although the oldest sediments in the area they exhibit very low-grade metamorphism.

(3) *A quartzite and micaceous-hematite schist formation*—About 100ft. thick. The quartzite bed underlies the hematite schist which serves as a useful "marker" bed.

(4) *A formation of dark-coloured bi-mica schists*—About 3,000ft.-4,000ft. in thickness; the most common rock-type being a fine-textured brown muscovite-biotite schist which changes from a grey-blue slate according to the degree of metamorphism. In the vicinity of pegmatite dykes the schists exhibit a knotty texture due to the development of cordierite (altered to pinite). The most characteristic feature of this formation is the presence of calc-silicate rocks ranging in thickness from a few inches to 20ft. They exhibit a medium- to coarse-grained texture. The principal constituent minerals are actinolite, and/or tremolite with epidote, albite, microcline, perthite, and scapolite. Sphene is abundant in some specimens. These calc-silicate rocks could be regarded as sills of basic igneous rock, but it is more likely that they were derived by metasomatism from impure magnesian limestones interbedded with the schists. Their high sodic content, manifest by the abundance in them of scapolite and albite, could well be attributed to selective metasomatic alteration of calcareous portions of this schist formation by soda-bearing solutions. As suggested by Stillwell, metasomatic alteration of schists and quartzites by soda-rich solutions is probably responsible for the genesis of the Gumeracha talc, and it is not unlikely these solutions were more widely distributed to produce these calc-silicate rocks as well. Petrological features of these rocks are incorporated in this report. Another feature of this formation is the widespread occurrence therein of pegmatite dykes generally elongated parallel to the bedding. Some of these pegmatites have outcrops nearly 1 mile in length and up to 150ft. in width, and one large dyke is worked by South Australian Silicates Co. Pty. Ltd.—1½ miles E. of Gumeracha—as a source of felspar.

(5) *The talc-bearing schist-quartzite formation*—The total thickness is difficult to determine because of folding and variation of thickness along the strike, but it is possibly of the order of 4,000ft. It is in these beds that the most intense folding of the area is to be found, and also most of the talc orebodies. The rock types can be grouped in different ways, but a convenient grouping for structural and economic purposes is to consider it as composed of three components, a quartzite horizon in the west—thickness varying up to 250ft.—(5a); overlain by brown muscovite-biotite schist—the thickness of which varies between extreme limits—(5b); which in turn is overlain by a group of quartzites or felspathic sandstone beds with interbedded bi-mica schists (5c). The greater part of the talc is located in the uppermost group of this formation, but a few occurrences are present in the western quartzite (5a), and also in the underlying schist formation (4) already described, and in proximity to the soda-rich calc-silicate bands in the schists adjacent to the western quartzite (5a). The important part played by the thin schist beds amongst the quartzites has been pointed out by Stillwell, namely, "that the magnesium content of the biotite of these schists is responsible for the talc". In places actinolite is found in the schist-quartzite formation, generally near the talc bodies, but the occurrences of this mineral are rare. A few small pegmatites have been found in the

formation north of the Gumeracha-Birdwood road. The quartzite beds outcrop reasonably well, particularly the fine-grained massive non-felspathic types, and provide the key to the broad structure of the area. In the vicinity of talc bodies where local folding and faulting is generally intense, the quartzite either changes into a fine even-grained, saccharoidal albite rock which usually preserves the bedding structures of the original quartzite, or into masses of fine-grained talc and albite which contain remnant boulders of quartzite in a more or less altered state lying in random orientation. These altered rock-types in many places have more pronounced outcrops than the original quartzite; in others they have been kaolinized to form a curious soft "clay" rock commonly found round the talc bodies with the original bedding of the quartzite well preserved in it. The schists which are interbedded with the quartzites seldom outcrop except in road cuttings and prospecting workings, and their variation in form and composition could not be studied in detail. Stillwell and Edwards have described in detail the occurrences in the mine workings. It may be noted from the plan that the eastern, or younger group, of quartzites and schists (5c) has undergone much greater deformation than the western quartzite, whilst the schists in between have been thinned and thickened enormously as a result of the much greater movement of the one relative to the other.

(6) *A formation of schists and dark-coloured micaceous quartzites*—This formation overlies the talc-bearing schist-quartzite formation. Outcrops are poor, but where exposed the quartzites contain abundant actinolite, and in a few places are rich in scapolite. The schists are substantially similar to those in (5) but, in general, the formation has no distinguishing features stratigraphically. The thickness is estimated at 900ft.

(7) *A formation of schists and calc-silicate rocks*—This formation is similar to (4) and is distinctive in that it contains numerous bands of calc-silicate rock ranging up to 30ft. in thickness and forming strong outcrops. The calc-silicate rock is typically fine-grained, with the constituent minerals scapolite, diopside, actinolite, and epidote arranged in bands—individually rich in one or other of these minerals—parallel to the bedding and producing a marked banded appearance. As in the case of similar beds lower in the series, the calc-silicate bands are presumed to have been argillaceous magnesian limestone interbedded with the schists. The richness in scapolite indicates considerable metasomatism along favourable beds. Diopside is common also in this formation, whereas it was not developed so abundantly in the underlying calc-silicate beds contained in (4) above. The thickness is estimated at 2,000ft.

(8) *A formation of schists and strong quartzites*—This sequence is notable for the presence of a thick quartzite horizon—500ft. maximum width—the uppermost horizon locally referred to as the "Birdwood" quartzite. The formation also contains several minor quartzites and minor bands of calc-silicate rock interbedded with mica schists. Garnetiferous quartz-mica schist has been noted in several places. The garnets are quite small and in the process of development. In addition, incipient growths of sillimanite occur within the micas of these schists. These observations are important in that they indicate that the country-rock has reached an advanced degree of regional metamorphism. Mount Torrens and the prominent hills north of Birdwood are all composed of the "Birdwood" quartzite. Farther north this quartzite becomes distinctly felspathic and kaolinized, and in places replaced

to form a clay rock with interbedded shales also kaolinized. The latter are worked extensively, about 3 miles N. of Birdwood, for a high-grade china-clay. The change from felspathic quartzite or sandstone to clay can be clearly traced in some of the underground workings. A strong development of pegmatite dykes also occurs in this schist-quartzite formation near Birdwood. Its total thickness is estimated at about 2,100ft.

(9) *A formation of mica schist and quartz-mica schist*—This is of very considerable thickness extending eastward from Birdwood, and although stratigraphically younger, generally speaking it exhibits a much more advanced stage of metamorphism than that of the older rocks already described. The schists are coarser in texture, with abundant flaky biotite, and the more arenaceous types comprise chiefly quartz-mica schists.

Broadly speaking the sediments in the Gumeracha area embrace approximately 18,000ft. of pre-Cambrian Adelaide Series ranging from the real basal beds through the distinctive hematite schist-quartzite formation to the Birdwood quartzite which may be the equivalent of the "Thick Quartzite" of the Adelaide Series.

The rocks have been so altered by metamorphism and metasomatic influences that few of their original characteristics have been preserved.

Structure

The dominating structural feature of the area is the intense folding in schists and quartzites lying between relatively undisturbed beds which have a general north-south strike and easterly dip. The talc mineralization is confined to this crumpled and broken zone. There are no major folds, and the intense deformation in this zone presumably resulted from forces acting parallel to the bedding planes in the sediments, with plastic flow in the schists largely bringing about the relief of stress. This structure is thus, broadly speaking, a series of asymmetrical folds, some overturned to the south and south-west, striking north and south to northwest-southeast and pitching to the south-east. These folds are broken by numerous fractures and fissures, with the most pronounced faulting evident along lines parallel to the fold axes. This structure is limited abruptly on the west by the micaceous-hematite schist formation and beds underlying it. These and the Barossian formation appear to have played the part of a consolidated mass against which a resistance to the relative movement of the beds in the talc-bearing formation (5) developed. To the east it dies out gradually in the overlying less-folded rocks. The general shape of the folding would require a southerly movement of the more easterly beds relative to those in the west, as part of the main regional movement which presumably raised, folded, and distorted the pre-Cambrian Adelaide Series along the axis of the Mount Lofty Range prior to igneous activity and the ingress of the mineralizing solutions which formed the talc and other related mineral deposits. The northeast-southwest block faults of the Mount Lofty Range are distinctly later (Tertiary) than mineralization and, generally speaking, step down the sediments to the west. One of these faults cuts across the north-western part of the area.

Metamorphism

The rocks of the Gumeracha district have already been described in detail, but relevant petrological features are noted in appropriate places in this report, thus a brief comment is only necessary on the metamorphic processes. The formation of the talc is considered separately under "Talc Deposits".

The rocks of the Gumeracha district have been extensively metamorphosed, first by the regional metamorphism during folding; secondly by the igneous activity associated with the formation of the Palmer granite mass with its associated contact metamorphic rocks occurring noticeably east of the Birdwood quartzite and forming an aureole round the Palmer granite itself; and thirdly by the hydrothermal solutions which produced the albitized zones, the talc orebodies, and the numerous pegmatite dykes and sills emplaced at a late stage of the igneous activity.

The Palmer granite is a somewhat gneissic granitic rock not unduly rich in sodic felspar, but generally containing an appreciable amount of oligoclase (composition $Ab_{75}An_{25}$–$Ab_{80}An_{20}$) in addition to an abundance of potash felspar. The mode of field occurrence of this granite, and its petrographic features, strongly suggest that it has been formed *in situ* by transformation of local rocks under granitizing influences. This change is clearly exhibited in the field by the complete gradation from massive granite, through gneissic granite, biotite-rich injection gneiss, to mica-quartz gneiss and schist. It is probable therefore, that the same large-scale felspathization responsible for the production of the Palmer granite, and its less completely granitized aureole rocks, has been the major factor in the development, metasomatically, of albite and talc at Gumeracha.

Examination of numerous pegmatites occurring in the country between Gumeracha and Palmer shows that most of them contain some sodic felspar of composition ranging from $Ab_{95}An_5$–$Ab_{85}An_{15}$. In some cases there is a local dominance of plagioclase over potash felspar.

There is little doubt that metasomatism is regional in character. The widespread occurrence of calc-silicate rocks (often rich in albite or scapolite) as far east at Tungkillo demonstrates the extent of felspathization. The sodic felspars appear to have migrated farthest from the centre of alteration at Palmer to produce, for instance, the albitized and scapolitized rocks in the Gumeracha-Birdwood district, while the potash felspars deposited in the central portion of the aureole form granite, granite gneiss, and injection gneiss.

A further development of this conception may provide an alternate explanation of the origin of the talc orebodies. Stillwell has suggested that the magnesium content of the biotite of the schists in the Gumeracha area provides the necessary magnesium requirement for the formation of talc in favourable structures. When the large quantity of talc, however, is considered in relation to the small magnesium content of the schists, it seems necessary that there must have been considerable introduction of magnesia from an outside source to provide sufficient for the formation of the large occurrences of talc. Stillwell postulates the migration of soda-rich hydrothermal solutions into the local favourable structures, but it seems most probable that magnesia has also been carried in by these solutions. In other words, the igneous activity producing the Palmer granite caused the more basic elements such as calcium, magnesium, soda, iron, and titania to be expelled from the central granitic area which became enriched in potash. On the other hand, the migrating elements enriched the surrounding country-rock in basic constituents. The intense local albitization and talc formation at Kenton Valley is possibly due to deposition in favourable structures of soda and magnesia in larger amounts, while the general occurrence of calc-silicate rocks rich in albite or scapolite (soda), diopside, tremolite, and actinolite (Ca,Mg,Fe) are possibly the result of less intense but general regional basification of country-rock. In this regard it is also noteworthy that titania, in the form of sphene, is abundant in the calc-silicate rocks, and also of very common occurrence, as rutile, in the talc orebodies themselves.

It is suggested, therefore, that there has been a progressive sequence of events in the igneous activity causing these various changes, starting with the formation of granite, and ending with the hydrothermal alteration of favourable structures and rocks with the deposition of talc.

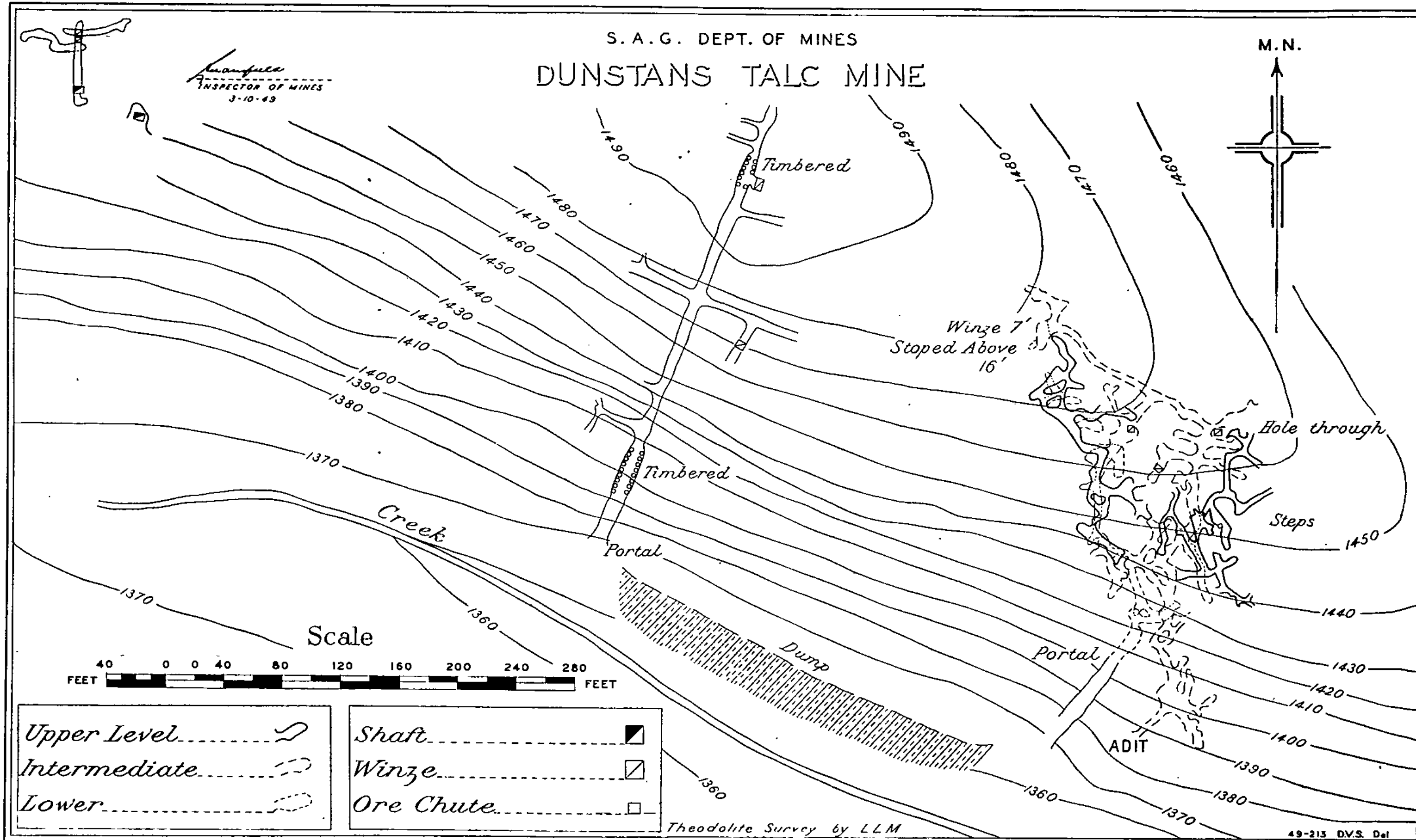
S.A.G. DEPT. OF MINES
DUNSTANS TALC MINE
INSPECTOR OF MINES
3-10-49
M.N.
Timbered
Winze 7'
Stoped Above
16'
Hole through
Steps
Timbered
Portal
Creek
Dump
Portal
ADIT
Scale
FEET
FEET
Upper Level
Intermediate
Lower
Shaft
Winze
Ore Chute
Theodolite Survey by LLM
49-213 D.V.S. Del

Plate IV

Pegmatites

Two distinct types of pegmatite occur in the district. The more common type is a normal coarse-grained potash-felspar-rich type usually containing albite or oligoclase in small amount. Pegmatite of this kind is particularly abundant in sills and dykes about 2 miles east of Gumeracha, in small veins adjacent to the talc-bearing formations, and in the vicinity of Birdwood and eastward from there towards the Palmer granite. It occurs principally in the vicinity of local faults and the more intense folds.

Less common, but more significant with respect to the talc formation, is the coarse-grained albite pegmatite and the graphic albite-talc pegmatite. Excellent examples are exposed east of Lobethal in the workings of Pyro-Meg & Felspar Co.; while Stillwell recorded similar but smaller occurrences as veins amongst the Gumeracha talc orebodies.

Apparently the former class of pegmatite is directly related to the Palmer granite mass, while the latter is not a true "igneous pegmatite" but has resulted from the crystallization of hydrothermal talc-forming solutions in favourable places. Some of the so-called "clay rock", particularly that which shows no bedding, also belongs in this category for it is a strongly kaolinized, weathered albite pegmatite rock.

Talc Deposits

The talc deposits of commercial value at Gumeracha are parts of albitized masses of schists and quartzite that have been for all practical purposes completely replaced by talc. The magnesian component of the talc—according to Stillwell—most probably was derived from the magnesium-bearing biotite of the original schist.

Both the albite and talc are formed in zones of strong fold distortion, more commonly in anticlinal crests, with the talc, in particular, tending to be concentrated along minor faults. The talc orebodies are very irregular in size and shape, and the presence of large boulders of albite rock or quartzite make systematic mining operations difficult.

Surface agencies caused partial oxidation and kaolinization extending to the present water-table about 20ft. to 30ft. below the valley floors. This is particularly noticeable in the albitized zones where the so-called clay rock has been formed. Generally speaking, however, the block faulting uplift in Tertiary times depressed the water-table faster than the superficial changes could take place, resulting in much fresh talc, containing primary pyrite, close to the surface well above the water-table.

The principal mineral constituents of the ore are talc (steatite), albite, apatite, rutile, and iron pyrite, with minor amounts of chlorite and biotite. The talc largely retains the foliated structure of the schist which it has replaced, whilst the large and small boulders of fine-grained albite rock represent partially replaced original rock, either schist or quartzite. Generally the schists are replaced to a greater extent than the quartzite. The margin of the deposits in most cases conforms with unreplaced quartzite beds; and, as the structure of the quartzite beds generally has some common relationship to the talc occurrences, it is possible to design drilling programmes which will indicate the broad limits of ore and so provide a basis for more systematic development and mining. Stillwell and Edwards have discussed the nature and origin of the talc in detail, and therefore only brief reference need be made here to the outstanding features of the main deposits.

John Dunstan & Son (W.A.) Limited

The talc deposit being worked by John Dunstan & Son (W.A.) Ltd. is the largest and most extensively developed deposit at Gumeracha. It occupies a shattered anticlinal fold in albitized schists and quartzites. Although the workings are discontinuous it probably extends in plan over 1,000ft. Locally it has been worked up to 150ft. in width and 50ft. to 100ft. in height. It underlies flatly to the north, following the general dip of overlying quartzite beds. Its limits have not been determined in depth, but on structural evidence one would expect the ore to gradually merge into albite rock and unaltered schist as it dips away from the major fold axis into relatively undisturbed beds on the northern limb of the fold. The steep-dipping faults striking transversely through the general NW.-SE. direction of the deposit have caused local enrichments along their walls, but on the other hand have subsequently aided oxidation processes, and it is not uncommon to find limonite staining along them and

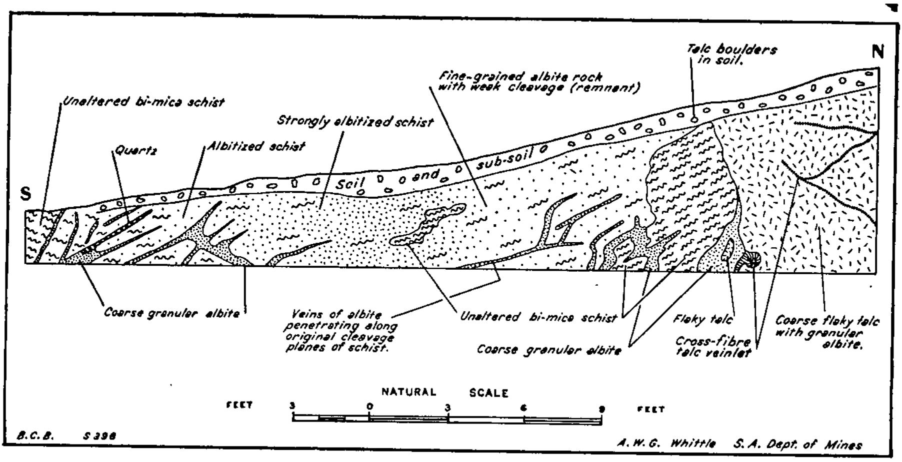

Plate V.—Gumeracha Talc Deposits—Diagrammatic section of eastern end of open cut in the southern workings of Dunstan talc mine showing detail of contact of talc against schist

permeating the adjacent rock. Because it is impossible to forecast the extent of the staining or the distribution of the boulders in the deposit it would be futile to attempt to make any estimates of ore reserves, and in the first place drilling should be carried out to determine more precisely its shape and size. It is possible to indicate where workable talc bodies may exist, knowing that their distribution is due to the control of deposition by intense folding and shattering and that bulges and enriched zones tend to be localized along well-defined faults.

There is no doubt that the deposit can produce steadily for many years to come, but it is necessary to introduce more systematic methods of development and mining.

If a milling plant were erected to eliminate or reduce the albite impurity the talc which could be exploited would be considerably increased. For instance, there is an extensive bed of this type of material, namely talc with visible albite impurity of the order of 10 per cent, outcropping over an extensive area south of the present working. This mass could probably be worked to advantage if a suitable milling process were developed. At present it is only worked for small amounts of soapstone used for furnace linings, etc.

The Torrens Mining Co. Limited

This company has operated a number of small shafts and open cuts on sections 245 and 6268, hundred of Talunga, since 1929. The known occurrences are similar in character to those of John Dunstan & Son (W.A.) Ltd., but are not nearly so extensive, nor is it possible to relate them to persistent geological features as in the case of those on the adjoining property. The Torrens Mining Co. Ltd. will undoubtedly continue to produce specially selected talc for many years, but unless a large deposit is located it is unlikely that any large-scale development will be possible. The deposits are small, and as talc—generally

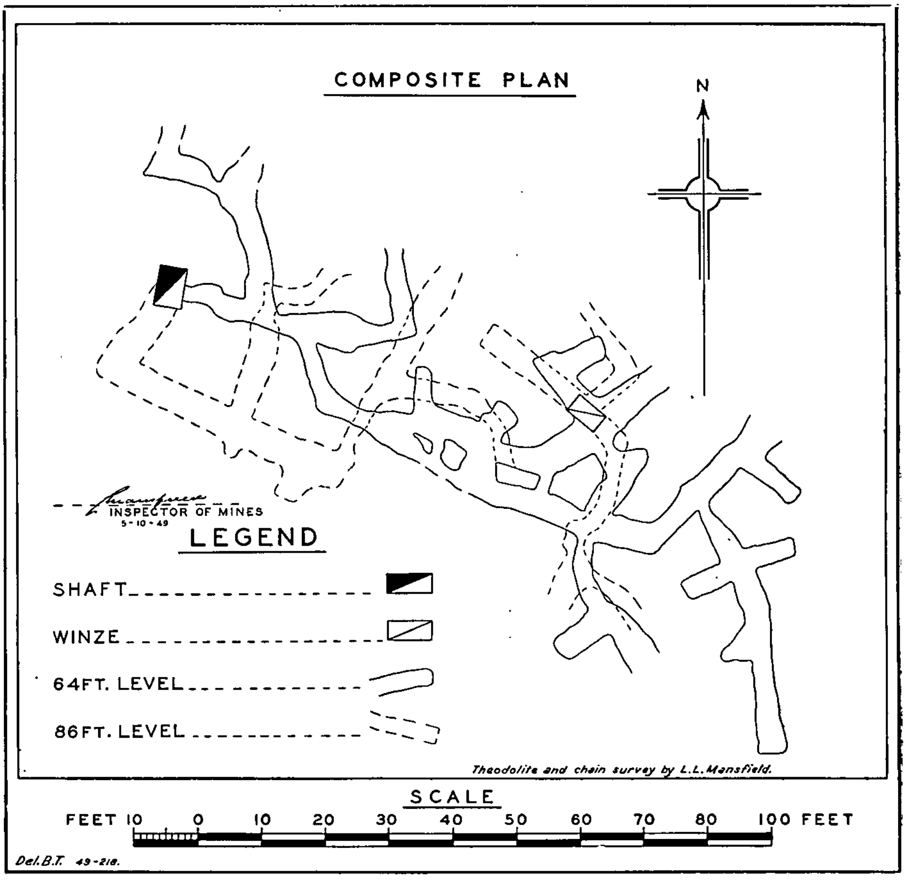

Plate VI.—Gumeracha Talc Deposits—Underground workings of the mine of The Torrens Mining Co. Ltd.

speaking—is a low-priced commodity it is unlikely that individual deposits will be worked to depths exceeding 100ft. to 150ft. On present evidence it is not possible to recommend any drilling or underground exploratory work which would materially assist in the development of this property as a vast majority of deposits can still only be regarded as erratic mineralized zones. However, it is hoped that by opening up a sufficient number of these small talc lodes it may be possible, as a result of further geological studies, to relate the occurrences to structural features. It may even be possible to indicate specific places to explore for new major talc occurrences.

CONCLUSION

It is evident from the geological investigations that there are numerous promising talc occurrences in the Gumeracha district, which have not been worked or investigated with sufficient thoroughness to reveal their potential value. Nevertheless, in the case of those properties which are being worked it is clear that ore will continue to become available as exploration and development proceeds and that production can go on for many years.

Furthermore, there is no reason why the output should not be substantially increased, and this can best be accomplished by the introduction of more systematic mining methods and the development of a suitable milling process. (30/5/49.)

Chapter 2

PETROLOGY OF THE GUMERACHA TALC DEPOSITS

BY

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AND

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(MINERAGRAPHIC INVESTIGATIONS OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH)

INTRODUCTION

This study of the genesis of the talc deposits of the Gumeracha district in South Australia was undertaken at the request of the Director of Mines for South Australia, as part of the programme of the Mineragraphic Section of the Council for Scientific and Industrial Research, Australia, to supplement the field mapping of the deposits. The deposits are among the largest known in Australia and provide an important part of present-day Australian talc production.

The talc deposits are situated in the hundred of Talunga, about 25 miles east of Adelaide. They consist of a series of apparently isolated bodies of talc occurring at intervals in a narrow belt—generally less than half a mile wide—that extends for a distance of 4½ miles in a northerly direction from section 6213, hundred of Talunga—about 2 miles south-east of Kenton Valley—to section 6380, hundred of Talunga, situated about 3 miles north-east of Gumeracha. (*See* fig. 1.) Further deposits occur along the continuation of the belt, in the hundred of Barossa, about 10 miles north of Gumeracha.

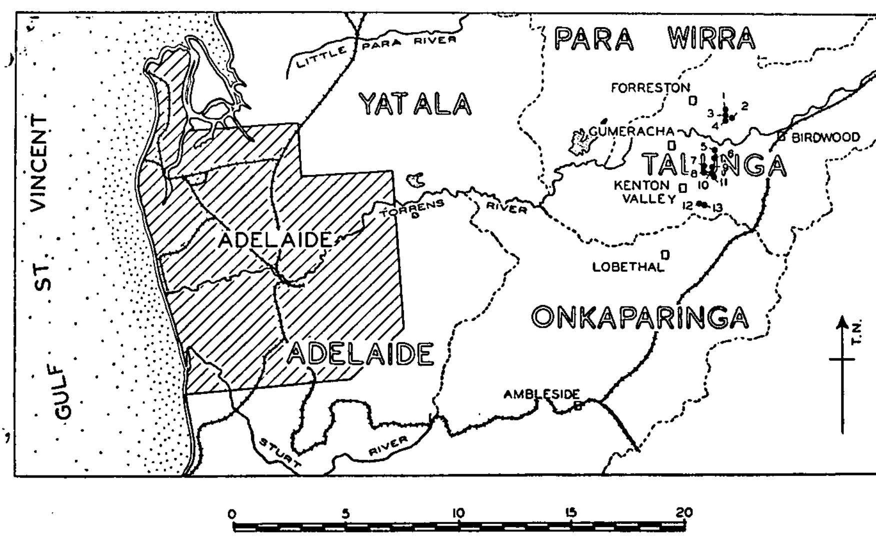

Fig. 1.—General locality plan of talc holdings

1—Warland: 2, 4—Tonkin: 3—Berry: 5, 6, 7, 8, 9—The Torrens Mining Co. Ltd.: 10, 11—John Dunstan & Son (W.A.) Ltd.: 12, 13—Porter

Outcrops are poor over much of the area, and the deposits that have been located occur on or near the crests of ridges, though they may prove continuous across the intervening valleys. The surface rocks are somewhat weathered, and the difficulties of mapping are increased by the close resemblance of certain albite rocks that are associated with the talc as part of the deposits, to quartzites that lie adjacent to the lodes.

Quarries have been opened in several of the bodies, and underground mining is in progress at Gumeracha. Examinations for this study were restricted to the various workings where fresh rocks could be seen *in situ.* Most attention was paid to the producing mines at Kenton Valley where drill cores are available from sections of the deposit not yet opened up.

The Gumeracha talc deposits differ in several respects from other known talc deposits of commercial size. Most such deposits have been formed either by the action of hydrothermal solutions on basic igneous rocks, where they are found closely associated with remnants of such rocks, or by the metasomatic alteration of dolomites, generally near granitic intrusions. There are, however, neither basic igneous rocks nor dolomites associated with the Gumeracha talc bodies, nor are such rocks known to occur in the district. Moreover, there are no granitic intrusives in the vicinity, although there are extensive pegmatites. The only rocks in the neighbourhood of the talc deposits are quartzites and biotite schists of sedimentary origin.

A characteristic feature of the Gumeracha talc is the abundance of albite associated with it and the presence of bodies of more or less pure albite rock. Another striking feature is the extremely irregular shape of the talc seams that have been exposed in mining.

The deposits are referred to as talc in this report, rather than as steatite or soapstone, the terms used in reference to these deposits in *Mining Review* No. 77.* Steatite, in the narrower mineralogical sense, is generally applied to massive, compact, cryptocrystalline talc without visible grain. Soapstone denotes a massive form that may contain only 50 per cent talc, and the name is derived from the greasy or soapy feel imparted to the rock by its talc content. Much of the Gumeracha talc, even when massive, occurs in the lamellar crystalline form for which the term "steatite" is not apt, except in so far as the term is synonymous with massive talc. Impurities occur in the talc deposits, but generally in such small proportions that the term "soapstone" is misleading. Moreover, the production of high-grade talc seems possible with the application of suitable ore-dressing.

THE TALC DEPOSITS

The talc deposits that are sufficiently exposed or developed for their shapes to be apparent appear as elongated lens-like or sheet-like bodies, with their long axes more or less parallel to the strike of the country-rock. These bodies consist essentially of talc, albite felspar, and unreplaced schist and quartzite; the relative proportion of the several components varying considerably from place to place. In some places the talc forms massive bodies 50ft. or more in width, while elsewhere it occurs as a system of anastomosing seams—up to 20ft. wide—filling the interstices between more or less rounded blocks of hard rock, known locally as "boulders", which consists of a sheath of albite of variable width about a core of more or less albitized schist or quartzite. Albite rock, which is sometimes not more than a few inches wide, invariably occurs between the talc bodies, or seams, and the incompletely replaced schists, as is strikingly illustrated in the Gumeracha No. 2 diamond-drill core (*see* fig. 2). In places, partially albitized schist, adjacent to such a "sheath", is traversed by anastomosing veins of albite, which range in thickness from a thread to a few inches, and

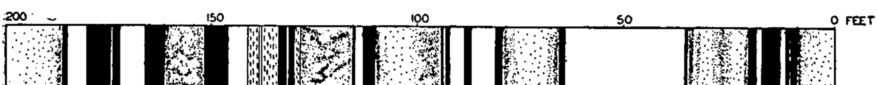

Fig. 2.—No. 2 diamond-drill core, Gumeracha
A—albite rock: Q—quartzite: S—schist: T—talc

* Cornelius, H. S., *Mining Review* 77, pp. 80-81, 1943.

clearly fill a system of fractures in the schist (*see* fig. 3). The albite also occurs as small grains disseminated through the talc, the proportions varying somewhat from place to place.

The varying relationship of talc to albite—and of the talc-albite rocks to the country-rocks—are best exposed in the Gumeracha deposits, where mining is in progress. Two talc-albite bodies occur here, one on either side of a small valley running east-north-east and west-south-west. They are exposed at intervals along the ridges on either side of the valley, for distances of 1,000ft. or more, along a direction transverse to the general northerly trend of the talc belt. The talc-albite bodies, and the sediments that flank them—which are predominantly biotite-quartz schists with some quartzite beds—have a general north-westerly strike, and dip to the north-east.

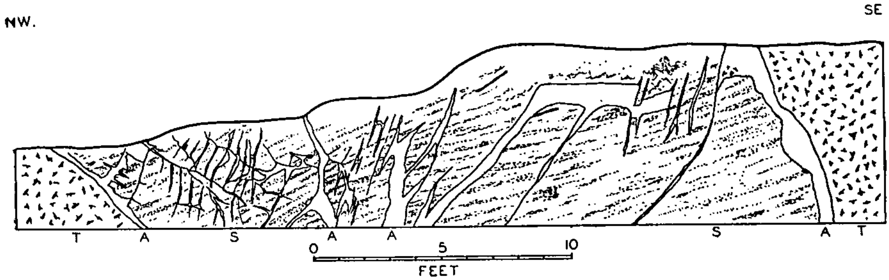

Fig. 3.—Sketch section of pegmatitic veins in an exposure of biotite-quartz schist on the margin of massive talc at Steatite Hill
A—albite rock: S—schist: T—talc

South of the valley is a ridge which may be distinguished as Steatite Hill because it contains the massive bodies of talc, which have been previously referred to as steatite or soapstone, and from which a considerable tonnage of blocks and slabs has been taken out in the past. Quarries, which are opened up to depths of 30ft., expose faces of massive talc up to 50ft. wide. The talc is not uniform in quality, some of it being gritty from disseminated albite, and some of it being stained with iron oxide derived from the weathering of disseminated fine and occasional coarse crystals of pyrite. An irregular zone of albite rock marks the contact of the talc bodies with the biotite schists that surround the deposits; and in some cuttings, thin anastomosing veins of albite are exposed in fractures in the schist (*see* fig. 3). At the south-eastern end of the deposit, the albite is developed over the whole width of the body almost to the exclusion of the talc, which occurs only as occasional thin bands containing abundant coarse disseminated albite.

The ridge on the north side of the valley contains the deposits which constitute the talc mine of John Dunstan & Son (W.A.) Ltd. and the workings of the Torrens Mining Co. Ltd. Most of the production of the district comes from this area. Mining at Dunstan's talc mine is in progress from adits near the eastern end of the ridge. The talc occurs in seams up to 10ft.—and occasionally 20ft.—wide, between masses or "boulders" of albite rock and albitized schist of much larger dimensions. The drives and other workings are considerably twisted by almost right-angle turns, and by falls and rises in the bottoms of the levels, because they follow the soft talc seams and avoid "boulders" of hard rock. A plan of the workings (*see* fig. 4) provides a picture, therefore, of the distribution of the main seams of talc in relation to the "boulders" of albitized schist in the deposit, for the particular horizon. There is a degree of parallelism between different parts of the workings that suggests that the talc seams might be filling a series of fractures, such as could be set up within a shear zone. A small "boulder" isolated in the workings after the extraction of the enveloping talc is illustrated in fig. 5.

North-west of Dunstan's talc mine, and on top of the same ridge, are the workings of The Torrens Mining Co. Ltd. Here, shafts have been sunk to depths of 40ft. and 70ft., and drives put out at several levels into a talc-albite deposit that is similar to the deposit worked in Dunstan's mine. The same relationship of talc seams to "boulders" of albitized schist has been encountered, but the talc seams are thinner and the "boulders" appear larger and more numerous in the sections so far exposed.

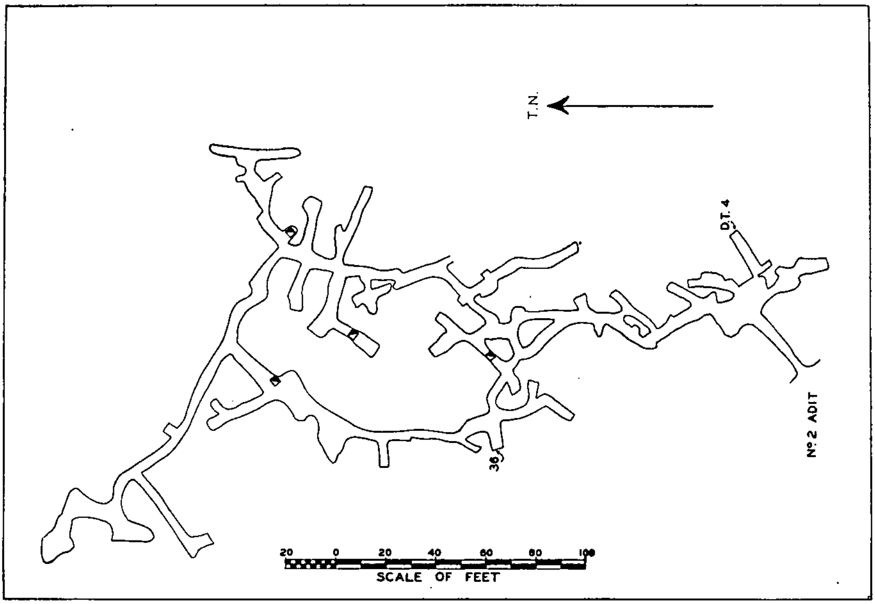

Fig. 4.—Level plan of No. 2 adit, Dunstan talc mine

The workings have been developed by following seams of soft talc from an adit on the hillside. The plan thus provides a picture of the distribution of the talc in relation to the albitized schist in the deposit for a particular horizon. D.T. 4 and 36 are localities of albitized quartzite

Outcrops of talc occur at intervals along a quartzite ridge leading northwards, through sections 6268 and 245, to the Birdwood-Gumeracha road (*see* fig. 1), where several pegmatite dykes outcrop in the biotite schists. After a blank interval of about 1½ miles, a further series of talc outcrops are found in sections 6275, 6274, and 6380, hundred of Talunga. Trenches and shallow shafts have been cut at a number of these deposits, exposing a similar association of talc, albite, and biotite schist to that found at Dunstan's talc mine and the Torrens Mining Company's workings.

Porter's talc quarry, section 6213—1½ miles south of Dunstan's talc mine—reveals a generally similar association of talc and albite. The exposures are limited, and the quarry, which is not in operation at present, has not penetrated to fresh rock. Massive albite rock, about 3ft. thick, marks the contact of the talc body with the country-rock, and is exposed in section in the trench leading into the quarry. The country-rock consists of quartzite and mica schists. The quarry is cut in massive white talc through which are dispersed small masses

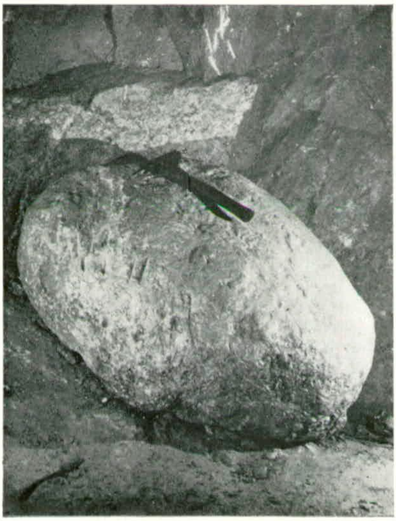

Fig. 5

Fig. 6

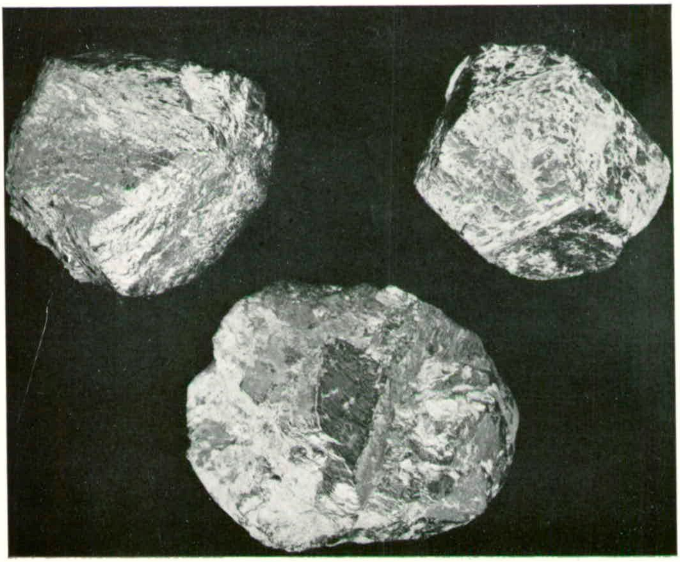

Fig. 7

Fig. 5.—A small "boulder" of albite and albitized schist as discarded in the workings of Dunstan talc mine after the extraction of the enveloping talc

Fig. 6.—Talc crystals with stellate structure, probably pseudomorphous after stellate amphibole; Dunstan talc mine

Fig. 7.—Pyritohedrons of pyrite found occasionally in the talc; Dunstan talc mine

of pink weathered albite, producing a strikingly spotted appearance. In places on the floor of the quarry, and in pillars supporting a deeply undercut face, large "boulders" of apparently massive albite were observed. In the face are occasional greyish patches, which owe their darker colour to an abundance of rutile grains disseminated through talc. It would appear that high-grade talc could not be readily obtained in quantity by selective mining from this part of the deposit.

South-east of Porter's talc quarry is another small open cut, known as Porter's asbestos quarry. The deposit exposed here consists essentially of albite, talc, and a fibrous form of talc (*see* table I, analysis No. 4) which resembles asbestos, and from which the deposit takes its name. Massive albite rock, several feet wide, marks the contact of the talc with the schists which are exposed in section in the portal of the quarry. In the quarry face talc occurs as seams through the albite rock, and some narrow seams contain large crystals of fibrous talc, with fibres 4in. or more in length. Some of the large crystals of fibrous talc are surrounded by massive lamellar talc and have the appearance of pseudomorphs after some pre-existing prismatic mineral, presumably an amphibole. The fibrous character of the talc as signified by the ease with which it can be teased out into fibres is more marked in weathered than in the unweathered portions. The albite rock shows banding, parallel to the schistosity of the adjacent schists.

PETROLOGY OF THE TALC DEPOSITS

The Talc Bodies

At Dunstan's talc mine (Gumeracha) the talc is graded according to its colour and freedom from "grit", that is, disseminated grains of albite. The first-grade talc is a white massive talc rock with the individual talc crystals forming plates from 2 mm. to 3 mm. across. It has an equigranular texture, without any trace of schistosity or preferred cleavage. The talc has refractive indices about 1·540 and 1·585 and is biaxial, negative, with a very small optic axial angle. Thin sections show that it consists chiefly of platy crystals of talc through which are dispersed occasional grains of albite felspar (*see* fig. 8) up to 1 mm. across. Minute shreds of greenish-brown biotite, with indefinite margins, are occasionally included in the talc along the cleavage directions. In places, the biotite is altered partly or wholly to chlorite. There are also scattered crystals of yellow to brown rutile, up to 0·2 mm. in cross-section, but generally smaller. An occasional crystal of apatite is also found.

The grade of the talc is lowered with the increase of these impurities. Increase in the amount of albite results in grittiness which may render the talc unmarketable. Increase in the amount of biotite may produce discoloration; and the amount of discoloration largely determines the selection of the second and third grades of talc which are marketed at Gumeracha. The second-grade talc is greyish by comparison with the first grade, and contains areas with small black spots of biotite. The third grade is much spotted with biotite.

Sometimes a thin section of the lower grade of talc discloses a thin band of biotite, as in fig. 9, in which a crystal of apatite is associated with the biotite band. Discoloration is frequently caused by residual, unreplaced shreds of biotite in the cleavage planes of talc (*see* fig. 10), producing dark spots in the hand specimen. In many instances, these shreds of biotite are recognizable by their colour and pleochroism; but there are cases where no pleochroism can be detected, despite the apparent similarity in colour and appearance. Similar evidence of replacement of biotite by talc has been described in C. S. Ross* at Monarat and other localities in the Ducktown district of the Southern Appalachian Region.

* Ross, C. S., "Origin of the Copper Deposits of Ducktown type in Southern Appalachian Region". *U.S. Geol. Survey Prof. Paper* 179, p. 32.

A greenish chlorite is also present in the lower grades of talc (*see* fig. 9). It occurs either as small lenses, which modify the pure white colour of the first-grade talc, or in bands associated with biotite. The chlorite tends to occur as crystals of the same size as the talc, and is interwoven with them. It is pale green in basal plates, and is pleochroic from pale green to colourless in cross-sections, which show interference colours up to orange and yellow of the first order. Basal sections show almost uniaxial figures which are optically positive. No observations have indicated the direct change of chlorite to talc, which Ross has described as common in talc occurrences in the Ducktown area. A rare occurrence of the chlorite is in the form of segregations in the talc bodies. These segregations are aggregates of numerous, exceedingly fine crystals of chlorite with a tendency to a granular outline and with no orientation in any particular direction.

Occasionally in the lower grades of talc there are small pockets, several millimetres across, of a pale-yellow phlogopite mica. They powder readily and are difficult to retain in thin section. The phlogopite is identified by the refractive index of the basal plates, which is less than 1·565; and it is distinguished from chlorite by its high birefringence and its uniaxial interference figure, which is optically negative.

Not infrequently, the talc in contact with the albite rock, or within the talc-albite zone, shows a columnar crystal structure—for an inch or so from the contact—the crystals standing at right-angles to the contact. A less common feature in the marginal zone is talc in the form of long, slender, radiating rosettes, presenting a structure in the hand specimen that is suggestive of talc pseudomorphous after stellate actinolite or tremolite (*see* fig. 6). In places these rosettes are spotted from the presence of thin residual plates of biotite along the cleavages of the talc. The specimens contain occasional pseudomorphs of limonite after pyrite and show iron staining, but no traces of a prismatic amphibole can be recognized.

Pyrite occurs sporadically in the talc, in both large and small crystals. In the deeper levels of Dunstan's mine, well-formed pyritohedrons of pyrite, up to 4in. in diam., are occasionally found in the talc, generally in clusters of several crystals (*see* fig. 7). In the higher levels, these crystals have been altered to limonite, and their former position is marked by cavernous pockets of friable, stained talc, some of which are several feet across. At Porter's talc quarry, pseudomorphs of limonite after pyrite, up to 2in. across, were observed in the talc a few feet below the surface. Smaller crystals are more commonly present, and are represented in the oxidized zone by small limonitic casts, which have contributed materially to the staining of the talc. A similar occurrence of pyrite sparsely disseminated through the talc was noted in the workings of The Torrens Mining Co. Ltd., and at Tonkin's, Berry's, and Symonds' workings at the northern end of the talc zone. The presence of this disseminated pyrite is revealed by the presence of sulphide sulphur in the several chemical analyses of the talc that have been made. It is possible that this proportion of sulphide sulphur will increase somewhat in talc taken from below the oxidized zone.

In two instances at Dunstan's talc mine, sulphur—instead of occurring in combination with iron as pyrite—has been found in the native form in cavities or vughs up to 6in. across. In both instances, the sulphur occurs as loosely compacted aggregates of fine crystals with attached traces of ironstained material. The talc walls of the vugh are also somewhat ironstained, and the probable explanation is that the sulphur has been produced from the oxidation of pyrite under conditions of low accessibility of air. Pyrite and marcasite, if acted on by ferric sulphate with the sulphide in excess, oxidize to ferrous sulphate, sulphuric acid, and free sulphur.* The occurrence of native sulphur is rare in

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* Allen, E. T., Crenshaw, J. L., Johnston, J., and Larsen, E. S., *Am. Jour. Sci.* 33 (4th ser.) 169, p. 175, "The Mineral Sulphides of Iron", 1912.

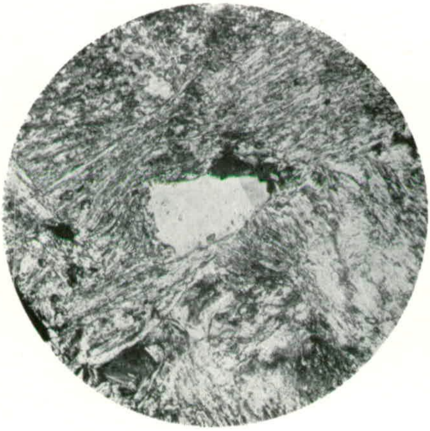

Fig. 8

Fig. 9

Fig. 10

Fig. 8.—Grain of albite in first-grade talc, Dunstan talc mine. Dark area below the albite grain is a hole

Fig. 9.—Lenticular area of chlorite in second-grade talc, Dunstan talc mine. Crystals of apatite visible on the course of a thin seam of dark biotite

Fig. 10.—Shreds of dark biotite along the cleavage of talc in third-grade talc, Dunstan talc mine. The section is fractured in the field of view

To face page 36]

the talc deposits; and if it were primary sulphur in the same sense that talc and pyrite are primary, and deposited in circumstances where there was insufficient iron for the formation of pyrite, it might be expected that the occurrences would be less isolated and more general.

Carbonate minerals are generally absent from the talc, and none of the chemical anaylses show any CO_2. At one point, however, near the northern end of the upper level from the No. 2 adit of Dunstan's talc mine (*see* fig. 4) a vein of carbonate, about 6in. wide, was found traversing the talc rock in a loose block that had broken from the face. No carbonate was visible in the face, so presumably the carbonate vein was short and lens-like. A partial analysis of the carbonate shows that it is a dolomite containing—

$CaCO_3$	53·7
$MgCO_3$	41·0
$FeCO_3$	6·3

A specimen has previously been obtained, from the same vicinity, which consisted of an aggregate of granular carbonate and talc.

Chemical Composition

Chemical analyses have been made, by the Department of Mines, of the best-grade talc from Dunstan's talc mine, the quarry on Steatite Hill, and the No. 2 shaft of the Torrens Mining Co. These, together with an analysis of fibrous talc—resembling asbestos—from Porter's asbestos quarry, and an analysis of a flotation concentrate of talc, are given in table I.

TABLE I

Analysis No.	1	2	3	4	5	6	A
SiO_2	61·90	61·42	61·98	60·66	61·98	61·86	63·50
Al_2O_3	1·88	0·72	5·74	0·78	2·71	0·59	
Fe_2O_3	0·65	0·70	nil	0·37	0·76	0·28	
FeO	1·66	1·75	1·93	2·94	1·70	2·57	
MgO	28·23	29·82	25·60	29·31	26·82	30·20	31·70
CaO	nil	nil	0·18	nil	0·22	0·08	
Na_2O	0·68	0·10	—	0·04	1·42	0·02	
K_2O	nil	nil	—	nil	nil	nil	
H_2O over 100°C..........	4·66	4·96	4·10	5·41	4·20	4·90	4·80
H_2O at 100°C...........	0·03	0·12	—	0·16	0·16	0·13	
CO_2	nil	nil	nil	nil	—	—	
TiO_2	0·07	0·10	—	nil	0·13	0·04	
P_2O_5	0·07	0·07	—	0·06	0·13	0·02	
S (as sulphide)	0·07	0·06	—	0·19	0·09	0·05	
SO_3	nil	nil	—	nil	—	—	
Cl	nil	nil	—	nil	—	—	
	99·90	99·82	99·53	99·92	100·32	100·74	100·00
Less O_2 for S...........	0·02	0·02		0·07	0·03	0·02	
	99·88	99·80	99·53	99·85	100·29	100·72	100·00

1—High-grade talc, hand-picked, Dunstan's talc mine. (Analyst: T. W. Dalwood).

2—High-grade talc, hand-picked, from Symonds' No. 2 shaft, Torrens Mining Co., Ltd. (Analyst: T. W. Dalwood).

3—Good white soapstone, quarry, Steatite Hill (*Mining Review*, No. 42, p. 70, 1925).

4—Fibrous talc, Porter's asbestos quarry. (Analyst: T. W. Dalwood).

5—Talc, Dunstan's talc mine. Bulk sample used in an ore-dressing test. (Analyst: T. W. Dalwood).

6—Talc flotation concentrate from ore with the composition of No. 5. (Analyst: T. W. Dalwood).

A—Theoretical composition of talc.

The percentage of TiO_2 in these analyses can be ascribed to rutile; and the percentage of P_2O_5 indicates that there is about 0·15 per cent of apatite in the hand-picked talc and 0·3 per cent in the bulk sample. The amount of sulphide sulphur indicates 0·11 per cent to 0·17 per cent pyrite. Na_2O is wholly contained in albite; the amount of albite varies from 0·8 per cent in the high-grade hand-picked sample No. 2, to about 12 per cent in the average ore, sample No. 5.

After rutile, apatite, and albite have been allowed for in the chemical composition, there still remain small amounts of alumina, ferric iron, and ferrous iron as impurities by comparison with the theoretical composition of talc. This is also the case with chemical analyses of the purest talcs in all parts of the world. In the Gumeracha talc, traces of pyrite and its oxidation product, as well as traces of biotite and chlorite, may account for the ferric iron. Traces of biotite and chlorite may account for the alumina in excess of that required for albite, and flakes of chlorite are sufficiently prominent in the Steatite Hill talc (sample No. 3) to account for its relatively high alumina. The percentage of ferrous iron is, however, too high to be explained in terms of these mineral impurities, and the suggestion arises that traces of ferrous iron are combined with magnesia in the talc molecule. This appears to be the most likely explanation of the relatively high percentage of ferrous iron in the fibrous talc (sample No. 4) and in the flotation concentrate (sample No. 6) from which rutile, apatite, and albite have been almost entirely removed.

The Albite Rocks

Albite-rich rocks occur consistently on the margin of the workable talc seams as a "sheath" between the massive talc and the albitized country-rock. The thickness of the albite sheath is variable and averages about 1ft., and appears to be independent of the thickness of the talc seam.

Chemical analyses of the albite rock, and of the felspar from such an albite rock after treatment with bromoform of sp. gr. 2·85 confirm the sodic character of the felspar.

TABLE II

Analysis No.	1	2
SiO_2	63·02	61·84
Al_2O_3	15·79	18·04
Fe_2O_3	2·59	2·08
FeO	0·63	—
MgO	2·84	2·71
CaO	1·22	0·86
Na_2O	7·54	9·31
K_2O	0·24	0·34
H_2O over 100°C.	0·76	0·27
H_2O at 100°C.	0·07	0·53
TiO_2	3·89	2·29
P_2O_5	0·76	n.d.
Cl	0·02	—
	99·37	98·27

1. Albite rock (40) from west drive, No. 2 adit, Dunstan's talc mine. (Analyst: T. W. Dalwood.)
2. Albite separated from the albite rock by bromoform. (Analyst: T. W. Dalwood.)

Assuming that the MgO in the analysis (No. 2) occurs as talc and the TiO_2 as rutile—not freed from the felspar by crushing—and calculating K_2O, Na_2O, and CaO as felspar, the felspar constitutes about 85 per cent of the rock and has a composition about $Or_2Ab_{93}An_5$. It is probable, however, that the albite is even more sodic than this because it is unlikely that all the biotite, apatite, and sphene have been separated by the bromoform, and that all the K_2O and CaO are contained in the felspar. The albite has refractive indices ranging from about 1·525 to 1·535 and is biaxial and positive, which is in accord with its determination as nearly pure albite.

The albite rocks are white or grey rocks consisting essentially of albite, generally with a small proportion of included talc; but all gradations are found between relatively pure albite rock and relatively pure talc rock. In places, the talc forms narrow bands 2 mm. to 3 mm. wide between wider bands of fairly pure albite, or bands of pure white albite up to 10 mm. wide lie between wider bands of greyish albite rock, which nevertheless contains a proportion of talc. In other places the talc is distributed uniformly through the albite, or it forms clusters of coarse crystals within albite. These features, which may occur within the limits of a hand specimen, are repeated on a larger scale; but, nevertheless, the contact between the albite rock and the massive talc frequently appears to be sharp, in the field.

Minor constituents in the albite rock are rutile, apatite, tourmaline, biotite or phlogopite, sphene, phenacite, pyrite, and quartz. Rutile is the most abundant of these, and nearly the whole of the 3·89 per cent TiO_2 in the analyzed sample is represented by rutile. Its distribution is variable, and fig. 13 illustrates an area of albite in which rutile crystals are more than usually abundant. The rutile is reddish brown, and the larger crystals are commonly 0·2 mm. in width, but there are also numerous small crystals. Titania that is not absorbed in rutile appears in the form of occasional ragged crystals of sphene; but there is seldom more than one or two particles of sphene within the limits of a section and, in many sections, it is absent.

Apatite crystals are not nearly as numerous as rutile in the albite rock, but their average size is larger. Measurement in one section indicated the ratio of rutile to apatite to be approximately 5 to 3 by volume. The amount of apatite in the analyzed rock is 1·8 per cent by weight.

Tourmaline occurs as occasional ragged crystals and needles, but its distribution is much more irregular than that of rutile or apatite. In a few places it forms segregations, several inches across, within the albite zone. Such a nodule, seen in thin section, consists of brown tourmaline with imperfect crystal form, set in a base of albite and biotite, the tourmaline being the dominant mineral. The biotite flakes vary somewhat in the intensity of their pleochroism, and some of them enclose thin needles of rutile. Grains of apatite and rutile are present in the albite matrix. The margin of the tourmaline segregations is lighter coloured than the core, and shows a passage to normal albite rock, which contains only insignificant amounts of tourmaline and biotite. Occasional crystals of pyrite—up to 1 cm. across—with traces of oxidation to limonite, occur in the transition zone.

The brown biotite tends to be restricted to narrow, somewhat indefinite bands in the albite rock, and is sometimes intergrown with talc. The consistent occurrence of biotite in parallel bands suggests that it is residual from the replaced schist. The direct passage of these bands into talc can sometimes be observed within the limits of a thin section. In some hand specimens of the albite rock, the mica can be observed to have a brownish-yellow colour and the basal plates, when isolated, have been found to have a refractive index of approximately 1·585. This value is below that of biotite and indicates that the mica is the magnesium variety, phlogopite.

Phenacite is an accessory mineral forming small, colourless crystals about 0·05 mm. by 0·02 mm. It is uniaxial and positive, with a high refractive index and second-order polarization colours which distinguish it from zircon. Some grains have a rhomboidal shape. This mineral was concentrated in the heavy residue obtained by suspending the crushed rock in bromoform of sp. gr. 2·85, in which the phenacite sank while the albite floated. The resulting concentrate was subjected to spectroscopic analysis by A. J. Gaskin, and the presence of beryllium in amounts adequate to form phenacite was established.

Quartz occurs in interstices between crystals of albite, forming particles of very irregular shape. At times it appears as the base for idiomorphic crystals of albite, which clearly indicates that the quartz was deposited after the albite and is not residual quartz from replaced schist or quartzite.

Albitized Schists and Quartzites

The country-rocks consist largely of biotite-quartz schists which—in the vicinity of the talc-albite zones—show varying degrees of albitization.

Surface Exposures

The best exposures at Gumeracha are the open cuts leading into the quarries on Steatite Hill and into Dunstan's talc mine. Some relatively fresh rock is exposed in outcrops on the hillside above Dunstan's talc mine, but it is often doubtfully *in situ.*

At the Steatite Hill quarry, a thin section of the schist (28), an inch from its contact with the albite rock, consists essentially of biotite and quartz. It also contains a number of cloudy grains consisting of albite with small inclusions of talc, sometimes associated with particles of residual biotite, similar to those illustrated in fig. 14. Biotite flakes often contain minute needles of rutile. An occasional crystal of tourmaline is present in the section as well as a few limonitic pseudomorphs after pyrite, and an occasional grain of garnet has been observed in the crushed rock. This rock is soft and readily crushed, and the biotite was concentrated from the powder by suspension in bromoform of sp. gr. 2·85. The heavy concentrate containing the biotite was then treated on an electromagnetic separator, and the product was finally cleaned on an inclined sheet of carboard. When the card was gently tapped, the remaining granular impurities and composite grains rolled down the card more readily than the free plates of biotite. The purified material has been analyzed by T. W. Dalwood, and the result shows that the biotite is an iron-magnesium variety, moderately rich in magnesium. The refractive index of the basal plates is 1·630.

BIOTITE FROM BIOTITE-QUARTZ SCHIST, STEATITE HILL

SiO_2	40·70
Al_2O_3	15·58
Fe_2O_3	13·35
FeO	1·26
MgO	11·27
CaO	0·32
Na_2O	1·03
K_2O	6·22
H_2O over 100°C.	5·84
H_2O at 100°C.	1·50
TiO_2	3·12
	100·19

A biotite-quartz schist (25) from a second trench cut on Steatite Hill, about 2yds. from its contact with the albite rock, was found to be a little finer grained with somewhat paler biotite than the preceding specimen. Inclusions of minute reddish-brown crystals of rutile are more abundant in the biotite. In addition to the biotite, there are scattered crystals of a colourless hornblende (actinolite), sometimes lying partly across the schistosity. These crystals tend to be acicular and cross-sections reveal the characteristic amphibole cleavage, intersecting about 56deg. Albite is present in the base of the rock, surrounding and cementing grains of quartz and biotite, and it also occurs in cloudy areas associated with talc.

Associated with the biotite schists in these two open cuts at the Steatite Hill quarry are (1) a thin intercalated bed, 6in. wide, which has the appearance in the field of a fine-grained sandstone, and (2) narrow transgressive pegmatitic veins.

Fig. 11

Fig. 12

Fig. 13

Fig. 14

Fig. 11.—Sagenitic web of rutile in basal plate of chlorite, associated with crystals of tourmaline with high relief. Dark patches are biotite, and colourless areas are albite. Albitized biotite-quartz schist at 80ft. in No. 2 bore

Fig. 12.—Fewer and larger prisms of rutile in basal plate of chlorite. Smaller prisms along cleavage in a cross-section of altered biotite. Dark patches are residual biotite. Albitized biotite-quartz schist at 31ft., No. 1 bore

Fig. 13.—Rutile prisms in a lenticle of albite in albitized biotite-quartz schist at 31ft., No. 1 bore

Fig. 14.—Cloudy areas of albite and talc, which appear to arise directly from alteration of biotite. Dark crystals are reddish rutile, and small biotite flakes are present (upper right). Clear areas are mostly albite enclosing some indistinguishable ragged areas of talc. Albitized biotite-quartz schist at 31ft., No. 1 bore

The apparent sandstone proves on investigation to consist of albite and a considerable amount of altered mica and talc with disseminated particles of rutile. Quartz is absent, and most of the talc crystals contain shreds of altered biotite along the cleavages. The albite crystals show a marked parallelism with the flakes of talc and altered biotite, indicating that the rock was originally a biotite schist in which the quartz has been replaced by albite and the biotite largely replaced by phlogopite and talc.

The pegmatitic veins are very narrow, mostly not more than 1in. in width, and form a network in the schists (*see* fig. 3). They are probably derived from the residual solutions after the production of the talc. They contain coarse albite, as well as quartz, occasional stellate groups of talc leaves, and rutile crystals up to 1·5 mm. long. A greyish to brownish mineral is present in some sections of these veins, appearing within the talc flakes and on their margins. It is identical with a clay-like mineral occurring in joints in the massive talc, and is described later as a relative of the magnesian clay mineral, attapulgite, (pp. 45, 46) derived from the surface alteration and replacement of talc.

The least altered example of the schistose country-rocks at the surface occurs in the open trench at the No. 3 adit of Dunstan's talc mine, about 70ft. from a talc-albite deposit. This rock has been analyzed (*see* table III, No. 1). It is a biotite-actinolite-quartz schist which shows incipient alteration of some of the biotite and actinolite, but it is otherwise unaltered. The biotite has a refractive index of 1·630 in the basal plates and is, therefore, similar in composition to the analyzed biotite. The actinolite occurs in small prisms about 0·1 mm. long, and is pleochroic from pale green to colourless and shows distinct amphibole cleavage. It is much less abundant than the biotite. The dominance of ferric iron over ferrous iron in the chemical analysis indicates that the rock is somewhat affected by surface oxidation. By comparison, an analyzed specimen of biotite schist from No. 1 diamond-drill bore (*see* table III, No. 2) is quite unweathered. The two analyses show that the schists associated with the talc deposits contain a notably higher percentage of MgO (5 per cent) than the average shale or mica schist (2 per cent to 3 per cent).

TABLE III

Analysis No.	1	2
SiO_2	63·50	63·26
Al_2O_3	14·20	13·98
Fe_2O_3	4·15	2·02
FeO	0·58	4·08
MgO	5·08	5·28
CaO	2·22	1·80
Na_2O	3·74	2·84
K_2O	2·18	3·28
H_2O over 100°C.	1·57	1·20
H_2O at 100°C.	0·15	0·04
TiO_2	1·71	1·47
P_2O_5	0·33	0·37
Cl	0·01	0·01
	99·42	99·63

1. Biotite-actinolite-quartz schist, from entrance of No. 3 adit, Dunstan's talc mine, Gumeracha. (Analyst: T. W. Dalwood.)
2. Biotite-actinolite-quartz schist, from core of a "boulder" at 109ft., No. 1 diamond-drill bore, Dunstan's talc mine, Gumeracha. (Analyst: T. W. Dalwood.)

Underground Exposures

Underground workings from the No. 2 adit rarely penetrate any distance beyond the surface of the hard "boulders", so that they generally expose little beyond the sheath of albite rock which envelopes the talc seams and which forms the outer zone of the hard "boulders". In a few places, however, specimens from deeper in a "boulder" have been obtained, and for the most part these are strongly albitized schists which were originally similar to those in the surface exposures.

These rocks consist largely of albite and talc, but they retain a banded appearance, owing to the elongation of the albite grains parallel to one another and to narrow bands of biotite that are parallel to the planes of schistosity in the original rock. In some of the bands the biotite is little altered, but in others it is partially decolourized, and occasionally converted into phlogopite or largely replaced by talc. The previous presence of biotite is frequently recognizable by the colour and pleochroism of the shreds that persist along the cleavages of talc.

One specimen (D.T. 1) from the most easterly wall in the northern part of the level below that shown in fig. 4, has the appearance, in the hand specimen, of a thinly bedded, sandy mudstone; but, in thin section it is found to consist essentially of minute platy crystals of greenish-brown biotite, generally less than 0·05 mm. across, and of equally fine-grained, untwinned albite, which occurs as a mosaic of allotriomorphic grains. The original bedding planes are sometimes marked by brown limonitic bands, which contain coarse flakes of iron-stained biotite and chlorite, up to 0·5 mm. long, together with a little muscovite or talc. Isolated brown limonitic spots up to 0·5 mm. across have developed from the oxidation of disseminated pyrite, and are associated with large plates of talc. Other minerals in the rock are apatite, rutile, and phenacite.

Diamond-Drill Cores

Diamond-drill holes, bored horizontally from the No. 3 adit, have passed through a series of talc seams. The position of the bores, and details of the cores, are given on pages 12, 21, and 22 in *Mining Review* No. 80 (for the half-year ended 30th June, 1944). The cores thus provide complete cross-sections of the "boulders" of country-rock that separate the talc seams. From these it can be seen that the "boulders" have cores of only partly albitized biotite-quartz schists or biotite-actinolite-quartz schists or quartzites, which pass rather abruptly near their margins into "sheaths" of albite rock.

A chemical analysis of a little altered schist at 109ft. in the No. 1 bore is given in table III, column 2, and shows that it is almost identical with the country schist at the entrance of the No. 3 adit (column 1).

While the hand specimens often show a relatively sharp junction between the albite "sheaths" and the schists that form the cores of the "boulder", there is an obvious gradation in some specimens over a distance of a few feet. Thin sections show that the change is always gradational, and that the schists in the interior of the boulders have invariably undergone partial albitization, with a corresponding partial alteration of biotite into talc.

Thus, in a series of sections cut at intervals of a few inches of the transition from schist to albite rock that shows between 77ft. 6in. and 80ft. 9in. from the collar of No. 2 bore, the least altered rock is a dark biotite-quartz schist containing small amounts of actinolite and chlorite. Occasional lenticles of clear albite with a few inclusions of biotite, rutile, and apatite occur between the strongly developed bands of biotite. Sometimes, as in fig. 13, numerous rutile crystals are embedded in these albite lenticles. In addition, there are numerous small composite areas of albite and talc scattered throughout and similar to those illustrated in fig. 14. Some of these talc-albite areas are continuous with biotite, some are pseudomorphous after biotite, and some include residual patches of biotite or chlorite.

A few inches closer to the albite rock, the lenticles of clear albite and associated talc are larger, and often include scattered remnants of biotite, together with rutile, apatite, and pyrite. The pyrite is idiomorphic and tends to occur in small strings of pyritohedral crystals along the schistosity. Some bands of the schists are coarser grained than others; and in the coarse bands where biotite is largely altered to chlorite, there are clots of relatively coarse crystals of tourmaline. Pyrite occurs in the immediate vicinity of the tourmaline clots, and the adjacent chlorite contains abundant fine sagenitic webs of rutile (*see* fig. 11).

Still closer to the albite rock, the transition rock becomes lighter in colour, and the unaltered biotite is restricted to a few prominent narrow bands across the section. The intervening area consists chiefly of a fine-grained mosaic of albite with minute flakes of talc, and grains of rutile and apatite. Occasional clots of tourmaline crystals appear in albite, similar to those in the less altered schists, and frequently there are associated with them remnants of coarse biotite flakes, or relics of the original biotite in the form of thin rutile needles derived from the titanium of the biotite, and oriented in the direction of the original biotite cleavages.

Immediately adjacent to the albite rock, the altered schist is light coloured, with only thin lines of biotite residuals remaining. It consists essentially of albite with fine talc, a little residual quartz, clots of coarse tourmaline crystals, pyrite, and sometimes sagenitic webs of rutile entirely embedded in albite.

A number of thin sections cut from other parts of the bore all show this general character. In some, the biotite is accompanied by actinolite, but generally the amphibole only forms a minor component.

Traces of alteration of biotite to chlorite are not uncommon; but the transition of chlorite to talc is not so readily observed. The development of chlorite is often accompanied by the discharge of titanium in the form of fine rutile needles along the cleavages (*see* figs. 11, 12).

Albitized Quartzites

With increase in quartz and decrease in biotite, the schists grade into quartzites, which in the vicinity of the talc lodes are always more or less albitized. The close association of the schists and quartzites is best seen in the underground workings and in the drill cores.

Underground Exposures

The locations of two specimens of albitized quartzites are shown in fig. 4. One (D.T. 4) from the easterly wall in the southern part of the upper level of Dunstan's mine is a banded brown to white rock that appears to be a metasomatized quartzite, in which the individual grains of quartz are rarely more than 0·5 mm. in length, with an average of 0·1 mm. or less. The quartz grains are angular and interlocking, indicating that they have been recrystallized. Many of them are cemented by albite, which varies in amount from band to band in the section. The banding is further marked by a difference in grain size of the quartz grains in successive bands. Occasional plates of greenish-brown biotite are present, and there is a relative abundance of minute crystals of rutile which tend to lie parallel to the banding. In addition, there are occasional larger crystals of rutile—up to 0·3 mm. long—and of apatite in well-formed prisms of the same dimensions, together with a little talc and phenacite.

The second specimen of partly metasomatized quartzite (36) was obtained from the western wall of the upper level. It is a dark rock, consisting of quartz grains about 2·0 mm. and rarely more than 0·4 mm. long, which are elongated parallel to the bedding, giving the rock a banded appearance. The quartz grains are cemented together by clear albite, which is mostly untwinned.

The banding is further marked by the parallelism of minute biotite flakes, and in lesser degree, rutile prisms and colourless needles of hornblende. Numerous small crystals of pyrite are present, and also occasional ragged grains of sphene. Sections a few inches away show an increase in the proportion of albite relative to quartz, as the dark quartzite passes into a white albite rock. In these sections also, the narrow bands of biotite can be seen to pass laterally into equally narrow bands of talc, and in some cases the individual crystals of talc include shreds of biotite.

Diamond-Drill Cores

A section of banded quartzite, at 186ft. in No. 1 drill core (118), clearly reveals that it is an altered sediment. The banding arises from a repeated alternation of fine-grained bands, in which the grain size averages about 0·05 mm., with coarser-grained bands, in which the grain size is between 0·2 mm. and 0·5 mm. The finer-grained bands are distinctly richer in biotite flakes than the coarse bands; and there can be no doubt that the rock represents an original finely bedded association of sandstone and shale, which was recrystallized, and subsequently invaded by albitizing solutions, which replaced the quartz and biotite in part, altering the biotite to talc, and cementing the residual quartz grains together. The talc grains in the coarse-grained bands commonly contain cores of residual biotite.

The transition from albitized biotite-schist to albitized quartzite can be observed in several sections (115, 116) from this bore core, being marked by a decrease in biotite and an increase in quartz, relative to the amounts of these minerals in the typical schists. Such specimens have a hard, quartzite-like appearance in hand specimen, but are dark coloured owing to the abundance of fine biotite flakes in them, and can be referred to as biotite-quartzites. As with the other rocks, they are extensively replaced by albite.

Similar rocks occur in the No. 2 diamond-drill core. A specimen at 138ft. (108) is a fine-grained albitized biotite-quartzite, in which the quartz has been replaced in part by albite, and the biotite somewhat altered to talc. A specimen at 130ft. (119) shows a more advanced stage of replacement with a greater development of talc, and less residual biotite. Small crystals of pyrite occur abundantly through the section.

True quartzite, somewhat albitized, occurs in this drill core at 175ft. (106). This consists of angular, irregular shaped grains, averaging about 0·2 mm. across, closely interlocking with one another. The albite occurs as irregular interstitial patches, with some tendency to elongation in one direction, presumably the original bedding direction. The albite is cloudy, and speckled with sericite. Associated with it are shreds of chloritized biotite and flakes of chlorite, together with occasional flakes of talc and grains of rutile. Small prismatic grains of greenish-brown biotite are distributed through the quartzite where albite is absent, and show a parallelism suggesting original bedding. Locally they become more abundant, and form bands approximating to biotite-quartzite.

Surface Exposures

Similar banded albitized quartzites and albitized biotite-quartzites outcrop to the north of the talc deposits, in close proximity to them. They extend, more or less continuously, from Dunstan's talc mine to the Torrens Mining Company's talc mine, and thence nearly to the Gumeracha-Birdwood road. The line of outcrops is marked by prominent ridges, which owe their existence to the relative hardness of the quartzites as compared with the associated schists.

In the hand specimen, the quartzites commonly have a finely banded texture. In some specimens the banding is marked by alterations of dark and light bands, corresponding to alterations of beds of quartzite and biotite-quartzite. In other specimens the banding is less distinct, and is marked by parallel elongation of the quartz grains, and of interstitial felspar grains, or lines of pits from which the felspar has been weathered. The proportion of the felspar varies greatly from place to place. In some rocks it is present in sufficient abundance to render the rocks as friable as normal sandstones where they are weathered. In other specimens it forms only a minor component.

Thin sections of the rocks reveal that they are, generally, similar to the quartzites observed in the workings and drill cores. A section of banded quartzite from the ridge above Dunstan's talc mine (22) shows that it consists of an interlocking aggregate of quartz grains with a lesser amount of felspar grains. The quartz shows elongation parallel to the banding, which is a reflection of fine bedding. The felspar grains are comparable in shape with the quartz grains. They include cloudy grains with simple twinning and grains with tartan twinning, which are either orthoclase or microcline. Others are clear, in places enclosing strongly birefringent fibres of talc or mica. There are also present a few flakes of muscovite which cannot, in all sections, be distinguished from the talc. Occasional clusters of talc crystals are present, basal sections of which show a very small optical axial angle, which distinguishes them from the muscovite. Limonite pseudomorphs after pyrite are scattered through the rock.

A section of finer-grained quartzite from near the Torrens Mining Company's mine is generally similar, but contains rather more albite and talc dispersed through the rock. The quartz grains, which show parallel elongation, are rather finer-grained than those in (22).

SURFACE ALTERATION OF THE TALC

The talc bodies persist to the surface, except in so far as they are covered by talus or a thin layer of soil. The talc generally shows little alteration, apart from discoloration by ferric oxide. In the quarries at Steatite Hill, however, a clay-like mineral occurs as veins—up to 1in. wide—along fractures and joints in massive talc. These veins extend for several feet below the top of the talc.

The clay-like mineral is greyish in the hand specimen, but in thin sections appears pale-brown. The thin sections reveal scattered crystals of albite and talc, and an occasional small grain of rutile included in large areas of the clay-like mineral. The mineral also occurs along the cleavages of the talc, and less frequently, along fractures in the albite, while minute needles of talc are sparsely scattered in the larger areas of the clay-like mineral. It is obvious that the clay-like mineral is derived from the alteration and replacement of the talc.

The clay-like mineral is feebly pleochroic, showing a varying intensity of the pale-brown colour on rotation. With crossed nicols it shows traces of a fibrous character with straight extinction. Polarization colours range up to reddish-yellow of the first order, and by comparison with the polarization colours of the albite in the same section, its birefringence is approximately 0·012. Interference figures show that it is biaxial, with a very small optic axial angle and negative in character. The lowest refractive index lies between 1·490 and 1·495.

This mineral was also observed in thin sections of narrow pegmatitic veins of albite traversing the biotite schists in two trench-cuts on the north-western side of Steatite Hill (*see* p. 40). Here it also appeared to be replacing talc flakes associated with the albite. Its occurrence in small amounts is probably widespread in near-surface exposures of talc.

Sufficient of the material was readily obtained for chemical analysis, and the following analysis of a relatively pure sample has been made by T. W. Dalwood.

SiO_2	63·08
Al_2O_3	11·71
Fe_2O_3	2·76
FeO	0·85
MgO	9·70
CaO	0·14
Na_2O	0·76
K_2O	0·14
TiO_2	0·35
P_2O_5	Nil
H_2O	10·60
	100·09

The alkalis in this analysis indicate the amount of albite present in the sample. After the equivalent amounts of alumina and silica for albite are subtracted, it is found that the analysis corresponds closely to the formula $2MgO.Al_2O_3.8SiO_2.6H_2O$.

The alumina in this mineral is presumably derived from weathered albite, and shows that the mineral is not a simple residual of decomposed talc. The presence of alumina distinguishes the mineral from sepiolite ($2MgO.3SiO_2.2H_2O$), while the proportions of magnesia and alumina are widely different from those of saponite ($9MgO.Al_2O_3.10SiO_2.15\text{-}16H_2O$). The nearest relative to the Gumeracha mineral is the magnesian clay mineral, attapulgite, described by J. de Lapparent.* Attapulgite is represented as an isomorphous series of magnesian clays varying between the limits $2MgO.3SiO_2.4H_2O$ (sepiolite) and $Al_2O_3.5SiO_2.6H_2O$ (which is unknown in the pure state). The Gumeracha mineral is thus a mixture of these two molecules in equal proportions, except for the fact that it contains less water. It also differs from attapulgite in having a lower refractive index and a much lower birefringence.

GENESIS OF THE TALC DEPOSITS

The broader regional features governing the location of the talc-albite deposits are outside the present study. Presumably the deposits mark the location of fracture zones that developed along a line of shear, prior to, or during, the period of metasomatism. The deposits consist essentially of three components, namely, albite, talc, and unreplaced albitized schist. Any hypothesis as to their origin must therefore account for the simultaneous concentration of sodium and magnesium that the masses of albite and talc represent.

Part of the sodium has been derived from some external source. This is indicated by the relatively small amount of soda present in the slightly metasomatized schists such as represented by analyses 1 and 2 of table III. Moreover, the albite is found occurring in veins filling fracture systems in the schist, and is accompanied by such minerals as tourmaline, apatite, phenacite, and pyrite—minerals not normally present in the schists to the same degree as in the strongly albitized rocks. These facts suggest that the soda was derived, in part, from hydrothermal solutions, originating from deeper-lying sources. The presence of large pegmatite bodies—locally rich in albite felspar—in the Gumeracha district, about 2 miles north-west from Dunstan's talc mine, appears to accord with this view.

The possible sources of the magnesium are either (1) derivation from the bodies of country-rock that previously occupied the place of the talc deposits, or (2) introduction from some external source. The petrological study of the talc rocks has demonstrated the complete absence of any bodies of basic igneous

* De Lapparent, J., *Comptes Rendus* 201, 1935, 481.

rocks or of dolomite from which the magnesium might have been obtained. It showed, however, that the talc has largely replaced biotite schists similar to those that now enclose the deposits. Unreplaced remnants of the schists have been encountered at a number of points in Dunstan's talc mine; and remnants of biotite flakes, more or less completely replaced by talc, are present in all but the highest grade of talc.

The chemical analysis of the biotite has shown that it is an iron-magnesium variety, moderately rich in magnesium. The biotite in several other examples of biotite schist has been proved to have a similar refractive index to the analyzed sample, and can, therefore, be regarded as having a similar chemical composition. It is clear, therefore, that a proportion of the magnesium in the talc must have been derived from the biotite of the replaced schist. The two analyses of the biotite-quartz schists in the neighbourhood of the talc deposits of Dunstan's talc mine show that the MgO content of the schists is about 5 per cent, sufficient to produce a body of pure talc of about ⅕ or ⅙ of the volume of a given body of schist.

No other source of the magnesium is apparent in the surrounding rocks. A trace of dolomite has been found in the talc, in the form of a short and narrow lens, or vein, of dolomite; but no trace of previously existing dolomite or basic igneous rocks has been found either at the surface or in the workings.

The possibility that a proportion of the magnesium was introduced from an external source, in hydrothermal solution, along with the soda seems unlikely in view of the relative incompatibility of soda and magnesia and the rarity of records, elsewhere, of talc as a vein mineral. As Harker points out* "magnesia . . . is selectively taken out (of the residual magma) in the earlier stages of crystallization . . . with the result that the residual magma in the final stage is normally devoid of magnesia. This is not to be forgotten when magnesian solutions, of magmatic origin, are invoked."

The intimate association of albite and talc leaves no doubt that they are genetically related, and that it was the reaction of the hydrothermal sodic solutions with the biotite schists that gave rise to the albite on the one hand, and to the talc on the other. The alteration of the biotite seems to have followed different paths. Mostly, the change to talc appears to have been direct, involving the substitution of soda for potash and the removal of iron.

$$\text{Biotite} + \text{quartz} + \text{soda} \rightarrow \text{albite} + \text{talc} + \text{potash} + \text{iron}$$

In some instances, the biotite was changed first to phlogopite—losing only its iron—and then the phlogopite altered to talc. Possibly, a local concentration of fluorine determined the formation of phlogopite, because phlogopite has a higher fluorine content than biotite. This fluorine, and the fluorine in the apatite, may be partly derived from the hydrothermal solutions. Sometimes the biotite changed first to chlorite, which is capable of persisting in the talc bodies to a greater degree than biotite. The iron and potash from the biotite have been removed from the sphene in the residual solutions; but some iron was precipitated as pyrite, presumably through reaction with a small amount of introduced sulphur that accompanied the hydrothermal solution.

The titania in the biotite, which amounts to 3·12 per cent in the analyzed sample, found no place in the talc or albite. The paucity of lime in the rocks prevented the formation of more than a small amount of sphene, so that the bulk of the titania was precipitated as rutile. The separation of the rutile from the biotite and chlorite can be directly observed in the formation of the sagenitic webs of rutile in these minerals (*see* figs. 11 and 12), and occasionally the sagenitic webs are preserved in albite. More often the rutile recrystallized and formed larger, stumpy, prismatic crystals.

* Harker, Alfred, *Metamorphism*: Methuen & Co., p. 135, 1932.

There is very little evidence of excess silica in the formation of these talc deposits. Traces of quartz, deposited after the albite, occur in the albite rock. Rarely, a nodule of quartz or a small segregation vein of quartz occurs in the marginal zones.

It might be thought that the belt of quartzites, adjacent to the talc deposits on their northern side, might owe its quartzitic character to deposition of excess silica from the solutions giving rise to the talc deposits, but certain considerations show that the amount of silica added to these rocks was probably small in comparison with the amount of soda introduced into them. It is a feature of many specimens of the quartzites that the interlocking quartz grains are elongated parallel to the bedding of the rocks. In view of the absence of foliation in the talc bodies, this elongation can only be interpreted as a feature induced in the quartzites during the recrystallization of the original sediments under the regional pressure that gave rise to the biotite schists, prior to the formation of the talc deposits. This means that the quartzites are to be regarded as a primary sandstone formation, and not as a secondary metasomatic formation, despite the considerable albitization they have undergone in places.

It is also necessary to account for the varying distribution of the talc and albite in the deposits. The talc was formed from the mica *in situ*—as is evidenced by the numerous remnants of mica in the talc—so that while the talc must have been segregated, it cannot be pictured in the main as crystallizing from solution, but must be regarded as a recrystallized residue after other minerals have been removed by a process of "metasomatic leaching". The crystallization of talc from solution is, however, not wholly absent, as occasional stellate groups of talc leaves occur with coarse albite in the small pegmatitic veins. Possibly the narrow seams or veins of columnar talc in the marginal zones have also formed by crystallization from solution.

The albite, on the other hand, is in a sense a chemically precipitated mineral, since the soda was brought in by hydrothermal solutions which attacked the schists, dissolving out the alumina, iron, and potash from the biotite, and silica from both biotite and quartz. The iron and potash, and any excess alumina and silica, were carried away in the solution; while a proportion or most of the alumina and silica, in combination with the introduced soda, precipitated as albite. The precipitation was not necessarily immediate, however. Where the sodic solutions were soaking into the schists through restricted channelways, such as bedding planes, the albite was presumably deposited soon after the constituents were available for chemical combination, as a true metasomatic mineral. Where, however, channelways were available which permitted freer movement, the dissolved constituents of the albite moved some distance before they crystallized as such. This is proved by such occurrences as veins of relatively pure albite filling fractures in only slightly albitized schist, and by veins of albitic pegmatite occurring under similar circumstances. There must, therefore, have been a tendency for the albite constituents in solution to move away from the residual talc—in the same way as the more soluble iron and potash did—and the escape of the albite from the deposit was only prevented by falling temperature causing an onset of crystallization.

This movement of the albite in solution must have led, concomitantly, to some segregation of the residual talc and, presumably, the bodies of relatively pure talc grew in width as the sodic solutions migrated farther and farther from their channelways into the schist. One might picture the sodic solutions passing outwards more or less as a wave of solution from the channelways by which it first entered the schists, leaving behind it a growing body of talc, and pushing before it a volume of solutions which carried away the soluble elements having no place in the newly-formed minerals.

The removal of albite from the talc must be related to the shrinkage in volume that accompanied the development of massive talc from the biotite schists, for the volume of the talc is not more than a fifth of the volume of the replaced rock. This decrease in volume can be regarded as a compaction under external pressure, which may have been in the nature of a shear. The absence of pronounced foliation in the talc deposits suggests, however, that the shearing component of any external pressure was small.

The tendency for the albite constituents to migrate in solution—prior to crystallization—and the fact that residual solutions definitely migrated away from the talc-albite zone, carrying dissolved material with them, will also account for the unequal development of talc and albite in different deposits. There is, for example, a distinct concentration of albite to the relative exclusion of talc at the south-eastern end of the Steatite Hill deposit. On the other hand, where conditions hindered the migration of the albite constituents, a talc deposit has been produced in which the talc is associated with a large proportion of disseminated albite, as at Porter's talc quarry. (7/12/45.)

Chapter 3

BENEFICIATION OF GUMERACHA TALC

BY

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(JOINT INVESTIGATION OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH AND THE SOUTH AUSTRALIAN SCHOOL OF MINES AND INDUSTRIES—REPORTS FROM THE BONYTHON LABORATORY, NEW SERIES No. 167, C.S.I.R. No. 152)

GENERAL

At the request of the South Australian Department of Mines an extensive programme of testing has been pursued for means of producing high-grade talc concentrates from local deposits. This report gives the results of work on a sample from the deposits of John Dunstan & Son (W.A.) Ltd., situated at Gumeracha, South Australia.

SAMPLE

The sample of ore used for this investigation was described as run-of-mine ore, and although the bulk of it appeared to be good quality, there were occasional patches of iron-stained material.

A sample of the material, as received, was analyzed by T. W. Dalwood with the following results:

SiO_2	61·98
Al_2O_3	2·71
Fe_2O_3	0·76
FeO	1·70
MgO	26·82
CaO	0·22
Na_2O	1·42
K_2O	nil
H_2O over 100°C.	4·20
H_2O at 100°C.	0·16
TiO_2	0·13
P_2O_5	0·13
S as sulphide	0·09
	100·32
Less oxygen equivalent to S	0·03
	100·29

The principal mineral constituents of the ore are talc, albite felspar, chlorite, biotite, apatite, rutile, pyrite, and iron oxides. The TiO_2 analysis gives the amount of rutile present. The P_2O_5 enables the amount of apatite to be calculated, and the remaining CaO together with the Na_2O may then be considered as combined to form the albite. In this way the following approximate mineral composition was calculated:

	per cent
Albite	12·4
Apatite	0·3
Rutile	0·13
Pyrite	0·17

The remaining 87 per cent is principally talc with minor amounts of chlorite, biotite, and iron oxides.

BENEFICIATION

Two means of beneficiation were investigated:

(*a*) Dry grinding followed by classification.
(*b*) Wet grinding followed by flotation.

Dry grinding is adopted almost universally in plants preparing talc for market, and in most cases no attempt is made to remove any impurities.

Taggart in *Handbook of Mineral Dressing,* pp. 6-49, states that all types of fine-grinding mills are used for talc, *e.g.,* ball mills, pebble mills, rolls, ring-roll mills, buhr mills, hammer mills, etc. In order to improve grinding efficiency it is customary to operate the mill in closed circuit with a classifier of the Gayco Sturtevant or Raymond whizzer type.

According to H. S. Spence, "Talc, Steatite, and Soapstone," *Can. Dept. of Mines Bull.* No. 803, the preferred types of mills for high-grade talcs are silex-lined pebble mills, Raymond high-side roller mills or Williams roller mills. The more recently developed "micronizer" has had a few limited applications in fine-grinding of talcs for special purposes, but the cost of "micronizing" excludes its use for anything but the high-priced products.

The generalized flow sheet shown in fig. 1 (reproduced from Spence) shows the alternative types of equipment in common use.

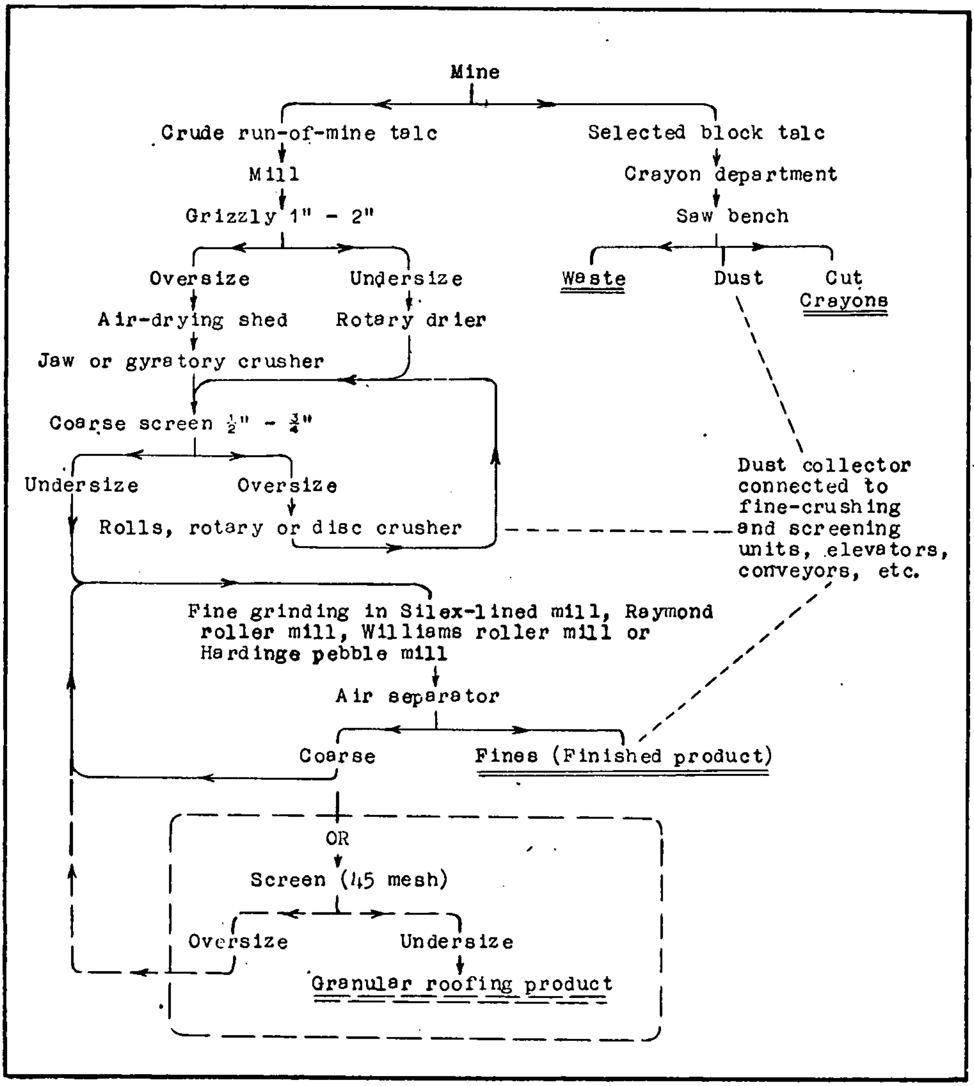

FIG. 1

In some dry mills it will be noted that some coarse material is segregated in the fine-grinding circuit and sold as a separate granular product. This does not necessarily imply that the talc is preferentially ground, although in cases where the grit has a relatively coarse grain size, a better grade of fine talc may be produced by this means. In most cases this procedure would result in the rejection of much talc in the granular product.

The relative grindabilities of minerals may differ according to their origin, and further variations may arise according to the type of grinding mill. For example, in a ball or pebble mill the forces which play the main part in grinding are impact and attrition, while in a ring-roller mill forces of compression and attrition are the principal agents. As will appear later, the writer's tests showed that under the conditions of pebble-mill grinding in the laboratory the coarse talc flakes are more resistant to grinding than the felspar grains, and in consequence no useful beneficiation could be achieved by this means. Whether this same conclusion would be reached on tests in a ring-roll type of mill cannot be decided at present as the writer has no laboratory facilities for making such a test, but other considerations lead to the opinion that any reject which could be made by such a process would contain a large proportion of talc and nothing approaching a clean separation could be obtained. For efficient fine grinding the fines should be removed as they are made since if left within the mill they give a cushioning effect and dissipate much of the energy input. This is achieved in a pebble mill by providing an air velocity through the mill sufficient to carry away the maximum sized particle permitted in the product, or by providing a velocity in excess and using an external separator from which the oversize material is returned to the mill. In a Raymond high-side mill or Williams roller mill a similar effect is obtained by a separator built into the machine above the grinding chamber. The separation in either case depends essentially on the relative sizes of talc and grit particles with the same settling velocities, and experiments described later indicate that unless there is a big difference, between the sizing of talc and grit particles after a single pass through the grinding unit, grit can only be rejected at the expense of a proportionate amount of talc.

Ladoo, *U.S. Bureau of Mines Bull.* 213, states: "Wet grinding of talc has not been used commercially at least in the United States, although some experimental work on it has been and is being done. The advantages that might be gained are as follows: the production of a finer-grained product with less consumption of power; the ability to use water classification for sizing and for removing impurities; an opportunity to remove iron stains by bleaching or to improve the colour by adding blue dyes. Iron staining may be minimized by grinding in silex-lined pebble mills or by acid bleaching. The problem of drying and disintegrating finely ground material is common in the clay, ochre, barytes and other industries, and progress is being made in improving drying methods. The system of drying by spraying into a heated chamber does away with the expense and inconvenience of repulverizing and resizing.

"Wet grinding has the further advantage of permitting water classification or flotation methods for the removal of impurities.

"The most expensive stage in wet treatment is that of drying the filtered product, but this is offset by the fact that no drying of crude ore is necessary and the cost of wet grinding and water separation is lower than that of dry grinding. It is claimed that the total cost per ton of finished product is no higher by wet methods than by methods now in use and that a finer, cleaner product can be made."

Gillson, "Talc, Soapstone and Pyrophyllite," *A.I.M.E. Industrial Minerals and Rocks,* 1937, says: "Wet grinding, classifying, and concentrating is under test at various plants and it is probable that these methods will replace the dry methods rather generally. Wet grinding, with pebble mills, in series with wet classifiers and hydroseparators, could replace the present methods. This equipment is already installed at Hemp, N.C., and is being considered elsewhere. An urge to adopt wet methods is being given by the wish to avoid silicosis hazards. Flotation as a method of concentrating talc has been seriously tested. Tests have been conducted at Rolla, Mo., by the U.S. Bureau of Mines in co-operation with a leading Vermont producer. A high-grade talc was made, and the low-valued 'grit' formerly sold for roofing, was converted to high-grade magnesite which may have real value. Tests abroad by Tanganyika Concessions have shown that a magnesite-talc rock can be beneficiated by flotation. Other tests have been conducted in Canada."

Flotation tests on a talc containing dolomite made at the ore-dressing laboratories of the Department of Mines, Canada (*Mines Branch Report* 736, pp. 231-234) reduced the lime content from 5·7 per cent to 0·5 per cent CaO. For purposes of comparison, dry grinding tests were made both in the laboratory and in commercial units. A test on an 80-lb. sample in a Raymond 00 pulverizer with an automatic throw-out gave 63 lb. of finished product containing 4·3 per cent CaO, and 17 lb. of reject material containing 13 per cent CaO. In this case the project was abandoned because buyers contended that the talc although beneficiated to meet their specifications as regards chemical analysis did not possess the slip qualities of either Italian or Spanish talc.

Flotation testing of talc has also been carried out by the United States Bureau of Mines in co-operation with producers, and as a result of their work a pilot plant was installed at Johnson, Vermont, in 1937, and increased to five times its capacity in 1938. The Bureau of Mines tests indicated that a flotation concentrate 94·8 per cent talc could be made.

A talc-magnesite ore from the Sudan has also been treated successfully by flotation (*U.S. Bureau of Mines, Mineral Trade Notes,* vol. I, No. 3).

The plant of the Eastern Magnesia Talc Co. is described in *Pit and Quarry,* vol. 32, pp. 28-30, October 1939, and also in *Deco Trefoil,* Feb. 1940. "The flotation process," it is stated, "was incorporated in this plant due to the inability of the dry-mill section to profitably meet the demand of changing market requirements, and to produce a superior grade of product. The flotation section acts as a scavenger unit taking the rejects of the dry-mill section. It is treating material which was formerly discarded or stockpiled and recovers talc which cannot be recovered in the dry plant. The wet section of this plant consists essentially of tables to recover a nickel-cobalt sulphide concentrate followed by flotation cells to separate talc from magnesite. The talc concentrate is filtered on a rotary vacuum filter and dried in a Ruggles-Coles rotary dryer. The filter cake contains 20 per cent moisture, and the fuel consumption in the dryer is about 15gall. per ton of dried material."

A simplified flow sheet of the complete dry and wet plant is shown in fig. 2.

A considerable amount of flotation test work has also been carried out by the U.S. Bureau of Mines in co-operation with the W. H. Loomis Talc Co. on talc ores from Gonverneur, N.Y. Three principal types of talc ore were tested, tremolite talc ore, limey talc ore, and green talc ore. The ores containing fibrous talc and those containing tremolite and calcite were difficult to separate, whereas those containing foliated talc and quartz were easy to float. Pine oil was suitable for foliated talcs, but reagents of the amine type were more suitable for fibrous talc.

DRY GRINDING OF TALC

A sample of the talc, as received, was crushed in a chipmunk crusher and rolls to minus 30 mesh. The minus 30-mesh material was then sized into six fractions by treatment in the laboratory Federal dust classifier.

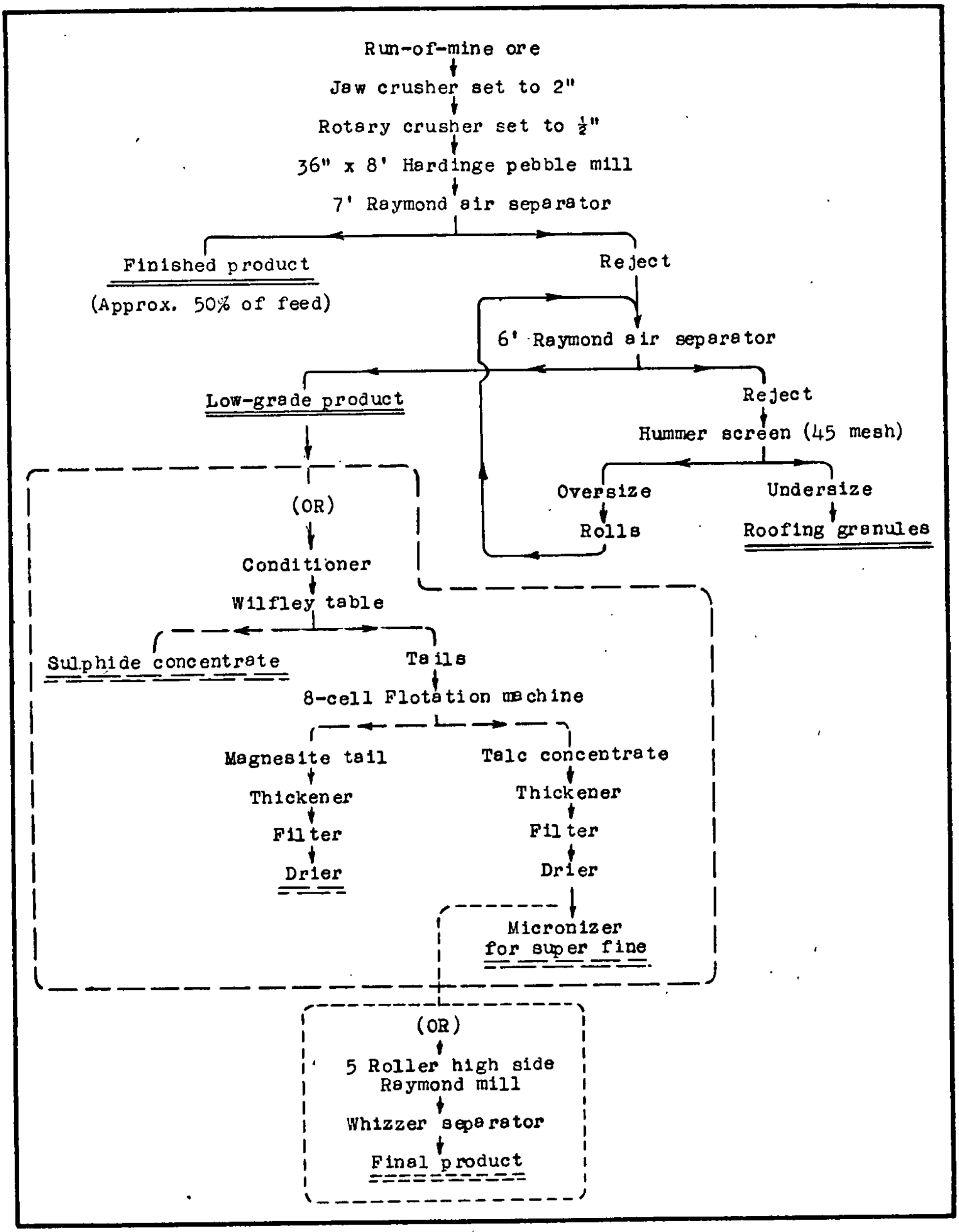
Run-of-mine ore
Jaw crusher set to 2"
Rotary crusher set to ½"
36" x 8' Hardinge pebble mill
7' Raymond air separator
Finished product
(Approx. 50% of feed)
Reject
6' Raymond air separator
Low-grade product
Reject
Hummer screen (45 mesh)
Oversize
Undersize
Rolls
Roofing granules
(OR)
Conditioner
Wilfley table
Sulphide concentrate
Tails
8-cell Flotation machine
Magnesite tail
Talc concentrate
Thickener
Filter
Drier
Thickener
Filter
Drier
Micronizer
for super fine
(OR)
5 Roller high side
Raymond mill
Whizzer separator
Final product

FIG. 2

Samples of each of these fractions were examined under the microscope to determine the average particle size and to note any substantial difference in mineralogical composition. The results of these observations are presented in table I. The size range quoted for each fraction represents that of the bulk of the sample. In all cases a certain amount of overlapping occurred.

TABLE I

Fraction	Size range	Weight	Cumulative weight
	microns	per cent	per cent
A1	0–10	1·6	1·6
A2	8–15	2·3	3·9
A3	15–30	2·5	6·4
A4	30–50	10·8	17·2
A5	50–100	25·6	42·8
A6	greater than 100	57·2	100·0

The finest fraction, A1, was definitely much darker in colour than the other fractions, indicating evidently that some concentration of the darker minerals (rutile, biotite, and pyrite) had occurred in this fraction, but the weight of this fine material (1·6 per cent of the total sample) would not be sufficient to bring about any appreciable improvement in the colour of the remainder. A qualitative microscopic examination of these samples immersed in a media of refractive index 1·58 indicated that under the above conditions of crushing there was no useful concentration of the albite felspar in any size fraction. A more comprehensive plan was then drawn up with the object of testing the possibility of removing grit and improving the colour by grinding followed by classifying in the Federal dust classifier.

A sample of the minus 30-mesh material was graded, by screening and dust classification, into six fractions, each of which was examined and the percentage of non-talc particles estimated by particle counts.

The sample was then ground in a laboratory pebble mill for ¼ hr. and the product was treated in the dust classifier to remove the fines, while ⅛ of the classifier reject was set aside for screening and microscopic examination of the fractions.

The remaining ⅞ of the classifier reject was ground a further ¼ hr. in the pebble mill and sampled as above, *i.e.*, the fines were all removed, ⅛ of the classifier reject set aside for screening by microscopic examination, and the remaining ⅞ of the classifier reject was put back in the pebble mill for further grinding.

This process was repeated for periods of ½ hr., 1 hr., and 2 hr. in succession, making the total grinding periods equal to ¼ hr., ½ hr., 1 hr., 2 hr., and 4 hr.

The sizing of the samples after each stage of grinding is set out in tables II to VII.

TABLE II

NO GRINDING

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc
	microns	per cent	per cent	
Plus 48 mesh	—	41·3	15	39
48/100	295	16·6	12	12
100/200	147	17·3	7	8
200/325	74	5·2	20	6
Minus 325 sand	44	14·1	25	23
Fine dust	20	5·5	35	12
Composite		100·0	16	

TABLE III

15 Min. Grinding

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc
	microns	per cent	per cent	
Plus 48 mesh	—	28·3	12	24
48/100	295	23·8	16	27
100/200	147	21·8	8	12
200/325	74	7·3	14	7
Minus 325 sand	44	14·2	20	20
Fine dust	20	4·6	30	10
Composite		100·0	14	

TABLE IV

30 Min. Grinding

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc
	microns	per cent	per cent	
Plus 48 mesh	—	18·1	10	14
48/100	295	26·0	16	33
100/200	147	26·3	9	19
200/325	74	8·3	10	6
Minus 325 sand	44	19·3	16	25
Fine dust	20	2·0	19	3
Composite		100·0	13	

TABLE V

60 Min. Grinding

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc
	microns	per cent	per cent	
Plus 48 mesh	—	7·4	8	6
48/100	295	22·4	12	26
100/200	147	29·6	8	23
200/325	74	10·6	10	10
Minus 325 sand	44	27·6	12	31
Fine dust	20	2·4	15	4
Composite		100·0	11	

TABLE VI

120 Min. Grinding

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc
	microns	per cent	per cent	
Plus 48 mesh	—	1·0	4	0·5
48/100	295	11·2	3	4
100/200	147	25·6	5	15·5
200/325	74	11·2	8	11
Minus 325 sand	44	44·1	11	59
Fine dust	20	6·9	12	10
Composite		100·0	8	

TABLE VII

240 Min. Grinding

Size	Upper size limit	Weight	Estimated non-talc	Distribution of non-talc.
	microns	per cent	per cent	
Plus 48 mesh	—	0·1	—	—
48/100	295	0·4	—	—
100/200	147	5·7	3	2
200/325	74	5·2	5	4
Minus 325 sand	44	42·0	6	35
Fine dust	20	46·6	9	59
Composite		100·0	7	

The above tables show that under the conditions of grinding in a pebble mill in the laboratory, the general tendency is for the non-talc particles to be ground more readily than the talc. This, no doubt, can be attributed to the greasy nature of the talc flakes as compared with the more brittle felspar grains.

The tabulated data show a concentration of grit in the finer fractions but the differences are insufficient to give any appreciable beneficiation if the fines were to be separated.

Table VIII shows the data of tables II-VII recalculated on the basis of the original weight of sample, and presented so as to exhibit more clearly how the grit content behaves. The figures show the grade of product and the recovery of talc which could be obtained by a grinding treatment followed by rejection of the finer fraction. Thus, in the column headed 44 microns will be found the grade and recovery of talc which could be obtained by rejecting all minus 44-micron material.

TABLE VIII

		Minimum size retained, microns				
		20	44	74	147	295
		per cent	per cent	per cent	per cent	per cent
No grinding	Recovery of talc	96	83	78	59	42
	Non-talc in product	15	13	12½	14	15
	Rejection of non-talc	12	34	40	48	61
15 min. grinding	Recovery of talc	92	80	73	50	28
	Non-talc in product	13	12	12	14	12
	Rejection of non-talc	21	39	45	56	79
30 min. grinding	Recovery of talc	90	73	65	40	17
	Non-talc in product	12	11½	12	13	10
	Rejection of non-talc	25	44	49	63	89
60 min. grinding	Recovery of talc	89	64	54	27	7
	Non-talc in product	10	9½	9½	11	8
	Rejection of non-talc	31	54	61	77	96
120 min. grinding	Recovery of talc	83	45	35	11	1
	Non-talc in product	8	5	4½	3	4
	Rejection of non-talc	43	80	87	97	99
240 min. grinding	Recovery of talc	45	8	4	—	—
	Non-talc in product	5½	4	3	—	—
	Rejection of non-talc	77	97	99	—	—

For instance, if the sample were ground equivalent to the 15-min. laboratory grind and minus 44-micron material separated out, the product coarser than 44 microns would contain 80 per cent of the total talc and would carry an estimated non-talc content of 12 as compared with 16 per cent in the original.

The best result recorded in the table would appear to be that corresponding to rejection of minus 20-micron material after 120 min. grinding. In this case the grit content was halved and the talc recovery was 83 per cent.

In general, however, it may be said that taking into account economic considerations, there is little hope of affecting a very useful beneficiation by this means. The idea of rejecting very fine dust, representing the expenditure of much energy in grinding is not appealing. If it were a matter of colour alone, the fine dust might be suitable for use in face-powders where colour is not so important, while retaining the coarser fraction for markets specifying good colour material, but the high non-talc content of the fine dust would probably make it unmarketable.

Further confirmation of the fact that the talc is more resistant to grinding than the felspar, etc., was obtained from the following test. Three samples of crude ore were taken and the minus 44-micron material separated.

(1) From the original sample.
(2) From a sample ground for 30 min. in a pebble mill.
(3) From a sample ground for 60 min. in a pebble mill.

These samples of minus 44-micron material were analyzed for MgO and showed respectively:

	MgO in fines per cent
No grind	28·8
30 min. grind	28·1
60 min. grind	27·2

This shows clearly that there is a progressive degradation in the fines and a corresponding enrichment of the coarse fraction as grinding progresses.

It may be argued that pebble-mill grinding as practised in the laboratory would produce a product very dissimilar to that of a ring-roller mill or similar machine, and that the laboratory scheme of grading by screening and classifying would not imitate that of a commercial dust-classifying unit built into the grinding circuit. With regard to the first point, it is proposed that a small laboratory-unit, with similar action to that of the ring-roll type of mill, shall be constructed. In respect to the differences between grading by screening and by classifying, laboratory tests have indicated that despite the marked differences in shape between talc and felspar grains, there is not a very marked difference in the average particle diameters of talc and felspar in a classified fraction made from a mixture. (The laboratory tests, on which this conclusion is based, are reported later.) If then it is supposed that the talc is preferentially ground in a ring-roll mill it would still be necessary to classify out the harder grit from the ground material, and it would appear impossible to do this without taking out a large amount of talc with it. Suppose, for instance, that it is arranged that all grit between, say, 100 mesh and 200 mesh is to be removed; then there are two requirements to be satisfied:

(1) The air stream carrying the ground material away from the mill must be sufficient to carry off 100-mesh particles of grit.
(2) The air velocity and volume in the classifier or settler must be sufficient to carry away all minus 200-mesh material.

But this must necessarily mean that the grit-trap will also catch all talc particles whose settling velocities lie between the same limits. Suppose these correspond to 80 mesh and 150 mesh. For a satisfactory separation it is therefore necessary that the grinding-mill product should contain only a small amount of talc between these limits, while containing as much grit as possible within the corresponding limits. But the ring-roll mill relies for its efficiency on the fact that the undersize material (in this suppositional case 80-mesh talc or 100-mesh grit) is continually removed from the grinding zone, while the oversize is kept within the mill for further grinding. It therefore appears impossible to satisfy the ideal requirements, and the best that can be done is to ensure that the classifying system will make a product in which the coarest grit particles are smaller than the coarsest talc particles. The actual amount of grit in the product would be of the same order as that in the raw material.

This conclusion is supported to some extent by Dr. F. L. Stillwell's report (No. 318) in which, in the case of four of the five samples examined, he reports that there was no appreciable variation in the grit content of different size fractions, while in the fifth case—that of a sample of Gumeracha talc—he reports that the 100 mesh and 150 mesh contained only an occasional grain of felspar, while the plus 200-mesh and finer fractions showed a distinct increase in the felspar content. This observation might also be taken as supporting the view that even under commercial grinding conditions, the felspar is ground more readily than the talc, for Stillwell remarks in the same report (p. 4) that "the albite occurs in relatively coarse particles" and yet, as noted above, in the ground product there is more albite in the 200-mesh and finer fractions than there is in the 100-mesh and 150-mesh fractions.

LABORATORY TESTING OF WET GRINDING AND FLOTATION

Test No. 1

A 500-gm. sample of minus 30-mesh material was ground 15 min. in a pebble mill with 400 ml. of water. The pulp was then floated with pine oil.

In this preliminary test the rougher concentrate was cleaned twice and the products kept separate for examination under the microscope and estimation of the non-talc content. The results of this test are shown in table IX. The figures given for the non-talc content are rough estimations obtained by microscopic examination and counting, but they serve to indicate the degree of selection.

TABLE IX
FLOTATION TEST No. 1

Product	Weight	Non-talc	Distribution	
			Talc	Non-talc
	per cent	per cent	per cent	per cent
Concentrate	74·2	1	85	5
Second cleaner tail	4·0	8	4	2
First cleaner tail	6·4	16	6	10
Rougher tail	15·4	70	5	83

The figures for the percentage of non-talc are probably high in all cases, since composite particles were counted as non-talc. The froth obtained with pine oil as a frother and collector was very stiff, and most of the gangue carried over with the rougher concentrate is undoubtedly entrapped mechanically.

Test No. 2

With hope of getting a more brittle froth, Dupont frother B 22 was substituted for pine oil used in tēst No. 1, but did not affect a very marked improvement in the appearance of the froth although it did break down more rapidly. Dupont frother B 22 is a mixture of aliphatic alcohols and ketones obtained as a higher-boiling by-product from the manufacture of butyl alcohol, and in general produces more brittle froths than the more common frothers, pine oil, cresylic acid, etc., but in the case of this talc flotation, the nature of the froth is doubtless modified to a considerable extent by the floatability of the talc and the large amount to be floated.

TABLE X

FLOTATION TEST NO. 2—DUPONT FROTHER B 22 IN PLACE OF PINE OIL
ONE STAGE OF CLEANING

Product	Weight	Non-talc	Distribution	
			Talc	Non-talc
	per cent	per cent	per cent	per cent
Concentrate	75·4	1	86	5
Cleaner tail	8·2	14	8	8
Tailing	16·4	70	6	87

The microscopic examination indicates that a single stage of cleaning in this case gave results similar to those in test No. 1.

The results of these two tests appeared so encouraging that a larger size sample was treated in a similar manner except that the cleaner tail was re-treated by flotation to yield a further small quantity of concentrate and a tailing which was added to the rougher tailing. The products of this test were sampled for analysis, and samples of the concentrate were submitted to Johnson & Johnson Pty. Ltd. and also to Ferro Enamels (Australia) Pty. Ltd. In addition, samples of the head, concentrate, and tailing were submitted to Dr. Stillwell for mineragraphic investigation. Since Stillwell's report includes the analyses and mineralogical compositions, the weights of the products and the recoveries are set out in table XI, which follows after his report.

MINERAGRAPHIC INVESTIGATION

BY

F. L. STILLWELL, D.Sc.

Samples of a flotation concentrate and tailing prepared from talc ore from Dunstan's talc mine, Gumeracha, have been submitted for examination by the Department of Mines, South Australia.

Chemical analyses of the ore, concentrate, and tailing have been made by T. W. Dalwood, and are as follows:

	Ore	Concentrate	Tailing
SiO_2	61·98	61·86	63·90
Al_2O_3	2·71	0·59	13·05
Fe_2O_3	0·76	0·28	0·55
FeO	1·70	2·57	1·08
MgO	26·82	30·20	10·38
CaO	0·22	0·08	0·84
Na_2O	1·42	0·02	6·30
K_2O	nil	nil	0·14
H_2O above 100°C.	4·20	4·90	2·07
H_2O at 100°C.	0·16	0·13	0·19
TiO_2	0·13	0·04	0·66
P_2O_5	0·13	0·02	0·44
S as sulphide	0·09	0·05	0·12
	100·32	100·74	99·72
Less oxygen equivalent to sulphur	0·03	0·02	0·04
	100·29	100·72	99·68

The ore consists essentially of talc with albite, chlorite (and biotite), apatite, rutile, pyrite, and iron oxides as impurities. The amount of sulphide sulphur indicates the amount of unoxidized pyrite. The amount of TiO_2 indicates the amount of rutile. The amount of apatite may be calculated from the percentage of P_2O_5, and the excess of CaO over that required for apatite, together with the percentage of Na_2O, can be used to determine the amount of albite. In this way it is estimated that the impurities in the ore and concentrate, apart from chlorite and biotite and iron oxides, are:

	Ore per cent	Concentrate per cent
Albite	12·35	0·47
Apatite	0·30	0·04
Rutile	0·13	0·04
Pyrite	0·17	0·09

If the equivalent amounts for these minerals are deducted from the chemical analyses of ore and concentrate, the hydroscopic water neglected, and the results recalculated to 100 per cent for comparison, we get:

	Ore	Concentrate
SiO_2	61·42	61·64
Al_2O_3	0·29	0·44
Fe_2O_3	0·78	0·24
FeO	1·95	2·57
MgO	30·75	30·21
H_2O	4·81	4·90
	100·00	100·00

These residual compositions of ore and concentrate correspond to nearly pure talc as is shown by their similarity, and they indicate that the remaining impurities of chlorite and biotite and iron oxides are very small. The only important difference is a variation in the proportions of ferric and ferrous iron, while the total iron is unaltered.

Microscopical Examination of Flotation Concentrate

The microscopical examination of mounts in Canada balsam, of the flotation concentrate, reveals a rare isolated grain of albite and rare minute crystals of rutile embedded in talc grains, which account for the traces of TiO_2 and Na_2O in the chemical analysis. There are very occasional, small, free particles of opaque iron oxide, either hematite or magnetite, as well as minute inclusions of opaque iron oxide in rare particles of altered mica. Further, an area of reddish-brown limonite has been seen to be enclosed in a flake of talc, slightly staining the talc around the somewhat indefinite margins of the limonite, which was probably derived from the oxidation of pyrite. A rare flake of green, greenish-brown, or brownish mica can be found, either embedded in talc or as isolated grains. In most cases, the mica shows apparent isotropism and an absence of pleochroism and is regarded as chlorite, but one example of a greenish lath showed the bright polarization colours of biotite. The only other type of impurity is an occasional particle of the brownish mineral, possibly related to hydrotalcite, which is a weathered product of talc.

These traces of iron oxide and micaceous matter (mostly chlorite) in the flotation concentrate will account largely for the Fe_2O_3 and Al_2O_3 (residual after satisfying albite) in the chemical analysis. It seems doubtful whether they can account for all the FeO. A suspicion therefore arises that traces of FeO are incorporated in the composition of the talc molecule.

Microscopical Examination of the Tailing

The microscopical examination of mounts of the tailing shows that most of the 10 per cent MgO in the analysis of the tailing occurs as fine minute particles of free talc that have not been floated. Most of the talc in this product is free, and only a small amount of it occurs as composite particles of talc and impurities. More plates of green chlorite are observed in this product than in either the concentrate or the ore, so that much of this impurity has been removed by flotation as well as nearly all the albite, rutile, and apatite. Albite is abundant, accounting for 54 per cent of the product.

TABLE XI

	Weight	Mineralogical composition					Mineral distribution				
		Albite	Apatite	Rutile	Pyrite	Talc, etc.†	Albite	Apatite	Rutile	Pyrite	Talc. etc.
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Concentrate	81·8	0·47	0·04	0·04	0·09	99·4	3	11	25	44	93
Tailing*	18·2	65·8	1·47	0·53	0·53	31·6	97	89	75	56	7
Head	100·0	12·4	0·30	0·13	0·17	87·0	100	100	100	100	100

* The composition given for the tailing was calculated by difference from the head and concentrate compositions given in Stillwell's report.

† The figures given for " talc, etc.," represent principally the talc content with minor amounts of chlorite, biotite, and iron oxides, but as indicated by the residual composition given by Stillwell the amount of these minor impurities is very small. Regarding these impurities in the flotation concentrate, Stillwell stated " it seems doubtful whether they can account for all the FeO. A suspicion therefore arises that traces of FeO are incorporated in the composition of the talc molecule."

From the behaviour of this material on heating, it seems almost certain that much of this FeO does in fact exist as a replacement of MgO in the talc molecule. When clean flakes of the talc were heated to between 900°C. and 1,000°C. in air, they all appeared to take on a fairly uniform buff colour, indicating the more or less uniform distribution of the FeO which on heating becomes converted to Fe_2O_3.

It appears then that the concentrate prepared in the above test represents almost the highest-grade product which could be obtained from this deposit, and it is therefore of considerable interest to compare this product with high-grade talc from other sources.

Johnson & Johnson Pty. Ltd. reported as follows on a sample of the above concentrate:

REPORT OF JOHNSON & JOHNSON PTY. LTD.

A. J. MURRAY, CONTROL CHEMIST

The sample which had a good sheen and was coarsely ground, was powdered and screened through a 200-mesh sieve before testing.

Colour

Superior to X141 (this represents the lowest acceptable material), inferior to "Standard Indian"—considered an improvement on regular Gumeracha deliveries.

Slip

Good, slightly inferior to "Standard Indian." Superior to regular Gumeracha deliveries.

Microscopic Appearance

Characteristic talc plates almost devoid of any "gritty" matter—showed considerable improvement on regular Gumeracha talc.

		Maximum allowable
Loss on ignition	4·7 per cent	5 per cent
Acid solubility	0·45 per cent	6 per cent
Water solubility	0·3 per cent	0·2 per cent
Bulk test	24·96 lb./cub. ft.	25 lb./cub. ft.

Summary

1. The sieved talc was of good quality as regards feel, but the colour, though better than our lowest permissible standard, could be improved.
2. However, the sample showed an improvement in colour when compared with recent Gumeracha deliveries, and feel was definitely superior.

In most respects it is seen that the sample comes well within their acceptable standards, the only property which calls for comment is that of the colour. It is believed that high-grade talc prepared from the Gumeracha material contains FeO combined in the talc molecule and that this FeO is the cause of the greenish appearance of the coarse flakes and the greenish-blue tint which appears in the fine powder. Whether this slight tint (which can only be detected by comparison with other samples) is detrimental would seem to be largely a matter of individual opinion. There is no doubt that the high-grade talc prepared by wet grinding and flotation in the laboratory gave a ground talc superior in colour to other samples of Australian talc available for comparison. Of three talc samples of Indian origin available, two showed a slight buff tinge, while the third, a sample of "Indian Standard", gave the best colour of all available. It is evident then that there are variations in the imported material—possibly dependent on their origin—and it is believed, therefore, that the beneficiated product, although differing slightly in tint, compares very favourably with much of the imported material.

It is of interest to compare the partial analyses of our high-grade product with that of an Indian Jaipur talc (*Compressed Air Mag.*, June 1941, 6457).

	Gumeracha talc concentrate	Jaipur talc
SiO_2	61·9	61·8
MgO	30·2	31·4
Al_2O_3	0·6	0·8
FeO (Fe as FeO)	2·8	0·7

It will be noted that the analyses are very similar, principal difference being, of course, in the proportion of FeO present, but if it is assumed that the FeO replaces MgO in the talc molecule, their molecular compositions becomes practically identical.

A further sample of this Gumeracha talc concentrate was submitted to Ferro Enamels (Australia) Pty. Ltd., who reported as follows:

REPORT OF FERRO ENAMELS (AUSTRALIA) PTY. LTD.

Unfortunately, the combined iron, as indicated in the analysis, is much too high, and in consequence the talc is not suitable for the manufacture of steatite insulators, nor as a material which would be used in a tile body. For your information, we require a talc with a combined iron content of less than 0·5 per cent. The remainder of the analysis appears to be very good indeed.

Regarding talc for steatite insulators, Klinefelter, O'Meara, Smith, and Truesdell, in *Mining Technology*, have stated:

"Talcs are alteration products and are more likely than not to carry a heavy load of impurities, particularly true if the talc is derived from serpentine deposits. Such talcs are invariably high in iron and furthermore, the iron is found as a stain or solid solution—that is, as an integral part of the talc mineral and not separable. All the talcs that are suitable for this particular work are found associated with limestone or dolomites, and the major impurities in such talcs are usually carbonates and tremolites.

"The few written specifications that could be obtained require that lime impurities and iron oxide should not exceed 1 per cent, but it was found that a somewhat greater percentage is permissible. Tests on talcs of various iron and lime contents showed that it was unsafe to exceed 1·5 per cent iron oxide or 1·5 per cent lime, if the talc were to be used alone.

"A high-grade California talc used by the trade assayed 0·42 per cent CaO and 1·21 per cent Fe_2O_3 with less than 1 per cent of carbonates and tremolite."

It is evident then that the limit of 0·5 per cent Fe_2O_3 set by Ferro Enamels Pty. Ltd. may be rather conservative if electrical properties alone are of interest, but where the colour of the fired product is of importance, as in a tile body, their limit of 0·5 per cent is quite reasonable. The paper just quoted states that "the product shows little change in colour up to 0·25 per cent Fe_2O_3, but as the content increases progressively, the colour goes to a light cream, cream, tan, buff, and brown."

FURTHER TEST WORK ON WET GRINDING AND FLOTATION

Several other aspects of wet treatment were examined in some further tests on the same sample of ore.

Effect of Varying Periods of Grinding

Three tests were made on 600-gm. samples of ore ground in a pebble mill for periods of 10 min., 20 min., and 40 min. respectively. The pulp was floated and cleaned with a total addition of frother B 22 equivalent to 0·15 lb./ton.

The concentrates from each of these tests were sampled and analyzed for MgO (regarded as the most reliable indication of talc content). The recoveries obtained in these tests are shown in table XII, and the sizings of the various grinds in table XIII. In table XII the rougher and cleaner tailings are shown combined as tailing.

TABLE XII

Grinding period	Product	Weight	MgO	Distribution of MgO
min.		per cent	per cent	per cent
10	Concentrate	79·7	30·5	90·7
	Tailing	20·3	12·3	9·3
20	Concentrate	80·5	30·7	92·2
	Tailing	19·5	10·8	7·8
40	Concentrate	80·2	30·3	90·7
	Tailing	19·8	12·6	9·3

TABLE XIII

SIZING OF VARIOUS GRINDS

Screen	Screen aperture	10 minutes		20 minutes		40 minutes	
		On screen	Cumulative	On screen	Cumulative	On screen	Cumulative
	microns	per cent	per cent	per cent	per cent	per cent	per cent
Plus 28 mesh	590	0·4	0·4	0·2	0·2	0·1	0·1
28/35	420	2·8	3·2	1·5	1·7	1·0	1·1
35/48	297	6·8	10·0	4·9	6·6	2·9	4·0
48/65	210	11·3	21·3	9·7	16·3	8·9	12·9
65/100	149	16·9	38·2	16·4	32·7	16·4	29·3
100/150	105	14·9	53·1	16·3	49·0	17·3	46·6
150/200	74	11·8	64·9	12·5	61·5	13·8	60·4
200/325	44	7·2	72·1	8·5	70·0	8·5	68·9
Minus 325 mesh	—	27·9	100·0	30·0	100·0	31·1	100·0

NOTE—These sizings were made on samples of the talc concentrates. The tails containing most of the grit would be finer than indicated by these figures.

Although neither the grades nor the sizings of the samples differ much, the small differences do appear significant and the second test, i.e., the 20-min. grinding period, is evidently the best result. The lower grade and recovery in the first test is attributed to insufficient liberation, while in the third test the larger amount of fines present has evidently caused more sluggish flotation and more grit carried over with the froth.

Effect of Grinding in an Iron Mill

A comparison was made between a concentrate prepared by grinding in a pebble mill and ore prepared by grinding in an iron mill. Subsequent flotation, filtering, drying, and fine grinding were identical. The colour of the sample ground in an iron mill was definitely inferior to that ground in the pebble mill and was only slightly better than that of the untreated ore. It is believed, however, that some of this contamination would be avoided if the concentrate sample were thickened by settling and decanting prior to filtering. Much of the contamination seems to arise from very fine oxides of iron which are carried over in the water, and in an actual plant where the product would be thickened prior to filtering some of this fine slime would be rejected. However, pebble grinding in a mill free from iron would be desirable to obtain the best possible colour in the final product.

Filtering

Since drying is likely to be an expensive item in a wet-processing plant, some filtering tests were made to determine the moisture content of filter cakes of these talc concentrates. The tests were made on a sample of talc ground to a similar sizing to the 20-min. pebble-mill grind, and the pulp containing 35 40 per cent solids was filtered on a laboratory Denver rotary drum filter. Filtering rates were determined at various drum speeds and moisture determinations were made on the resulting filter cakes. Filtering rates are expressed as lb. of dried solids per hour per sq. ft. of filtering surface.

It will be noted that the best filtering rate was obtained at the highest drum speed, *i.e.,* with the thinnest cake—actually the average cake thickness at this speed was about ¼in. Slower speeds gave somewhat thicker cakes, but the cake resistance evidently rises very rapidly with such flaky material so the filtering rate dropped while the moisture content increased.

TABLE XIV

Filter speed	Filtering rate	Moisture in filter cake
r.p.m.		per cent
0·177	8	30
0·307	12	27
0·411	13	26
0·625	14	25

SUMMARY

Dry Grinding and Classification

1. Laboratory tests using a pebble-mill grind, followed by classification, gave no indication of any useful beneficiation by this means.

2. The pebble-mill grinding conditions seemed to favour grinding of the impurities rather than the talc, and although it is realized that the grinding action in a ring-roller mill is not the same as in a pebble mill, other evidence seems to support the opinion that there is no hope of making anything approaching a clean separation of grit from talc by this means.

Wet Grinding and Flotation

1. Laboratory tests indicate that a considerable improvement in both colour and grit content can be obtained by a wet-process treatment as outlined in this report. The product obtained was superior to all dry-ground samples from this locality which were available for comparison.

2. The optimum grade of talc which could be obtained still carried over 2 per cent FeO, and it is highly probable that this FeO is an inherent feature of all talc from this locality. The high FeO content renders such material unsuitable for high-frequency radio insulation work and for use in high-grade white-ware ceramics, but it should not constitute any drawback to most of the common uses. The principal effect is the imparting of a slight greenish tinge to the flake and this in turn seems to give an almost imperceptible tinge to the fine powder which renders it slightly inferior in colour to the highest grade "Indian Standard", but at least the equal of many of the lower-grade Indian samples which appear to have a slight buff or cream tinge. These slight variations in tinge can, however, only be perceived when the various samples are compared under almost ideal conditions.

3. In order to obtain the best results in the final product, pebble-mill grinding in a mill free from iron is necessary.

4. The talc concentrate filters satisfactorily on a rotary filter, but the cake carried from 25 per cent to 30 per cent moisture and the cost of drying would constitute a considerable part of the total cost.

5. Fine grinding of the beneficiated product could be carried out wet or dry—each system seems to have certain advantages. Fine grinding wet should be more economical, as far as power is concerned, but the thickening, filtering, and drying would present additional problems, for, unless drying was done by a system of spray-drying or something similar, the dried cake would require a further dry-pulverizing and air-sizing. Dry grinding of the dried filter cake would eliminate certain of these difficulties, but would probably cost more for power. There is, however, a further possibility in that drying and dry grinding might be combined in the one step. It is claimed that by feeding heated air into a ring-roller mill, a dried product may be obtained from wet solids containing up to 50 per cent moisture. The turbulent action, permitting rapid

exposure of all the surface area to the heated air, would probably be conducive to good heat economy, and in addition use is made of some of the heat generated in grinding.

General Remarks

Throughout this report no account has been taken of the possible variations of the ore, and although these difficulties might not arise if the ore was carefully mined they should nevertheless be kept in mind.

1. Biotite occurs in small quantities throughout this deposit, but earlier samples from the area contained a considerable amount of this mineral, and although there is a certain degree of concentration of biotite in the flotation tailing, any large amount in the flotation concentrate would doubtless cause a general darkening of the product. Owing to the rather similar flaky nature of the two minerals—biotite and talc—there would be great difficulty in making a concentrate low in biotite if much occurred in the ore.

2. Some samples which have been brought into the laboratory from this deposit showed very bad iron-staining—evidently resulting from weathering of the pyrite—and although flotation does eliminate some contamination of this nature, it would not be possible to make a very good concentrate from such ore. (20/11/45.)

PART III

MOUNT FITTON DISTRICT

Chapter 1

FLINDERS No. 5 TALC DEPOSIT

BY

S. B. DICKINSON, M.SC. (DIRECTOR OF MINES AND GOVERNMENT GEOLOGIST)

Situation:—About 3 *miles S. of Billy Springs, on Moolawatana Station, outside of counties, North-Eastern division. Mineral Lease No.* 2876 *held by G. A. Greenwood, W. B. Greenwood, J. G. Ford, and W. Mackay.*

HISTORY AND PRODUCTION

The talc occurrences at Mount Fitton, in the northern Flinders Range, were discovered by J. G. Ford (Manager of Wooltana Station) in 1944. Samples were sent to the department by G. A. Greenwood of Mount Serle Station, and were found to be of high-grade quality. Specimens were also sent to F. L. Stillwell of the Council for Scientific and Industrial Research for mineragraphic investigation, and in his initial report (C.S.I.R. *Mineragraphic Investigations Report* 318) Stillwell reported on the remarkable purity of the Flinders Range talc by comparison with that of Gumeracha.

The No. 5 deposit is so-called as it was the fifth occurrence pegged by the discoverers. It is also the largest known outcrop in the area.

The deposits are situated 80 miles E. by road from Lyndhurst railway siding, a siding on the Quorn-Alice Springs railway line (3ft. 6in. gauge), 392 miles north of Adelaide. They were first examined by R. C. Sprigg, Assistant Government Geologist, in November, 1944,* to ascertain their economic possibilities at the beginning of prospecting operations when only a small excavation had been made in the No. 1 deposit. He reported that the talc occurred over a wide area, and in view of the keen demand for high-grade talc it was likely to have considerable commercial value.

In June, 1945, Ford and Greenwood, who in the meantime had undertaken certain prospecting work to determine the extent of the occurrences, dispatched a 15-ton trial sample from the No. 4 deposit to Johnson & Johnson Pty. Ltd., one of the chief consumers of high-grade talc. The No. 4 deposit was at that time the most promising occurrence, and had been opened up to a depth of about 20ft. To facilitate the delivery of this parcel, a grant of £300 was made to the claimholders for the construction of an access road, and, in August of 1945, an additional £300 was provided by the State Government after advice had been received that the trial parcel was satisfactory and that further deliveries were desired for more detailed testing.

In November, 1945, E. Broadhurst, Assistant Government Geologist, reported on the No. 4 deposit,† and in 1946 furnished a preliminary report (unpublished) on the No. 5 deposit shortly after limited prospecting work had revealed that there was likely to be considerable reserves present. This report includes the following statements with regard to the quantity and quality of the talc in the No. 5 deposit:

> "From a quick examination of the deposit there appears to be a surface area of 46,000 sq. ft. of talc, giving approximately 4,000 tons of talc per vertical foot. Rejecting half of the talc in fines and impurities, there would be about 2,000 tons per vertical foot.

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* Sprigg, R. C., *Mining Review* 81, p. 90, 1945.

† Broadhurst, E., *Mining Review* 82, pp. 76-81, 1946.

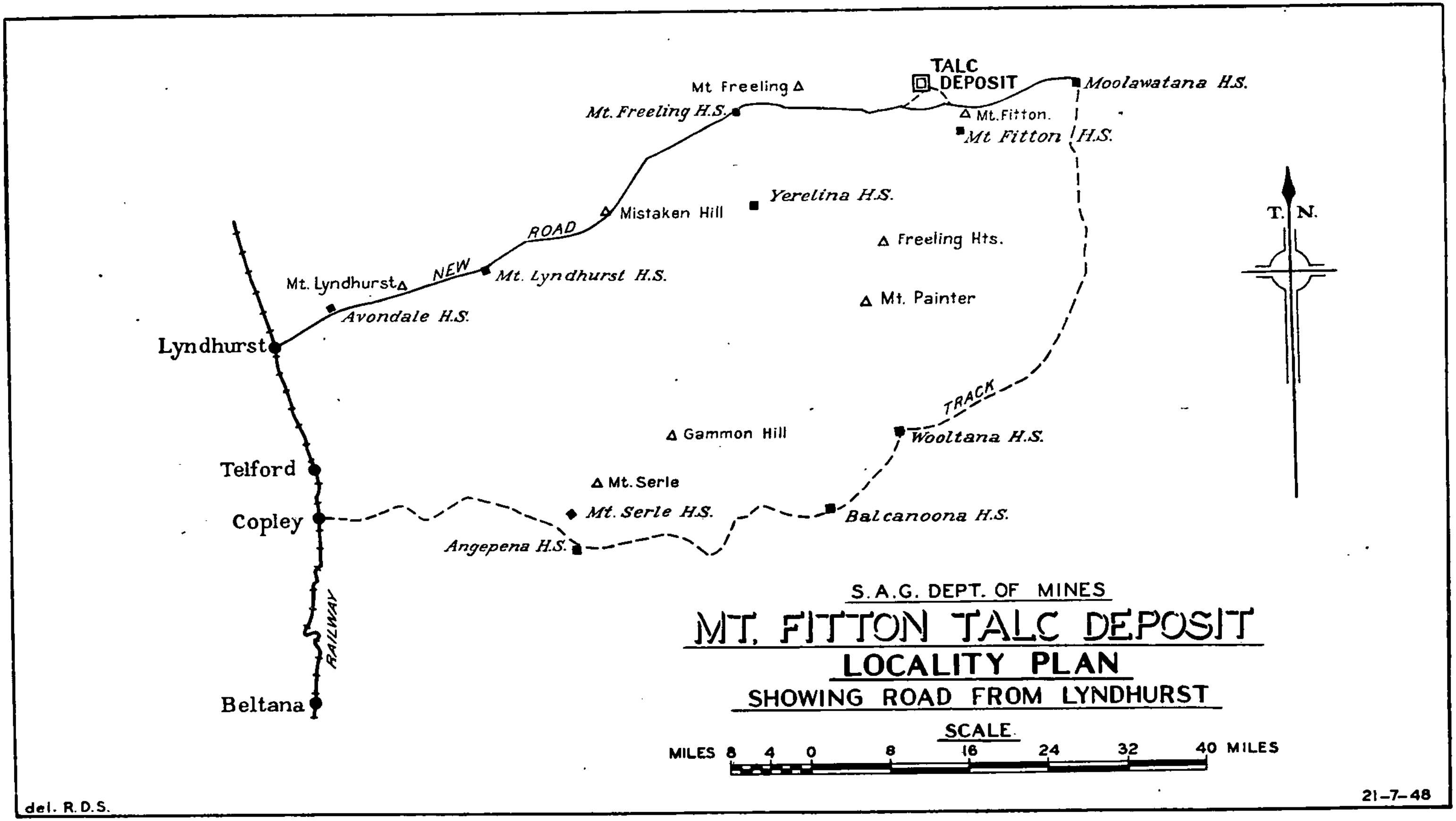
TALC DEPOSIT
Mt Freeling
Mt. Freeling H.S.
Moolawatana H.S.
Mt. Fitton.
Mt Fitton H.S.
Yerelina H.S.
Mistaken Hill
ROAD
NEW
Freeling Hts.
Mt. Lyndhurst
Mt. Lyndhurst H.S.
Avondale H.S.
Mt. Painter
Lyndhurst
T. N.
TRACK
Gammon Hill
Wooltana H.S.
Telford
Mt. Serle
Copley
Mt. Serle H.S.
Balcanoona H.S.
Angepena H.S.
RAILWAY
Beltana
S.A.G. DEPT. OF MINES
MT. FITTON TALC DEPOSIT
LOCALITY PLAN
SHOWING ROAD FROM LYNDHURST
SCALE
MILES 8 4 0 8 16 24 32 40 MILES
del. R.D.S.
21-7-48

Fig. 1

"There are branches or lenses adjoining the main deposit, which on the removal of a comparatively small amount of waste would make available more talc for open cutting. These, however, were not considered.

"The talc as a general rule is greyish or greenish in colour, but powders white. This characteristic, however, seems to be a general feature of massive talc. The talc seems quite as pure as that in the deposits now being worked. It remains, however, for the consumers to pass their opinions on the quality of the talc.

Conclusions

"The new deposit (the No. 5 deposit) is much more extensive than any previously discovered. With a road made to the site the cost of mining would be reduced considerably, because it occurs on the side of a hill and it is easier to dispose of the waste. This factor makes the selection of talc much easier.

"The desirability of working the new deposit depends on whether there will be an increased output. At present there are a comparatively small number of customers on whose satisfaction the output depends. However, production has just commenced, and as the product becomes known the demand for it will probably increase. (26/6/46.)"

In January, 1947, the two claims held by (Mrs.) E. M. Greenwood were converted into leases (M.Ls. 2876 and 2877) and regular production was commenced by the Flinders Talc syndicate. To assure adequate deliveries to consumers, the State Government was approached for funds to finance the construction of a graded road from Lyndhurst railway siding to the mine, and the request was acceded to in March, 1947, on terms mutually acceptable to all concerned. By 4th March, 1948, a distance of 45 miles had been completed at a cost of £5,732. Present production is of the order of 20 tons per week, and (about) 20 men are employed by John Dunstan & Son (W.A.) Ltd. This company is now working the deposits under a sub-lease granted by the present lessees. Recorded production since the discovery of the deposits is as follows:

Year ended	Tons	Value £
31st December, 1945	27	102
31st December, 1946	361	3,328
31st December, 1947	748	7,290
	1,136	10,720

SCOPE OF PRESENT INVESTIGATIONS

The report deals with the detailed geological investigation of the No. 5 deposit carried out during a period of four days ended 28th October, 1947. An accurate geological map was prepared on a scale of 50ft. to an inch, with contours at 5-ft. intervals. D. R. Bowes, Assistant Geologist, assisted in the field mapping and with petrological work, and D. J. Simes, Assistant Mining Engineer, undertook the plane-table survey work and assisted in calculations of reserves and production data. The examination was made at the time that the operations were changing from essentially prospecting to those of a productive character. A mess hut and other facilities were being erected for employees; and steps were being taken to determine the most economical methods of mining, beneficiation, and transport. These aspects are not considered in this report which is confined to geological features and possible ore-reserves based on geological observation. A minimum annual output of 2,500 tons of high-grade talc was fixed at that time as an initial production objective.

Fig. 2.—Mount Fitton talc mine—General view, July, 1950

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ILLUSTRATIONS

(1) Locality map.
(2) Photo—General view of the Mount Fitton talc mine (July, 1950).
(3) Geological surface plan of Flinders No. 5 talc deposit.
(4) Sketch of vertical section showing contact with schistose dolomite.
(5) Sketches illustrating interpretation of extent of Flinders No. 5 talc deposit.

PREVIOUS REPORTS

Published

Sprigg, R. C.—"Talc Deposit West of Mount Fitton": *Mining Review* 81, p. 90 (1944), 1945.

Broadhurst, E.—"Talc Deposit West of Mount Fitton": *Mining Review* 82, pp. 76-81 (1945), 1946.

Stillwell, F. L.—"Rock Specimens, Talc Deposit West of Mount Fitton, Northern Flinders Range—C.S.I.R. Mineragraphic Investigations Report 330": *Mining Review* 82, p. 81 (1945), 1946.

Unpublished

Broadhurst, E.—"Mount Fitton Talc, New Deposit" (26/6/46).

ACKNOWLEDGMENTS

Acknowledgments are due to Dr. F. L. Stillwell and Dr. A. B. Edwards of the Council for Scientific and Industrial Research whose report on the "Petrology of the Talc Deposits of Mount Fitton, Flinders Range" was available for this investigation; to Mr. R. C. Sprigg, Assistant Government Geologist, who reported on the regional geology of this area; to Mr. T. W. Dalwood, Departmental Analyst, for analytical data; and to Messrs. Johnson & Johnson Pty. Ltd., for the results of tests carried out on numerous samples. Messrs. John Dunstan & Son (W.A.) Ltd. supplied detailed information of the company's operations, and extended courtesies to the party during their visit to the mine. Thanks are also due to pastoralists and other residents of the district whose assistance and guidance were much appreciated.

GEOLOGY

The regional geology is described by Sprigg, and the petrology by Stillwell and Edwards, in the reports already referred to, and therefore the following statement deals solely with the geological features of the deposit.

Reference to the surface geological plan will show that the outcrop of the No. 5 talc deposit has an irregular lenticular form with a general east-west strike. It extends over a length of about 1,000ft.; has a maximum width of 250ft.; and its surface area covers 97,400 sq. ft., of which 5,200 sq. ft.—or about 5 per cent—comprise inclusions of country-rock and segregations of other minerals. The latter include calcite, dolomite, tremolite, and silica.

The shape of the deposit in depth is not known, as the deepest opening is a shaft 20ft. deep in the southern open cut. From surface evidence the lens would appear to have a similar dip to that of the schistosity which ranges from 50deg. at the eastern extremity to about 75deg. to 80deg. in its widest part. For purposes of estimating the potential reserves, it is inferred that the long axis of the lens has a flat pitch corresponding to the general westerly dip (15deg.) of the dolomitic marble beds in which the deposit occurs. These conclusions, however, require testing by drilling, and a programme is outlined elsewhere in the report.

The deposit occurs in schistose dolomite near its contact with massive hornfels which overlies the dolomite. The continuity of this contact is broken in two places by normal faults, with down-throws to the south and of pre-mineral origin. The faults appear to have had some influence on the location and concentration of talc mineralization, the eastward extension of the northerly one lining up with a massive calcite formation on the northern edge of the deposit, and the extension of the southern fault likewise marking the southern limit of the deposit. The deposit itself is elongated in a direction inclined at 15deg. to 20deg. to these faults which is parallel to that of the foliation in the dolomite. The vertical displacement along the fault planes is of the order of 50ft.–100ft. A feature of the contact zone is the marked schistose structure of the dolomite which has presumably facilitated the penetration of the mineralizing solution. Farther from the contact the schistose dolomite grades insensibly into massive dolomite completely devoid of foliation. In contrast to the schistose dolomite the hornfels is a hard, dense, black rock, except adjacent to the faults where it has developed a sheared and bleached character, the bleaching presumably being accomplished by the penetration of mineralizing solution. Metasomatism has caused the formation of the talc, and is described in detail by Stillwell and Edwards. The masses of silicified dolomite, calcite, and tremolite shown on the geological map are probably segregations formed by this process. Talc formation excluded, the strong silicification of the schistose dolomite is the most marked feature of the mineralization; but, it is noteworthy that the silicified dolomite zones, as well as the unreplaced inclusions of schistose dolomite in the talc, have clear-cut contacts and rarely show partial alteration to talc. In consequence the larger ones are readily separable from the talc in mining operations.

SIZE OF THE DEPOSIT

The study of the geology of the deposit has indicated that pre-mineral stressing set up a fracture pattern which provided a fundamental control for the localization of the deposit. The mineralizing solutions probably rose along the contact of the dolomite and hornfels, also along the faults, and replaced the dolomite adjacent to and between the faults near the hornfels contact.

It is concluded, therefore, that the deposit is lenticular in shape; is located between the faults; and pitches to the west at an angle of about 15deg., corresponding with that of the dip of the hornfels-dolomite contact. The pitch of 15deg. is measured in the foliation direction.

If it is now assumed that the shape of the talc body is ellipsoidal—with its outcrop representing a horizontal section through its centre—the following calculation of the possible size can be made from dimensions on the plan, section, and projection drawn to give expression to this conception.

Long axis (*a*) in the direction of pitch—600ft.
Intermediate axis (*b*) in the plane of schistosity—300ft.
Short axis (*c*) at right angles to the plane of schistosity—200ft.

$$\text{Volume} = \frac{\pi}{6}\ a.\ b.\ c.$$

$$= \frac{3{\cdot}141 \times 600 \times 300 \times 200}{6}$$

Taking the specific gravity of talc at 2·81, and 175 lb. per cub. ft.—

$$\text{Tonnage} = \frac{3{\cdot}141 \times 600 \times 300 \times 200 \times 175}{2{,}240 \times 6} = 1{,}470{,}000 \text{ tons.}$$

$$\text{Quantity in ground} = \tfrac{1}{2} \times \frac{3{\cdot}141 \times 600 \times 300 \times 200 \times 175}{2{,}240 \times 6}$$

$$= 735{,}000 \text{ tons.}$$

Maximum depth = 150ft.

At the time of the inspection (28/10/47) the total production of first-grade talc from the shallow open cuts amounted to approximately 600 tons. Measurements of these openings indicated that the total quantity of material mined was about 1,910 tons; that is, the production of 1 ton of first-grade, carefully selected talc had required the removal and dressing of 3 tons of rock. This

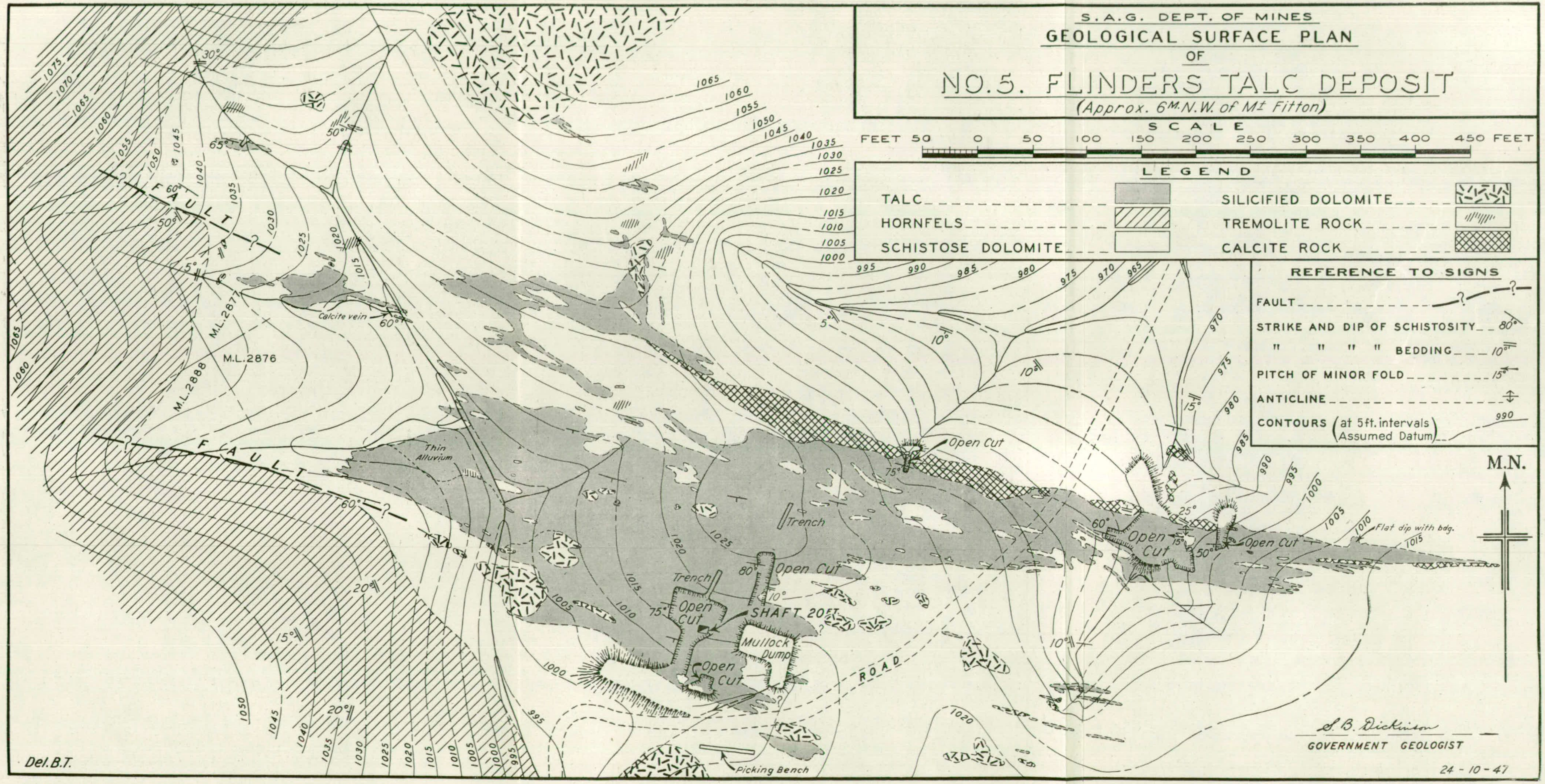

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Fig. 3

initial selection, however, was haphazard, and an appreciable quantity of first-grade talc had been rejected with the waste rock. Slightly off-colour talc was also discarded, and it is reasonable to assume that with improved methods of handling, and the adjustment of standards of quality, that at least two-thirds of the output could be classed as marketable grades—so called "firsts" or "seconds"—the proportions varying according to changing standards.

Hence, on purely geological evidence, it is estimated that the reserves of marketable talc amount to about 500,000 tons, for the recovery of which—by open-cut methods—it would be necessary to mine a total of about 1,000,000 tons of rock, which includes an allowance for batters in the dolomite as the

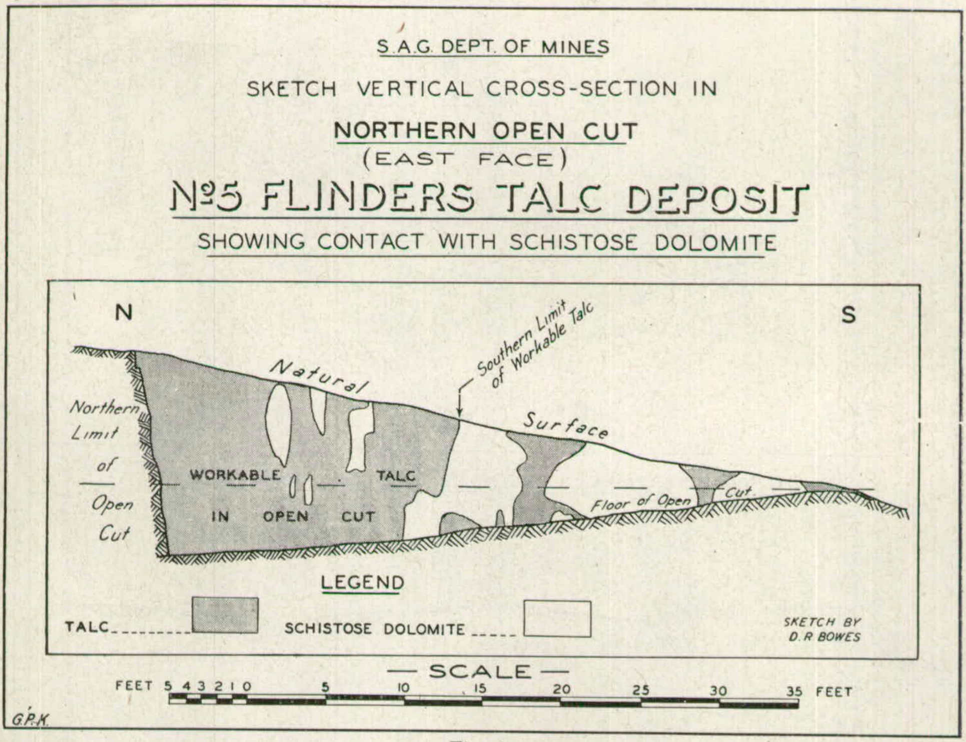


Fig. 4

excavation becomes deeper and deeper. For an annual production of 2,500 tons of first-grade talc, approximately 2,500 tons of second-grade talc would also be available, in present standards, and the deposit would have a life of 100 years.

TESTING

Whilst the surface geological evidence provides a clear picture of the relationships of talc mineralization and geological structure in plan, no geological data are available to indicate the form of the deposit below the surface.

The conception of the shape of the deposit in depth—already described—is therefore largely speculative; and, in the interests of future mining operations, it is desirable that a small expenditure on drilling should be authorized to remove the chief elements of uncertainty, and if necessary, to evolve entirely new interpretation. It is considered that the three diamond-drill holes shown on the plan would provide sufficient data for this purpose. They will also provide data for the estimation of actual and probable reserves, and the design of a sound scheme for development. The total footage required would be approximately 800ft. to 1,000ft.

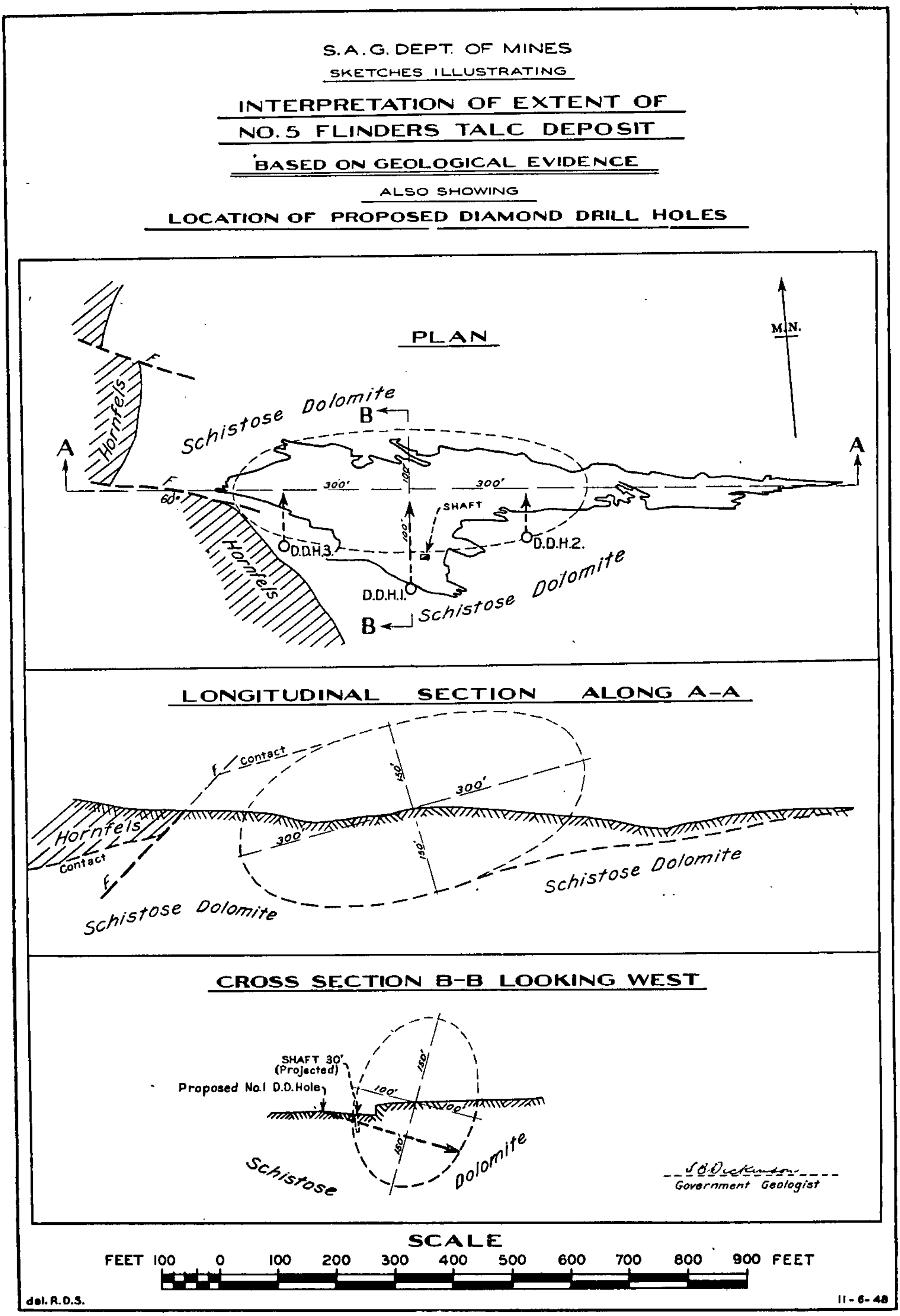

S.A.G. DEPT. OF MINES
SKETCHES ILLUSTRATING
INTERPRETATION OF EXTENT OF
NO. 5 FLINDERS TALC DEPOSIT
BASED ON GEOLOGICAL EVIDENCE
ALSO SHOWING
LOCATION OF PROPOSED DIAMOND DRILL HOLES
PLAN
M.N.
Hornfels
Schistose Dolomite
A
A
B
B
300'
300'
100'
100'
60°
SHAFT
D.D.H.3.
D.D.H.2.
D.D.H.1.
Hornfels
Schistose Dolomite
LONGITUDINAL SECTION ALONG A-A
Contact
150'
300'
Hornfels
Contact
300
150'
Schistose Dolomite
Schistose Dolomite
CROSS SECTION B-B LOOKING WEST
SHAFT 30'
(Projected)
Proposed No.1 D.D.Hole
100'
150'
100'
150'
Schistose Dolomite
Government Geologist
SCALE
FEET 100 0 100 200 300 400 500 600 700 800 900 FEET
del. R.D.S.
11-6-48

Fig. 5

CONCLUSIONS

The No. 5 deposit at Mount Fitton is a valuable one of exceptionally high-grade talc outcropping at the surface over an area of a little over 2 acres, and on purely geological evidence is estimated to contain approximately 500,000 tons of marketable grade recoverable by open-cut methods.

Drilling should be undertaken as soon as possible to confirm this estimate, as well as to guide development work. Its chief disadvantage is that it is situated in a remote locality, which entails high transport and labour costs; but the former will be considerably reduced when the access road—being financed by the Government—is completed; the latter, by the installation of mechanical equipment.

The profitable working of the deposit depends on the exclusion, or restriction, of imports of high-grade talc from overseas; an ample domestic consumption; and the introduction of suitable mechanical equipment for mining and ore dressing.

Satisfactory solution of the problem of continuous production at the deposit, and the establishment of a successful manufacturing industry in Adelaide, require the immediate and careful consideration of the three aspects referred to above.
(8/6/48.)

Chapter 2

REGIONAL GEOLOGY IN THE MOUNT FITTON TALC AREA

BY

R. C. SPRIGG, M.SC. (SENIOR GEOLOGIST)

ABSTRACT

The Mount Fitton talc deposits lie in an area of regionally metamorphosed Adelaide System sediments, flanked to the north and east by granite complexes.

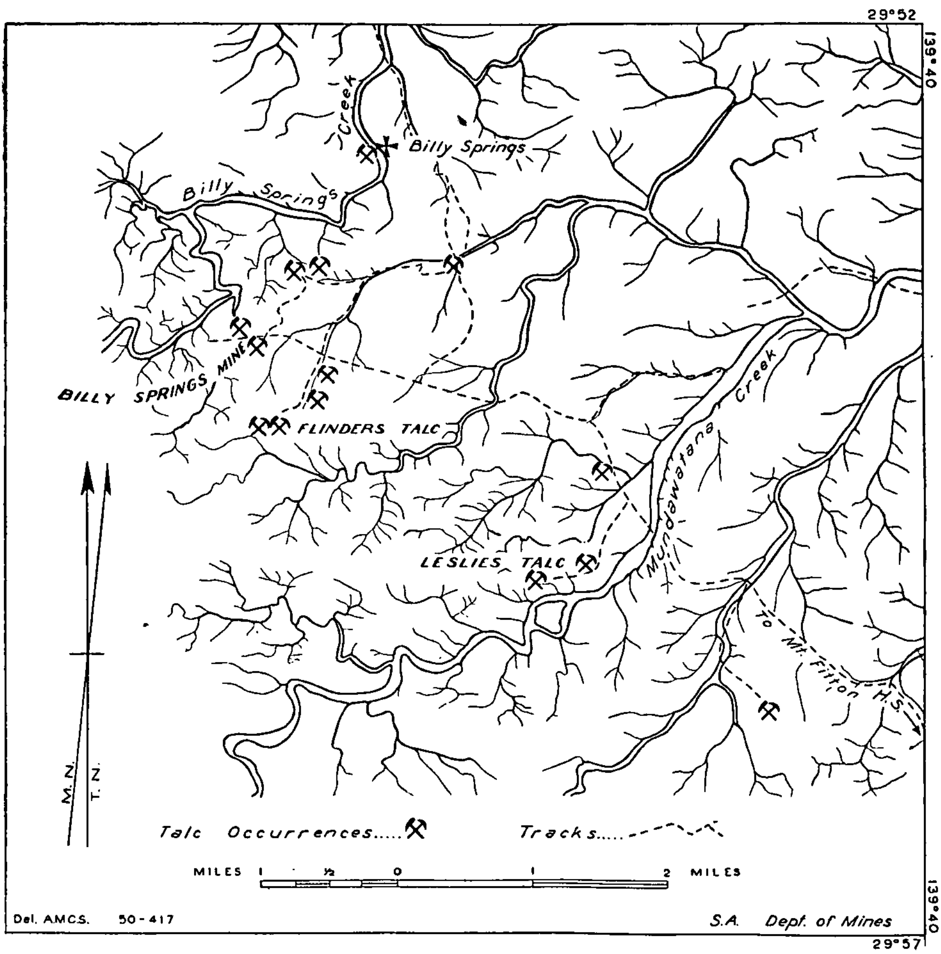


Fig. 1.—Mount Fitton talc occurrences—Locality plan

The talc deposits occur in an extensive tremolite marble formation interbedded with a series of fluvioglacials and tillites. In folding, the relatively incompetent marble has "flowed" considerably. About its junction with the enclosing beds, drag folding and minor faulting has produced weaknesses which have favoured the entrance and selective activity of hydrothermal solutions to produce talc by processes of metasomatism.

INTRODUCTION

The Mount Fitton talc deposits are situated in a region practically free of significant soil cover. The country is well dissected by streams, and consequently geological structures are readily explored. Geological features are essentially simple and broad, and much of the broader structure can be delineated on aerial photographs.

The immediate talc area (fig. 2) has been mapped in broad reconnaissance detail on a scale of 20 chains to the inch, but in order to elucidate the regional relations of this more restricted area, a reconnaissance sketch plan has been prepared to include several hundred square miles of the surrounding country. This latter plan has been prepared largely from trimetrogon aerial photographs and a few field traverses. It is intended only to indicate broader structural features.

PHYSIOGRAPHY

The Mount Fitton area covers portion of the north-eastern prolongation of the Flinders Range. Its more prominent hills range in altitude between 1,000ft. and 2,000ft. above sea-level. Local physiography is typically that of a north-down-tilted exhumed base surface, now in an advanced stage of dissection. Since exhumation of this base surface, there appear to have been very incomplete tendencies toward the establishment of local secondary erosion surfaces.

Hill tops in general conform with the assumed tilted base surface, and at Mount Babbage and elsewhere the basement rocks are capped by sub-horizontal (?) Eyrian sediments which have preserved portions of the base surface intact. The age of this surface is not known, but a Mesozoic age is inferred.

To the east the ancient base-surface is lost below the Lake Frome Plains by block-faulting. This latter fault has been active relatively recently (? Kosciusko Epoch) as it has disturbed the local (?) Eyrian formations considerably.

Local stream patterns are well entrenched on the fossil base-surface, and the trunk streams, which are frequently very broad, are usually well graded and often strongly sinuous in their courses. Trunk streams in general trend northwards, perhaps under a relict influence of the old north-plunging surface, but a strong control is also exercised by the resistant granitic massifs flanking the eastern and northern margins of the range. A case of deserted ox-bow or meander is recorded on the Mundawatana Creek, and its position is indicated in fig. 2.

REGIONAL GEOLOGY

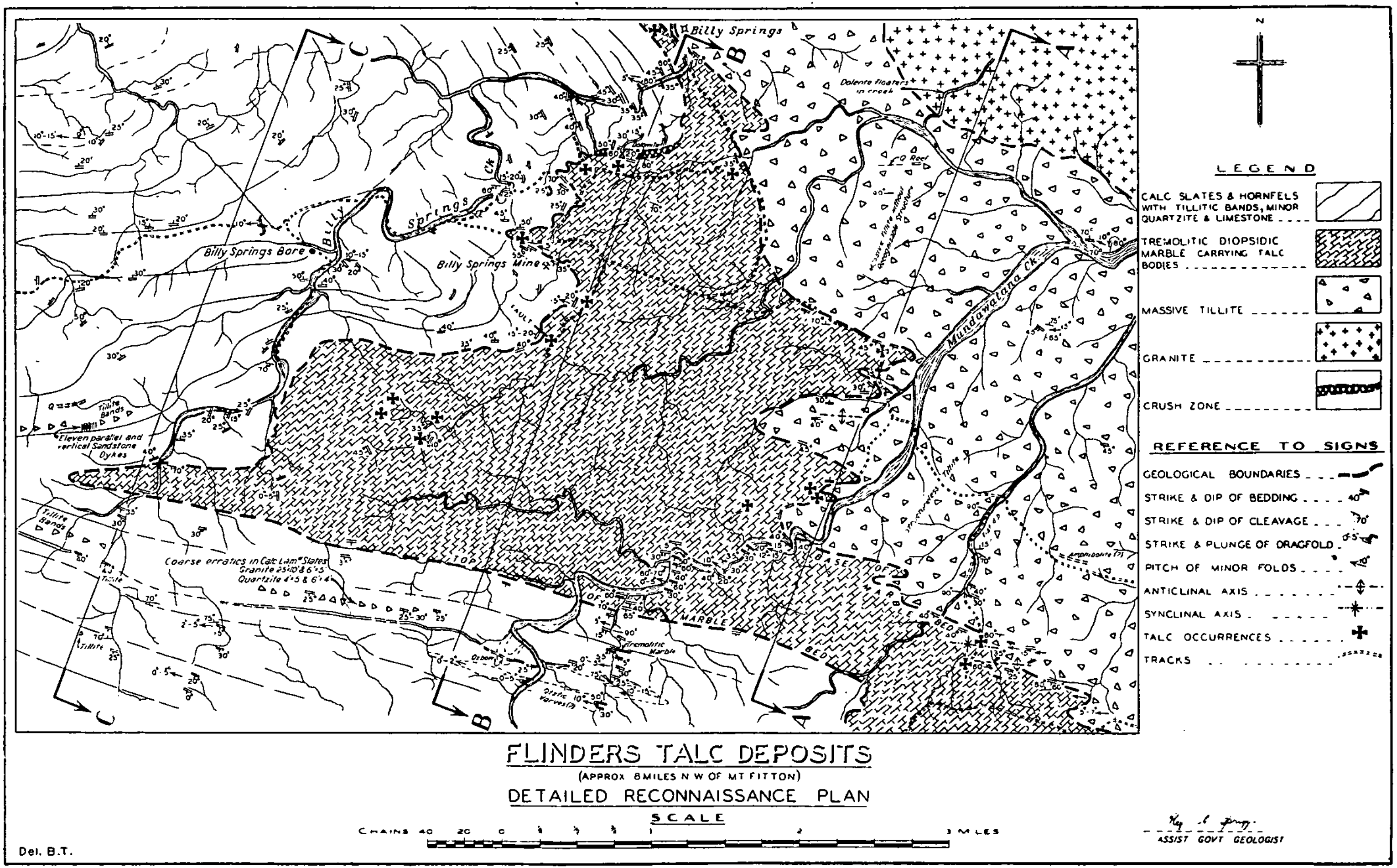
Basement rocks in the north-eastern Flinders Range are Adelaide System sediments (Upper pre-Cambrian) which have been folded, regionally metamorphosed, granitized, and intruded by granite.

Stratigraphic Succession

The sediments of the immediate Mount Fitton vicinity are predominantly tillites and fluvioglacials, the latter frequently being calcareous, and carrying at least one major and several smaller limestone horizons. These limestones are now tremolitic marbles.

The sedimentary sequence, commencing with the younger sediments, is as follows:

ft.	
2,000 (+)	Grey and greenish-grey slates, structureless or laminated, and calcareous or tillitic in part.
50–100 (+)	Sandy quartzitic varves.
30	Siliceous white quartzite.
400	Grey laminated calcareous slate.



FLINDERS TALC DEPOSITS
(APPROX 8 MILES N W OF MT FITTON)
DETAILED RECONNAISSANCE PLAN
SCALE
CHAINS 40 20 0 1 MILES 2 3 MILES
LEGEND
CALC SLATES & HORNFELS WITH TILLITIC BANDS, MINOR QUARTZITE & LIMESTONE
TREMOLITIC DIOPSIDIC MARBLE CARRYING TALC BODIES
MASSIVE TILLITE
GRANITE
CRUSH ZONE
REFERENCE TO SIGNS
GEOLOGICAL BOUNDARIES
STRIKE & DIP OF BEDDING
STRIKE & DIP OF CLEAVAGE
STRIKE & PLUNGE OF DRAGFOLD
PITCH OF MINOR FOLDS
ANTICLINAL AXIS
SYNCLINAL AXIS
TALC OCCURRENCES
TRACKS
N
Billy Springs
Billy Springs Bore
Billy Springs Mine
Billy Springs Ck
Mundawatana Ck
Dolerite Floaters in creek
Q Reef
Tillite Bands
Eleven parallel and vertical Sandstone Dykes
Coarse erratics in Calc Lam^d Slates
Granite 25'-10' & 6'-5'
Quartzite 4'-5' & 6'-4'
TOP OF MARBLE
BASE OF MARBLE BED
Tremolitic Marble
Ozbom
Ozbric Varves (?)
Amphibolite (?)
Tillite
Fault
Del. B.T.
ASSIST GOVT GEOLOGIST

Fig. 2

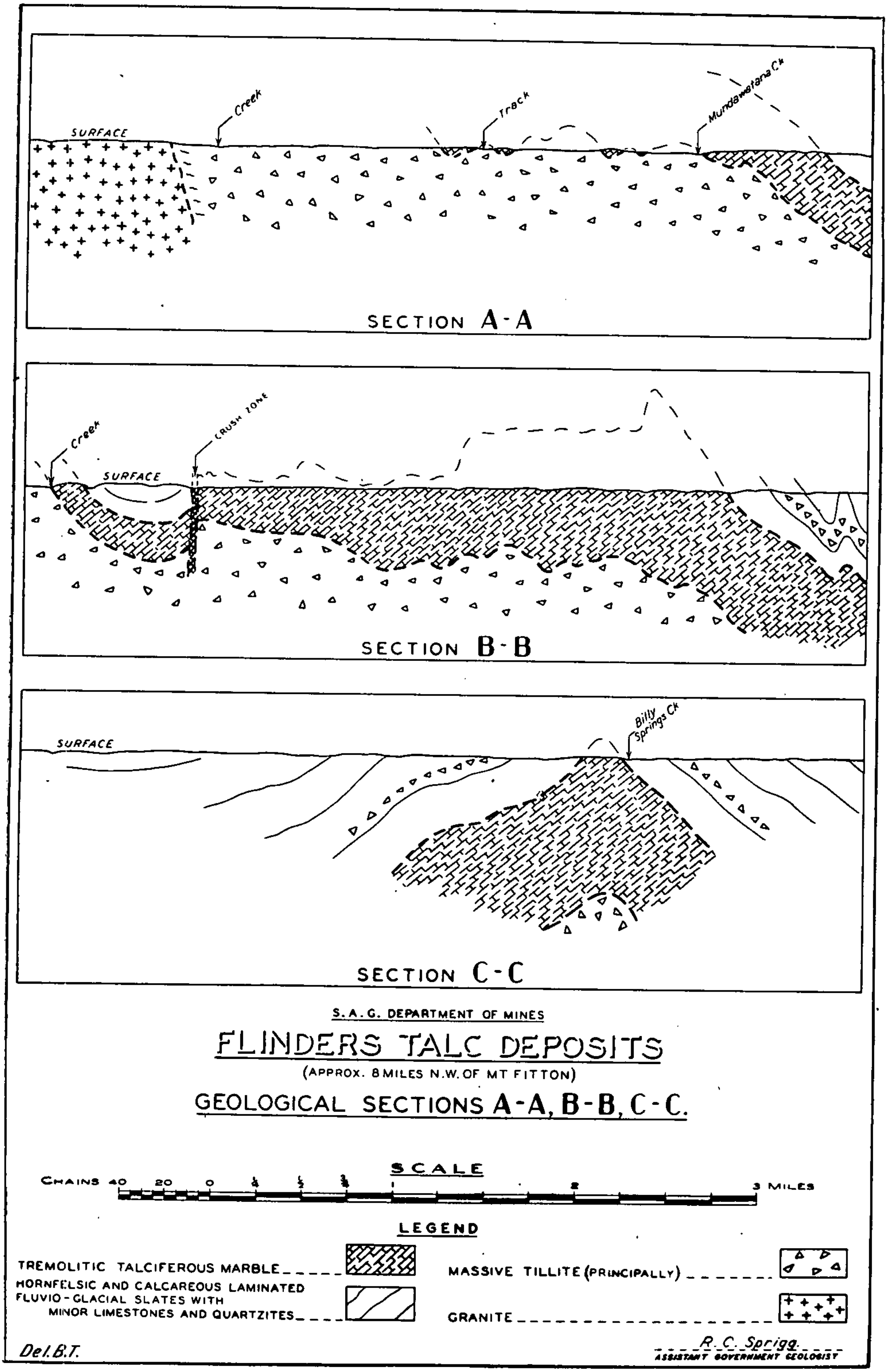

SURFACE
Creek
Track
Mundawatana Ck
SECTION A-A
Creek
CRUSH ZONE
SURFACE
SECTION B-B
SURFACE
Billy Springs Ck
SECTION C-C
S. A. G. DEPARTMENT OF MINES
FLINDERS TALC DEPOSITS
(APPROX. 8 MILES N.W. OF MT FITTON)
GEOLOGICAL SECTIONS A-A, B-B, C-C.
SCALE
CHAINS 40 20 0 ¼ ½ ¾ 1 2 3 MILES
LEGEND
TREMOLITIC TALCIFEROUS MARBLE
HORNFELSIC AND CALCAREOUS LAMINATED FLUVIO-GLACIAL SLATES WITH MINOR LIMESTONES AND QUARTZITES
MASSIVE TILLITE (PRINCIPALLY)
GRANITE
Del. B.T.
R. C. Sprigg.
ASSISTANT GOVERNMENT GEOLOGIST

Fig. 3

ft.	
50–100	Tillite and fluvioglacial tillite; the tillite includes quartzite and granite erratics of huge dimension, one of which is Rapakivi type granite measuring 25ft. by 10ft. in outcrop.
17,000	Grey laminated slates, with beds of yellow tremolitic and sideritic marble up to 20ft. in thickness.
600–4,000	Yellowish tremolitic (and talciferous) marble.
2,000 (+)	Massive tillite, with very little structure. Erratics of granite, porphyry, and quartzite are very abundant. Includes several more slaty bands.

The great variation in thickness of the marble horizon is due in part to the lenticular nature of the bed, but also to rock flowage under applied pressure and regional metamorphism. The bed has thickened greatly along the axis of major folds.

Folding

Sediments of the Adelaide System have been folded locally, with major fold axes directed east and west. Regional cleavage, which is dominantly steep, is aligned in sympathy with this direction. Although the east-west element infolding is most prominently developed, its effect, as viewed on a regional basis, is modified somewhat by north-south axis cross-warping. The interaction of these influences tends to basin and dome formation, but such complication is not so evident where small-scale structures only are concerned. In this way the major and minor folds conform strongly with the regional cleavage, and so in the restricted Mount Fitton area, folding is strongly east-west in character with west-directed pitch at low angles.

Faulting

Within the area, faulting is generally of only minor structural significance. The fault near Billy Springs, the eastern block fault, and possible shear movements along portions of the granite boundaries are exceptional in this respect. On the other hand, in dealing with the genesis of talc bodies, certain of the minor faults cutting the major tremolitic marble are of definite importance. Their significance will be discussed later.

Igneous Activity and Metamorphism

Much of the north-eastern extension of the Flinders Range has been subjected to low- or medium-grade regional metamorphism which apparently accompanied granitization and granite intrusion.

Granites occur in two separated masses. That skirting the eastern margin of the range is the northerly continuation of the Mount Painter igneous complex, and appears to be largely a case of granitization *in situ* with only moderate mobilization. In general, where the writer has observed it, the periphery of this granite complex in contact with metasediments is abrupt, but apparently not of the instrusive type. For example, near Terrapinna Waterhole, the adjacent fluvioglacial tillites over a transverse distance of only a few feet become more granitic, and finally the matrix and included erratics become absorbed in granitic rock. It is noted, though, that in this zone there is evidence of considerable shearing; to what extent this amounts to significant faulting is undetermined. This is a factor which requires much additional investigation of the granite itself, much of which exhibits lineation, thought to reflect metasedimentary variations. In general the directional textures appear to be sympathetic with those of the metasediments skirting its border. This eastern or "Terrapinna" granite varies from highly gneissic to coarsely felspathic (Rapakivi) types.

The other occurrence—the Mount Babbage granitè—is also more aptly termed a granite complex. To the west, the coarsely felspathic types appear to dominate, whereas near the south-eastern margin the granite is strongly "gneissic", and

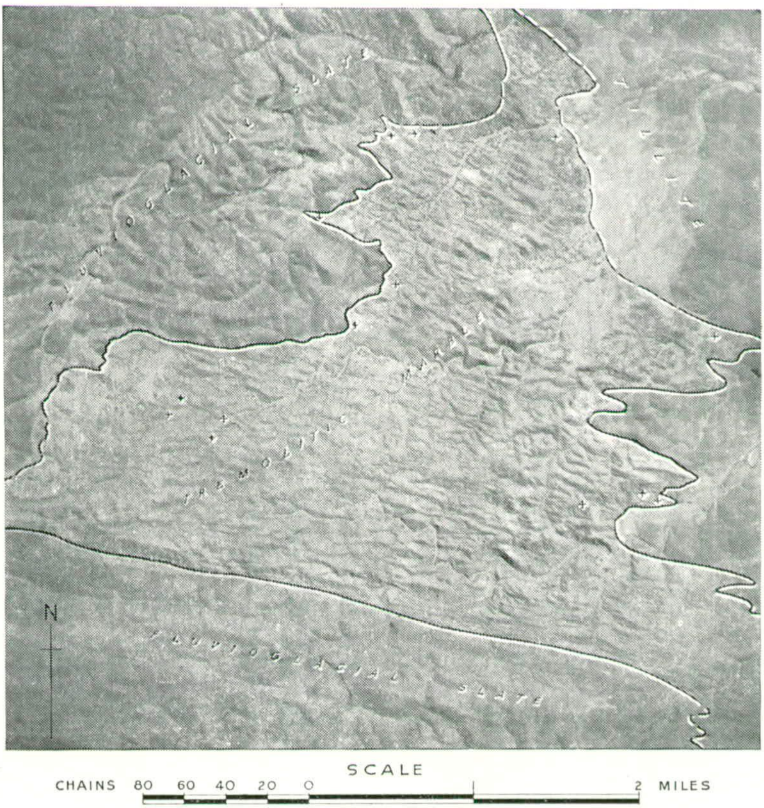


Fig. 4.—Mount Fitton talc occurrences—Aerial photo showing disposition of main talc occurrences within the tremolitic marble

[Photo by courtesy of the R.A.A.F.

at the actual border it is highly sheared and silicified. On its southern aspect the granite border parallels the adjacent metasedimentary structures fairly faithfully, but elsewhere sedimentary structures run obliquely into the granite. Faulting along the margins is therefore a probability. In view of the regional structure of the enclosing metasediments, the granite appears to have been mobilized, and emplaced bodily, forcing sediments apart. The outline of the granite, which is subcircular, appears to support a theory of batholithic intrusion; but the degree of marginal faulting must be investigated before any definite assertions of this type can be made. The granitic mass is traversed by pegmatitic dykes, and to a lesser extent by doleritic dykes. Dyke rocks rarely occur outside the limits of the granite complexes, and then usually in a narrow marginal zone. Such distribution favours a theory of the infaulting of the granite masses. However, there are exceptions to this general rule. Mr. S. B. Dickinson has noted an amphibolite dyke occurring near Billy Springs, and the writer has found what is presumed to be a related dyke formation within the massive tillite adjacent to the Mount Fitton track near Billy Springs.

Beyond the immediate influence of the granites, sediments have been metamorphosed to varying degrees over a wide area. Slates have become phyllites and infrequently grade into fine-grained schists, while limestones and dolomites have been altered to marbles with or without tremolite, actinolite, siderite, and diopside; in extreme cases the marbles may approach tremolitic schists in character. Sandstones and quartzites become silicified, and some tillitic horizons are schistose or hornfelsic. There appears to be no prominent display of contact metamorphism adjacent the granites, and the adjoining metasediments show little sign of pegmatite invasion. In general, metamorphic gradients are suspiciously steep in this boundary zone.

There is a fine development of garnet gneisses in the vicinity of Twelve Springs, but these are included within the so-called granite complexes.

Phenomena

Within the Adelaide System sediments the writer has discovered a set of 11 sandstone dykes. They occur in a tillite band stratigraphically above the major marble horizon, and their strike coincides with a rather poorly developed regional jointing system which lies transverse to the regional cleavage and the local sedimentary structure. They occur close together and rarely exceed 50ft. in length and 2ft. in width. Several show laminations extending from wall to wall. The dykes are strongly discordant features, and possibly relate to some phase in the buckling of the geosynclinal sediments. As they exhibit laminations they deserve more careful study, particularly with regard to microscopic structure and lamination orientation in relation to the bedding of the enclosing sediments. There is a suggestion, for example, that dyke formation may have occurred soon *after* the commencement of folding.

Mineralization

The Mount Fitton area is one of widespread low-grade metamorphism. Copper, lead, zinc, silver, and gold have been mined on a restricted scale, and copper perhaps most successfully. Other minerals include vanadium and bismuth. Practically all of these occur in the metasediments in fissures, although some lead occurs as metasomatic replacement deposits in a marble bed near Billy Springs. Copper has been prospected within the granite complexes. Talc is now the only mineral being mined locally on a commercial scale.

Overmass Sediments

(?) Eyrian (Cretaceous or early Tertiary) formations overlie the basement rocks in the vicinity of Mount Babbage, and they dip north at a low angle in sympathy with the exhumed and dissected base-surface upon which they lie.

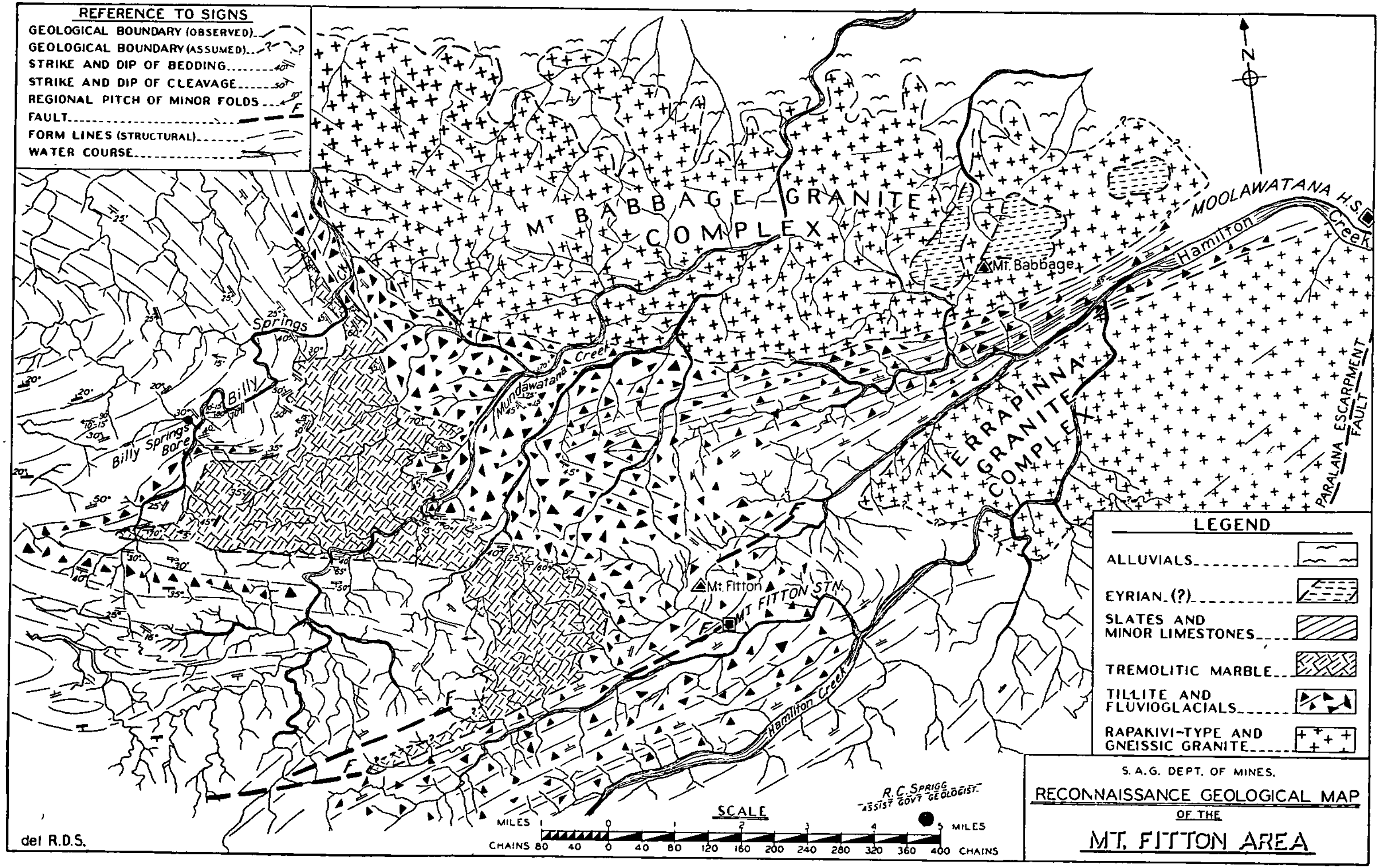

REFERENCE TO SIGNS
GEOLOGICAL BOUNDARY (OBSERVED)
GEOLOGICAL BOUNDARY (ASSUMED)
STRIKE AND DIP OF BEDDING
STRIKE AND DIP OF CLEAVAGE
REGIONAL PITCH OF MINOR FOLDS
FAULT
FORM LINES (STRUCTURAL)
WATER COURSE
Mt BABBAGE GRANITE COMPLEX
TERRAPINNA GRANITE COMPLEX
MOOLAWATANA H.S.
Hamilton Creek
Mt. Babbage
Mundawatana Creek
Billy Springs
Billy Springs Bore
Mt. Fitton
MT FITTON STN.
PARALANA ESCARPMENT FAULT
LEGEND
ALLUVIALS
EYRIAN (?)
SLATES AND MINOR LIMESTONES
TREMOLITIC MARBLE
TILLITE AND FLUVIOGLACIALS
RAPAKIVI-TYPE AND GNEISSIC GRANITE
S.A.G. DEPT. OF MINES.
RECONNAISSANCE GEOLOGICAL MAP
OF THE
MT. FITTON AREA
R.C. SPRIGG ASSIST GOVT GEOLOGIST
SCALE
MILES 1 0 1 2 3 4 5 MILES
CHAINS 80 40 0 40 80 120 160 200 240 280 320 360 400 CHAINS
del R.D.S.
N

Fig. 5

They were not visited, but appear to be mainly sandstones in various stages of silicification, although J. H. Shepherd (personal communication) has recorded tillites in them. A further small outlier of sandstones, which seems not directly related in view of inferior location on a later secondary base surface, has been noted by S. B. Dickinson on a low divide about 1 mile NE. of Billy Springs. These sediments contain vegetable matter, but at present their age in unknown. In the hand specimen, the material has the appearance of certain Jurassic sandstones, but on the other hand, many Tertiary sandy beds, preserved in the adjacent Frome sunken lands, appear similar.

THE TALC OCCURRENCES

The known talc deposits all occur within the thick regionally metamorphosed marble horizon. This formation is extensively altered to tremolite, and is notable for considerable and rapid variation in thickness along its strike.

To the present, talc has been found only in the vicinity of Billy Springs and within the west-pitching major anticline to the south of that locality. However, the "parent" marble is continuous to the south and east, eventually swinging to the west in conformity with the south limb of the regional syncline. To the north-west of Billy Springs, the bed appears to be lensing out, but its continuation is apparently terminated by a strike fault.

The marble horizon has been mapped in broad reconnaissance detail in the vicinity of the major pitching anticline. Particular attention was paid to its upper and lower face-traces as, except in larger creeks, reliable structural information could be observed only with difficulty and some uncertainty. The marble formation is notably "incompetent" and has buckled extensively into minor crenulate folds which are best seen at the face boundaries (fig. 2 and cross-sections). For example, on the lower face-trace seven well marked minor synclines appear in a distance of less than 4 miles. On the upper limit, the crenulations are not so evenly developed, but many minor undulations occur superimposed on larger ones. As described previously the marble bed varies considerably in thickness, and while some of this variation is probably related to original sedimentary lensing, the extremes have been heightened considerably by rock flowage under stress of deformation. The formation is thickened along crests of the major anticline and syncline, and thinned out relatively on the fold limbs.

The more important talc deposits are all situated adjacent either to the top or bottom of the marble bed, and all can be related closely to minor fold axial planes or to faults. It would appear that such lines of weakness have provided easy access for circulating hydrothermal waters at the time of regional metamorphism.

On purely theoretical grounds it may be anticipated that drag folding and minor folding would attain best expression near boundary faces of the relatively very incompetent marble formation. At these junctions, during folding, the inter-relation of more competent slates and tillites with the marble would have been expected to intensify deformation locally. On the other hand, toward the centre of the marble mass, such intense stresses of folding would tend to be dispersed, finding expression in less-confined rock flowage accompanying mineral recrystallization. In this way it would appear improbable that minor fold axes would be transmitted faithfully through the thickness of the marble on any simple geometrical plan. This is well shown in fig. 2 and the cross-sections; there appears to be no reliable matching of the minor folds on the two faces of the marble. It is agreed therefore, that structural weaknesses in the form of minor folds and faults will be most pronounced only adjacent to the boundaries of the marble formation, and it is in these zones then that hydrothermal solutions have been most active in the formation of talc bodies.

Following upon these considerations it is anticipated that the talc bodies will pitch west with the folds, or in the case of the dip faults, with the marble face-traces; they would assume a general compressed pipe-like form. The talc deposits will become shallower up-pitch, but they will plunge below the hornfelsic fluvioglacials in the reverse direction.

In exploring for new deposits, the submarginal zone of the marble formation should be inspected carefully, particularly where faults can be observed traversing the bed facings or where there has been acute minor folding. Already a preliminary inspection of several such zones has revealed new talc occurrences.

CONCLUSIONS

A study of the broader field relationships of the Mount Fitton talc bodies has given a much clearer picture of the genesis of these mineral deposits. A set of controls active in the localization of talc ore has operated very strongly, and their elucidation has and should continue to be of assistance in the search for new commercial orebodies. (7/9/47.)

Chapter 3

MINING OPERATIONS, FLINDERS No. 5 TALC DEPOSIT

BY

A. T. ARMSTRONG (STATE MINING ENGINEER)

Situation:—About 3 miles south of Billy Springs, on Moolawatana Station, outside of counties, North-Eastern division. Mineral Lease No. 2876 held by G. A. Greenwood, W. B. Greenwood, J. G. Ford, and W. Mackay.

INTRODUCTION

Mr. S. B. Dickinson, in his report on this deposit, estimates "on purely geological evidence that the reserves of marketable talc amount to about 500,000 tons, for the recovery of which—by open-cut methods—it would be necessary to mine a total of about 1,000,000 tons of rock which includes an allowance for batters in the dolomite as the excavation becomes deeper and deeper". (*See* page 73.)

Referring to the production of 600 tons of first-grade talc from the original shallow open cuts he states that—

> "Measurements of these openings indicated that the total quantity of material mined was about 1,910 tons; that is, the production of 1 ton of first-grade, carefully selected talc had required the removal and dressing of 3 tons of rock. This initial selection, however, was haphazard, and an appreciable quantity of first-grade talc had been rejected with the waste rock. Slightly off-colour talc was also discarded, and it is reasonable to assume that with improved methods of handling, and the adjustment of standards of quality, that at least two-thirds of the output could be classed as marketable grades—so-called 'firsts' or 'seconds'—the proportions varying according to changing standards."

WORKINGS AND SELECTION OF TALC

The main working is still the western open cut. The western portion of the T-head has been extended to the outside of the hill slope making the main face about 100ft. long. The small "island" of talc left by this operation between the old and new entrances to the quarry is now being removed.

The main face is from 8ft. high at the western end to 15ft. high at the eastern end of the quarry.

The talc is quarried by boring short 3-ft. to 4-ft. holes and firing them with gelignite. The faces are worked down from the top, and the firing breaks or shatters a lot of material that is afterwards barred down.

The talc is hand-spalled at the faces and selected into grades. The main classifications are:

1. Special first grade.
2. First grade for the dressing-table—discards to second grade.
3. Fine run-of-mine.
4. Second grade.
5. Fines for screening—
   (*a*) Fine run-of-mine.
   (*b*) Discard to waste.
6. Waste.

At the time of the inspection, owing to transport difficulties, only first-grade material was being sent in to the railway—some of it special material, the rest hand-dressed.

The special material was collected into piles in the quarry pending shipment. The material for the dressing-table was loaded on a motor truck as soon as it was spalled and taken to the table.

The other grades were taken in the truck and dumped at appropriate points awaiting further handling for transport to the railway and/or selection.

The material for the dressing-table is unloaded into piles behind the operators. The spalls of talc are broken to roughly 6-in. pieces and trimmed with tomahawks. The dressed material is bagged in hundred-weight bags.

DISCUSSION

In the following analysis of the operations of the company at the quarry, emphasis is placed on:

(1) Transport from the mine to the railway.
(2) Selection and dressing of various grades of talc at the mine.
(3) The quarrying of the talc.

Transport

Each of the above matters affects the other two. Transport has been placed first because for all practical purposes the production from the deposit is the amount of talc transported to the railway.

At the present time an arrangement with various contractors gives the mine a very haphazard service. It would appear that the contractors send vehicles out to the mine when they can spare them.

It is understood that the company is aiming to produce 100 tons of talc per week, say, 50 tons of first-grade and 50 tons of second-grade material. At least 12 trips would have to be made with 10-ton trucks to move the 100 tons to the railway. Each trip would take 1½ days to 2 days under normal circumstances.

Allowing for spare or relief vehicles, six 10-ton trucks would be needed to carry on an uninterrupted service.

Selection and Dressing of Talc

First-grade talc is now dressed at the mine. The operation performed on the dressing-table at the mine could be done just as well away from the mine. A tomahawk is used to break the lumps of talc and to trim the impurities from the edges, and a wire brush cleans any outside stains away. At a special table there are several circular wire brushes worked by mechanical means.

Experiments are to be made on selected talc in Adelaide to determine whether the ore can be dressed or beneficiated by metallurgical means.

There are a number of possibilities:

(*a*) An overall treatment of run-of-mine ore.
(*b*) Treatments for selected grades roughly sorted in the quarry.
(*c*) Hand-dressing aided by mechanical handling in a treatment plant.

The first possibility seems very remote, so, in view of the fact that one-third of the ore is waste, the ore should be sorted as early as possible in its handling to eliminate this waste rock and avoid as much contamination as possible.

The procedure best suited to present conditions at the mine is to sort the ore into grades in the quarry while the talc is in freshly broken lumps.

Quarrying

The talc deposit has a rough east-west strike with a schistosity dipping to the south at a fairly steep angle. The safest way of working the deposit is to have the face of the quarry at right angles to the strike. Working across the beds, the face would be subject to slips on the cleavage planes.

A better chance of selective mining would also be afforded by a face running across the strike. The variation in the quality of the talc for the most part follows the cleavage, and the face of the quarry would show a cross-section of the deposit. It is recommended that the cutting be extended across the width of the deposit as soon as possible. This move will enable the company to open up two faces at right angles to the strike for extension to the ends of the deposit. At this stage it seems more than likely that much of the value of the talc will depend on the preliminary sorting of the broken material in the face of the quarry. Seeing that, to date, no specific metallurgical treatment has been evolved for the beneficiation of run of mine ore, selection of the material will most likely be necessary because of the amount of waste rock in the deposit. Costly hand-sorting seems inevitable since it is not feasible to introduce much mechanical equipment to handle the broken material, a step that might be possible if an overall cleaning process were discovered to rid the broken material of waste and clean up the talc.

Subject, therefore, to the results obtained in the present series of metallurgical tests, it seems likely that selection will be by hand sorting in the quarry. On this assumption, the following recommendations are made for the handling of broken material at the mine:

(1) That a skip-and-dumper system be introduced for the handling of the material in and from the quarry. A series of small skips are placed at suitable points near the face. As these are filled a motor vehicle picks them up and takes them to dumping points.

(2) That a 100-ton bin be provided to store the selected grades of talc. The bin should be divided into four 25-ton compartments—one for special material, one for first-grade talc, one for second-grade talc, and one spare.

A further recommendation is made that the top foot of the face be removed, or at least the very weathered surface-talc, before the faces are shot down for sorting.

With the skip-and-dumper system it would be possible, after the preliminary hand-sorting, to dispose of the talc with a minimum of handling. Each steel bin will be taken either to the waste dump or to a compartment of the main storage bin. From the storage bin it will be loaded into motor trucks for transference to the railway.

ECONOMIC ASPECTS

(1) Estimated output per week (based on present commitments):

	tons
50 tons first grade talc	50
50 tons second grade talc	50
	100

equivalent to, say, 5,000 tons per year for the next five years. When the deposit is opened up more, it would be capable of a larger output.

(2) Estimated value of talc on trucks at Adelaide (current prices and freight):

	per ton £ s. d.
Price of first-grade talc on trucks at Lyndhurst Siding	10 10 0
Price of second-grade talc on trucks at Lyndhurst Siding	7 10 0
Average price	£9 0 0
Plus rail freight, Lyndhurst to Adelaide	2 13 5
Value of talc on rail trucks, Adelaide	£11 13 5

Value, on trucks at Adelaide, of years production of 5,000 tons = £58,355.

(3) Estimated costs:

	£	s.	d.
(*a*) Rail freight, Lyndhurst to Quorn, per ton	1	2	10
Rail freight, Quorn to Adelaide, per ton	1	10	7
	£2	13	5

Total freight as percentage of total value—

$$= \frac{5{,}000 \times £2\ 13s.\ 5d.}{£58{,}355} \times 100\%$$

$$= \frac{£13{,}355}{£58{,}355} \times 100\%$$

$= 22{\cdot}8\%$ or £13,355 per annum.

Freight on S.A. Railways as percentage of total value—

$$= \frac{5{,}000 \times £1\ 10s.\ 7d.}{£58{,}355} \times 100\%$$

$$= \frac{£7{,}646}{£58{,}355} \times 100\%$$

$= 13{\cdot}1\%$ or £7,646 per annum.

(*b*) Number of men employed at the mine at present for production of 50 tons:

	men
Quarrying and camp	8
Talc dressing	5
	13

In addition there are 4 or 5 men engaged in carting the talc to the railway.

With the quarry opened up for production of 100 tons per week, and the dressing of the talc done, say, in Adelaide, total requirements would be—

	men
Cartage to railway	5
Quarrying and camp	10–12
	15–17

(*c*) Estimated costs at the mine based on present output:

	per ton £	s.	d.
Quarrying	1	10	0
Dressing	2	5	0
Cartage	3	0	0
	£6	15	0

(4) In the event of cheaper material becoming available from other sources, the mine is not likely to close down. In the first place, half the total production from this mine is covered by agreement respecting sale. In the second, cheaper material is available now in competition with the remainder. It is the quality of the talc that ensures its sale, and makes very remote the chance of stoppage due to competition with cheaper material.

(5) It should be mentioned here that, in accordance with the agreement referred to above, a crushing and grinding plant is at present being erected in Adelaide to prepare the talc for manufacturers. This plant will handle other materials besides talc. It is estimated that the 35-45 employees will spend roughly a third of their time on Mount Fitton talc. So that, in considering the employment attributable to the talc mine, an additional 12 men at least should be added to the mine total since the new crushing plant will do work which is now being done on this talc in Melbourne and Sydney.

(6) Further, the value of the milled product will be approximately £19 per ton *ex* Adelaide works, as against £11 13s. 5d. per ton unmilled on trucks Adelaide.

(7) The milling company, S. N. Rodda Pty. Ltd., advises that for the first two years after the plant commences operation, and possibly longer, 3,000 tons of milled talc per annum will be sent by rail, *via* Broken Hill, to Sydney. The 3,000 tons would not necessarily be from Mount Fitton.

(8) Freight charges on this material to Cockburn, on the New South Wales border, would amount to:

Adelaide to Cockburn, per ton	35s. 6d.
On 2,000 tons (estimated Mount Fitton talc) the total freight per annum would be	£3,550.

SUMMARY

1. The potential tonnage of talc in the deposit (500,000 tons), its excellent grade, and the guaranteed market for it make the exploitation of the deposit a very attractive one.

2. The present quarrying operations are limited, since the opening up of the deposit is not very far advanced. Attention should be paid to the necessity of working across the deposit until it is possible to turn the faces so as to work along the strike. The present face is on the dip of the talc because of the manner in which the deposit had to be opened up.

3. Hand sorting is being done in the quarry at the present time. It seems most likely that, whether the talc is dressed or beneficiated by mechanical means before the manufacture into goods, hand sorting will be necessary in the quarry to maintain the high standard required by manufacturers.

4. Experiments are now being made to see whether it is possible to improve the grade of run-of-mine or selected material by metallurgical means.

5. These experiments may have some bearing on the question whether the dressing or beneficiation of the talc should be done on the mine or at some other more convenient centre. The main point in favour of doing the work on the mine would be that all waste material would be eliminated and no freight would be payable on this excess waste material. However, since the amount of waste in selected grades of talc is very low the point is not very important.

6. Statistics (covering, say, the next five years):

Estimated output from mine—first- and second-grade talc	5,000 tons per annum
Value of talc on trucks Adelaide	£11 13s. 5d. per ton
Total value on trucks Adelaide	£58,355 per annum
Value of milled talc *ex* works Adelaide	£19 per ton
Total value of milled talc *ex* works Adelaide	£95,000 per annum
Total freight on 5,000 tons crude talc on S.A. Railways, Quorn to Adelaide	£7,646
Total freight on possible 2,000 tons milled talc S.A. Railways, Adelaide to Cockburn	£3,550
Men employed at mine:	
Mine 8	
Dressing 5	
Cartage 4	
17	
Men to be employed at grinding mill, Adelaide ..	12

7. Materials handling.

It is recommended:

(1) That a skip-and-dumper system be introduced into the quarry to enable the selected talc to be handled in grades quickly, efficiently, and without contamination.

(2) That a bin of 100 tons capacity be erected, having four 25-ton compartments for the storage of selected talc.

(3) That the transport system at present in use to get the talc to the railway be revised. In that country, for the output desired, six 10-ton trucks would be needed to ensure that there would be four available for carting all the time. (4/4/49.)

Chapter 4

BENEFICIATION OF TALC FROM MOUNT FITTON

BY

N. JACKSON, B.E., A.S.A.S.M. (METALLURGICAL ENGINEER)

INTRODUCTION

This report discusses the impurities in the Mount Fitton talc deposit (Flinders No. 5), and considers:

(1) The requirements of a sorting procedure to eliminate hand dressing.

(2) The possibility of mechanical beneficiation to increase the proportion of first-grade talc available.

SUMMARY

(1) Four types of impurities are noted, and a simple sorting procedure discussed.

(2) Assistance from mechanical beneficiation depends on the ability to separate chlorite from talc.

(3) The measurement of the whiteness of talc is discussed.

(4) Separation tests were attempted in a dry way, but without useful results, by—

(*a*) differential grinding,

(*b*) electrostatic separation,

(*c*) magnetic separation.

(5) Separation by wet grinding and flotation was more successful, but the product after wetting was not acceptable to the cosmetic industry.

GENERAL

The geology of the Mount Fitton talc deposit has been described by S. B. Dickinson,[1]* the mineralogy by F. L. Stillwell and A. B. Edwards,[2] and the mining by A. T. Armstrong.[3]

The talc is sorted into several grades, some of which are hand-dressed. After milling only two grades are marketed:

(*a*) first grade for cosmetics,

(*b*) second grade for industrial uses.

The value of the deposit would be increased if a greater proportion of the talc could be sold as first grade, or the expensive hand-dressing could be eliminated. Sorting and dressing, or mechanical beneficiation, would have to cost less than the price difference of £3 for each ton of extra first-grade material obtained. The nature of the sorting or beneficiation possible has been investigated by examination of the various impurities present in the ore. The characteristics required of the cleaned talc are discussed. Each of the impurities is then considered in the light of these requirements.

IMPURITIES PRESENT

Samples were taken at the mine which is operating on No. 5 deposit. Specimens of inclusions which can be selectively rejected in mining were not considered. In each sample a different impurity was emphasized. These are:

(*a*) iron oxide stain and red clay inclusions in the cleavage cracks,

(*b*) hard scale of lime-bearing material in the cleavage cracks,

(*c*) grey bands of chloritic material,

(*d*) pale-grey disseminated chlorite.

Analyses by the Departmental Analyst, T. W. Dalwood, are shown in table I. They are compared with clean talc from the No. 4 deposit.

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* *See* "References" listed at end of report.

TABLE I

Mount Fitton Talc Analysis

Sample	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	H_2O over 100°C.
Iron stain	56·14	4·34	0·30	0·52	32·30	0·08	6·56
Lime scale	57·76	2·96	0·21	0·52	31·10	1·04	5·69
Chloritic bands	51·58	8·38	0·21	0·68	31·34	0·06	7·53
Disseminated chlorite	53·36	5·88	0·50	0·48	32·78	0·06	7·26
No. 4 clean	62·16	0·61	0·13	0·45	32·06	—	4·51

REQUIREMENTS OF PRODUCT

The cleaned talc has to be suitable for a particular section of the cosmetic industry, which demands that the talc has to remain dry, as wetting of the talc affects the property of "slip". Also the particle size of the ground material has to be such that the platelet nature of the crystals is preserved. Extreme fineness in grinding is not allowable. The colour of the talc has to be better than a standard of whiteness set by the consumers. The acid solubility has to be lower than 2·5 per cent, to give a material whose perfume-fixing properties are suitable. The loss on ignition must be lower than 5 per cent.

DESCRIPTION OF IMPURITIES

Red Iron Stain

The talc which carries iron stains and red clay seems to be confined to a small portion of the surface of the deposit. Small quantities reduce the whiteness of the talc. The mined material is split with a hand-axe along the cleavage cracks, and all coloured material removed with a wire brush. If it is necessary to mine this portion of the deposit, the talc should be dumped in an isolated stock-pile, to be used as a market demands.

Lime Scale

The hard lime-scale which fills the cleavage cracks in some surface areas is the most important impurity at the moment. It should be present in surface material only, and will affect a smaller part of the product as development proceeds. The talc is split along the cleavages and scraped clean with a hand-axe, as the wire brushes are not very effective. If the talc is crushed dry the lime coating tends to flake away and accumulate in the fines.

Chloritic Bands

Irregular bands of chloritic material occur throughout the orebody, not necessarily in the direction of the cleavages. These bands are cut from the spalls with a hand-axe. They are harder than the talc, give the milled product an inferior slip, and reduce the whiteness. The material would be largely separated from the talc if reduced to minus 6-in. pieces. These can be readily sorted because of the colour difference.

Disseminated Chlorite

Pale-grey areas of talc are formed by dispersed chlorite. This material is generally sorted into second-grade talc, as it affects slip and colour as do the slaty chloritic bands, but to a lesser extent. The material shades from near white to the slaty bands. The proportion allowed into first-grade talc is decided from the milled product, which must be superior to a "minimum acceptance" standard supplied by the consumers.

SORTING AND DRESSING

The economics of the hand-dressing operations, and consideration of the place at which sorting should be done is discussed by A. T. Armstrong.[3] From consideration of the above impurities, and the requirements for cosmetic talc, the following is suggested:

(*a*) ironstained material to be left in place, or if mined, stacked in place,

(*b*) talc with lime scale to be coarse crushed and fines eliminated. At the moment this would probably apply to the whole production,

(*c*) chloritic bands and talc, with dispersed chlorite, to be sorted at the face, as second-grade talc.

MECHANICAL BENEFICIATION

To increase the proportion of talc available as first grade, it is necessary to find a method for separation of the chlorite and talc, as chlorite is the impurity which can be expected to persist throughout the orebody. The samples used for tests were those high in chloritic material, because, unless some success could be obtained with these, there was no point in testing a sample representative of the mine output. Samples containing iron and lime were generally subjected to the same tests. The methods investigated were:

(*a*) gravity separation,
(*b*) differential grinding,
(*c*) magnetic separation,
(*d*) electrostatic separation,
(*e*) flotation.

COLOUR OF MILLED TALC

It became evident, at the commencement of the test work, that complete chemical analyses would take an undue proportion of time. There seemed to be no one assay to give a lead to the percentage impurity except perhaps alumina (*see* table I), which takes almost as long as the complete analysis. The measurement of off-whiteness of the colour would give a measure of the usefulness of the talc. It was expected that if enough chloritic material was removed to give a suitable whiteness, then the other properties would also be satisfactory. In the case of lime, a simple acid extraction would suffice, as the lime included in the talc molecule could not be regarded as separable.

The question of how much grey material could be allowed in the first-grade talc has depended in the past on the standard set by the consumer. This has been checked by visual comparison. Some consideration has therefore been given to the measurement of colour. Ralph M. Evans[4] states:

> "Photoelectric measurements and the like are basically less precise than the equivalent measurement by a trained observer. This fact is so frequently overlooked when instruments are considered that some phases of the subject are becoming confused. Such instruments are convenient, rapid, repeatable, and economical if properly designed and operated. With rare exceptions, these are their chief recommendations, however, not higher precision. The fact that two instruments will give the same reading, whereas two observers may not, comes under the head of convenience, not precision."

Measurement of Colour

The variables in measuring colour, such as nature of light, position of light and object, and position and type of receptor, can be standardized for one instrument, so that results are repeatable. Further, if reflectance measurements are confined to one surface-type they become comparable. If the spectral reflectance curves have steep gradients they can only be plotted with a series of light rays restricted to a narrow region of wave lengths. These are obtained in a spectro-photometer using a quartz prism and selecting slit. When the reflectance curves are not steep, a cheaper instrument using filters which provide lights of somewhat wider bands of wave lengths may be used. This abridged type is suitable for comparison of percentage reflectance of surfaces similar in colour and texture.

If the colour of the talc is grey, because of a general lowering of reflectance—as is caused by chlorite—then total reflectance may be measured. It is desirable to correct the yellow light source and the characteristics of the receptor to give a result similar to that of daylight as source and the eye as receptor. A filter used for this purpose is called a "spectral response" filter. In the case of an impurity which mixes a colour with the white talc, the reflectance would be least, or the instrument most sensitive, if the filter used cut out light of the colour of the impurity. Thus iron oxide, giving a red colour, can best be measured with light from a filter which eliminates red from white light, and gives "minus-red" light. A reflectometer of the abridged type has been used in the following work because of its convenience in providing figures which can be logged for purposes of comparison and record. It is suitable because the surfaces measured are similar, and colours compared are of the same hue, but varying saturation. It must be remembered, however, that the instrument will not detect differences which are just perceptible to the eye.

Instruments Used

The instrument provided by Evans Electro Selenium Ltd. is built to a design approved by the Paint Research Station of Great Britain. It uses a low-intensity light with a series of filters in a search unit attached by necessary wires to a meter unit. The search unit is placed on a sample of talc powder, and diffused reflected light, received by a photo cell in the unit, is measured on the meter. Total reflectance is measured using the spectral response filter, and a block of magnesia as standard, to set the meter on 98 per cent reflectance. The search unit is then transferred to the sample of powder and the comparative reflectance noted. With the coloured filters the logarithmic scale on the meter is used, and the Mount Fitton No. 4 talc is used as a standard of whiteness. The figure of 10 is taken as an arbitrary standard, and when the search unit is transferred to the sample the increase or decrease in that particular part of the spectrum is noted.

Table II shows the percentage reflectance of the talc samples. All reflect more of the blue end of the spectrum than the standard. The iron-stained sample reflects comparatively more red and yellow.

TABLE II

REFLECTANCE MEASUREMENTS OF TALC SAMPLES

Sample	Spectral response	Minue blue	Minus red	Minus yellow	Minus green
Mount Fitton No. 4	per cent 95·5	10	10	10	10
Minimum acceptance	93·5	10·1	10·1	10·1	10·1
Iron stained	88·5	10·5	10·6	10·5	10·4
Lime scale	89·0	10·5	10·3	10·2	10·2
Chloritic brands	88·0	10·5	10·4	10·3	10·2
Disseminated chlorite	90·5	10·3	10·2	10·1	10·1

Variations of Particle Size

In using the reflectometer for comparisons it was assumed that the surface texture was the same. With a mixture of talc and chlorite at various sizes the appearance to the eye changed from a "pepper-and-salt" effect to one of uniform greyness as the size of the particles was reduced. The effect of this size-reduction on the reflectometer was noted. A Fisher sub-sieve sizer was used to give a nominal average particle diameter in each sample. It is realized that due to shape effects, etc., this figure is only useful for comparisons of the same material ground with similar size-distribution.

TABLE III

Reflectance with Variations in Size of Particles

Sample	Grind	Reflectance	Minus red	Fisher reading
	minutes	per cent		
Mount Fitton No. 4	—	95·5	10	3·1
Lime scale	½	88·5	10·4	5·7
	1	89·0	10·4	5·3
	3	89·5	10·3	4·5
	6	89·5	10·3	3·9
Chloritic bands	½	85·0	10·5	6·4
	1	86·5	10·5	5·2
	3	87·5	10·4	4·1
	6	88·5	10·3	3·4
	12	88·5	10·3	3·2
	24	87·0	10·4	2·9
Disseminated chlorite	½	87·0	10·5	5·5
	1	87·5	10·4	4·6
	3	88·0	10·4	4·0
	6	88·0	10·4	3·7

Table III indicates that a lower reflectance is obtained with coarse samples, but the effect is not recorded below a Fisher reading of approximately four. As the standard Mount Fitton No. 4 talc, as prepared for cosmetic use, has a Fisher reading of 3·1, this is satisfactory. The surfaces for comparison were prepared by smoothing level the powder in a petrie dish, with a flat glass plate. No differences with change in packing density were apparent with material ground to give a Fisher reading less than four. Grinding was done in a locally made ring-roller mill to be described later. The excessive grinding (24 min.) on the chloritic-band sample gave a distinct grey colour, probably due to abraded iron.

BENEFICIATION TESTS

Gravity Separation

Talc samples when powdered are difficult to wet. Specific gravity determinations were made on material minus 10 mesh and plus 48 mesh, Tyler screens.

The results shown in table IV indicate that no useful separation would be achieved in equipment available for gravity separation.

TABLE IV

SPECIFIC GRAVITY OF TALC SAMPLES

No.	Sample	Specific Gravity
1.	First white	2·68
2.	Chloritic bands	2·60
3.	Disseminated chlorite	2·66

Differential Grinding

The five samples obtained from the mine were crushed in a laboratory jaw-breaker, and then passed through laboratory rolls. Three of the products, as listed in table V, were sieved on screens to give four fractions, each of which was pulverized for reflectance measurements. The results indicate, in all cases, some segregation of impurities in the minus-200 portion. Apparently scaling effects are more important than specific hardness in determining the distribution. This would be expected with the clay and lime, but not with the chlorite.

TABLE V

PER CENT REFLECTANCE FROM ROLL PRODUCTS

Sample	Mesh	Weight	Reflectance	B	R	Y	G
		per cent	per cent				
Red stain	Plus 8	31·4	89	10·5	10·5	10·5	10·5
	8/28	44·6	91	10·3	10·4	10·4	10·3
	28/200	17·6	88·5	10·5	10·6	10·6	10·5
	Minus 200	6·4	87	10·5	10·7	10·7	10·6
Lime scale	Plus 8	25·6	90·5	10·3	10·3	10·3	10·3
	8/28	47·2	90·5	10·3	10·3	10·3	10·3
	28/200	17·6	90·5	10·3	10·5	10·3	10·3
	Minus 200	9·6	89	10·5	10·5	10·5	10·4
Chloritic bands	Plus 8	32·6	88·5	10·6	10·4	10·5	10·5
	8/28	43·2	87·5	10·6	10·5	10·5	10·5
	28/200	16·0	87·5	10·6	10·5	10·5	10·5
	Minus 200	8·2	86·5	10·1	10·6	10·7	10·6

In some talc mills silica is separated from talc by use of a "throw out" in the milling or pulverizing circuit. Some tests were made to see if the difference between specific hardness of impurities and talc would affect their grindability.

For fine grinding a small ring-roller mill, which can treat batches of 200-600 gm., was used. It consists of two rollers, 2¼in. in diameter, on horizontal swinging arms, attached to a vertical spindle rotated at 570 r.p.m. The rollers are confined by a hardened-steel ring 7½in. in diameter, and 2in. deep. The ring and rollers are enclosed in a vertical cylinder which has two 1½-in. openings at the top, for feeding the sample. Attached to the vertical spindle are two horizontal blades for throwing material from the base of the cylinder back against the grinding ring.

The mill can also be run in circuit with a standard laboratory Federal classifier. The fan of the classifier is used to carry the feed through the mill and into the settling-cones. The proportion of material caught in the coarse and fine settling-cones can be varied by adjusting the air flow in the circuit using a series of standard restrictions supplied with the classifier. After some scout tests the following plates were used:

Orifice at M = ¾in.
V = 1½in.
G = 1 3/16in.

The feed to the mill was obtained from the roll product of the previous test. A sample of 500 gm. was added over a period of 8 minutes. The products from the two cones are shown in table VI, with reflectance measurements and Fisher readings. The material from the small cone contains particles too large for good reflectance readings. However, even allowing for this factor, the fine product is definitely cleaner. Assays for acid soluble CaO in the talc with lime scale showed, fines 0·53 per cent, coarse product 0·87 per cent. The hardness of each impurity relative to talc apparently shows on fine grinding. The separation obtained is not enough to give a useful product.

TABLE VI

PER CENT REFLECTANCE FROM ROLLER-MILL PRODUCTS

Sample	Fisher reading	Weight	Reflectance	B	R	Y	G
Red stain	2·1	per cent 70·4	per cent 90·5	10·4	10·4	10·2	10·2
	5·5	29·6	87·5	10·5	10·7	10·6	10·5
Lime scale	2·0	31·0	91·0	10·4	10·3	10·1	10·2
	4·5	69·0	89·5	10·4	10·5	10·4	10·4
Chloritic bands	1·7	49·0	89·5	10·4	10·4	10·4	10·3
	4·7	51·0	87·5	10·5	10·6	10·5	10·5
Dissemin-ated chlorite	1·6	38·6	92·0	10·3	10·2	10·1	10·1
	3·6	61·4	89·0	10·5	10·5	10·2	10·4
Clean white talc	1·8	32·0	93·5	10·2	10·1	10·0	10·1
	3·4	68·0	92·5	10·2	10·4	10·2	10·2

Magnetic Separation

Tests made in the C.S.I.R.O. Ore-Dressing Laboratory, in Melbourne,(5) using a Rapid high-intensity separator on a sample containing approximately half clean talc and half chloritic bands, gave better separation than by gravity or differential hardness methods. The sample was sized and tests made on the 100/150-mesh and 28/150-mesh fractions gave the results shown in the first part of table VII.

TABLE VII

REFLECTANCE OF MAGNETIC SEPARATION PRODUCTS

Sample	Mesh	Product	Weight	Reflectance
			per cent	per cent
Chloritic bands (C.S.I.R.O.)	100/150	Magnetics	13·5	83·0
		Non-magnetics.........	86·5	89·0
	28/150	Magnetics	3·6	84·5
		Non-magnetics.........	96·4	88·0
Chloritic bands	10/28	Magnetics	0·4	81·5
		Non-magnetics.........	99·6	86·0
	28/150	Magnetics	2·0	83·0
		Non-magnetics.........	98·0	85·0
Disseminated chlorite .	10/28	Magnetics	0·7	83·0
		Non-magnetics.........	99·3	85·0
Iron stains	10/28	Magnetics	1·0	85·0
		Non-magnetics.........	99·0	86·0
	28/150	Magnetics	1·5	81·5
		Non-magnetics.........	98·5	86·0

These results were so encouraging that further tests were attempted on a similar Rapid separator, using an over-voltage supplied from a 2-amp. rectifier from the AC. line in series with the DC. line normally supplying the machine. The following loads were carried by the magnetic circuit:

Normal running from DC. mains	5·0 amp. cold, 4·5 amp. hot
Using 50 per cent overload	7·0 amp. cold, 6.2 amp. hot
Using 75 per cent overload	8·2. amp. cold, 6·8 amp. hot

The normal gravity feed, *via* a cone and orifice, was changed to a small Van Gelder vibrating feeder, which enabled very low feed rates to be used, and so allowed pole settings to be made for least possible air gap. The products were tested for reflectances, shown in the remainder of table VII. Results are similar to those obtained in Melbourne, but the proportion of material removed by the magnets is less. Particles of clay, but not grains of iron-stained talc, were removed from the last sample. Again, no useful separations were obtained.

Electrostatic Separation

Magnetic separation appeared to be limited in application because it could not be applied to lime scale. Talc carrying finely dispersed chlorite would require fine grinding—to liberate the chlorite—to a particle size much less than that normally handled by magnetic separators. Electrostatic methods, if they obtained a separation, could possibly be developed to treat powdered material by modification of equipment. The apparatus available at the C.S.I.R.O. Ore-Dressing Laboratory, in Melbourne, is designed to treat granular material. Tests were therefore confined to crushed and sized talc containing chloritic bands, of which the 28/150-mesh fraction was used.

Tests were first made on samples of talc and chlorite to investigate the individual properties. Talc and chlorite were found to have similar conductivities, but there was a slight difference in the contact potentials. The machine was set for what appeared to be optimum conditions, and the samples shown in table VIII were prepared. These were pulverized for reflectance measurements. A small measure of separation was achieved, but not enough to warrant further tests on pulverized talc.

TABLE VIII

REFLECTANCES FROM ELECTROSTATIC SEPARATION PRODUCTS

Sample	Mesh	Electrode	Product	Weight	Reflectance
				per cent	per cent
Synthetic chlorite and talc	48/100	Chrome plated	Tail	46	90·5
			Talc ...	54	92·0
Chloritic bands	28/150	Shielded shellac-coated	Tail	51	89·5
			Talc ...	49	91·0
		Chrome plated	Tail	36	89·0
			Talc ...	64	91·5

Flotation

Use has been made of flotation for separation of calcite, quartz, and tremolite from talc.[(6),(7)] Wet grinding can be used. If large tonnages were treated the decreased grinding costs would largely offset the extra cost of drying. However, from the point of view of the cosmetic industry, wetting and drying of talc destroys the important property of "slip", which characterizes the natural talc. It seems that the hydration of the talc molecule is altered—even with careful drying of the product—although complete dehydration is not obtained until the talc is fired. The slight change on normal drying is enough to alter the natural slip.

Even though flotation was not expected to assist in obtaining a product suitable for cosmetics, the effectiveness of this method of separation was tested, as the information might be of future use. Only a small amount of extra work was involved at this stage of the investigation.

Some preliminary tests were made in a 50-gm. test-cell to note the effect of several common frothers and collectors. The talc floated readily with any frother without collectors. The froth tended to be very sticky, making cleaning inefficient. Of the reagents tried, Dupont frother B22 gave the most suitable froth.

A series of simple batch-tests was then made using a laboratory sub-aeration cell. Each sample of 500 gm. was first ground in a pebble mill with 400 ml. of water for one hour, to give a product of 80 per cent minus 325 mesh Tyler. The pulp was placed in the cell at approximately 25 per cent solids. The talc was floated for 10 min., using two drops of Dupont frother B22. The natural pH in tap water was 7·6. The products were dried carefully, but had a greasy feel and more pearly lustre than usual when dry. The colour measurements as shown in table IX should not be compared with those of talc prepared in a dry way. In general appearance the floated talc was much whiter than the rejected tailing.

TABLE IX

REFLECTANCE OF FLOTATION PRODUCTS

Sample	Fraction	Weight	Fisher Number	Reflectance
		per cent		per cent
Iron stain	Concentrate	71·2	3·0	88
	Tailing	28·8	3·2	85
Lime coating	Concentrate	75·4	3·8	89
	Tailing	24·6	3·4	86
Chloritic bands	Concentrate	61·6	3·4	89
	Tailing	38·4	3·1	85
Disseminated chlorite..	Concentrate	71·8	3·1	90
	Tailing	28·2	3·1	87

DISCUSSION OF RESULTS

The following points were noted from the inspection of samples taken at the mine:

1. In the mining operation, major inclusions in the orebody are rejected when the talc is handled from the floor of the quarry.

2. This gives an opportunity for sorting of the talc at the quarry face, into several products, either for rejection or market.

3. Examination of the talc shows that iron stains and lime scale are probably associated with surface material, and will in future contaminate a smaller proportion of the mine output.

4. The lime scale tends to flake away from the talc with coarse crushing of the ore.

5. The chloritic material, likely to exist throughout the deposit, causes talc to be classed as second grade.

6. All tests to remove impurities from the talc, mechanically, gave some measure of beneficiation, but failed to produce a talc satisfactory to the cosmetic industry:

   (1) The densities of talc and chlorite are too close to allow gravity separation.

   (2) Crushing caused some segregation of impurities in the fines.

   (3) Fine grinding, followed by air classification, sorted minerals in accordance with hardness, and the finest fractions were cleanest.

   (4) Magnetic separation removed coarse clay, and a small proportion of highly chloritic material.

   (5) Electrostatic separation was not efficient as talc and chlorite have similar conductivities and only slightly different contact potentials.

   (6) Flotation gave fair results, though the method was not tested exhaustively, as talc, after wetting, was not acceptable to the cosmetic industry. It is possible that spray drying with controlled humidity would give a satisfactory powder.

RECOMMENDATIONS

1. All material should be rejected in mining, other than:
   a. Clean talc, first grade.
   b. Chloritic talc, second grade.
   c. Talc with lime coat, which can be improved by crushing and screening.

2. Rejected material should be stacked in an orderly manner:
   a. Non talc.
   b. Iron-stained talc.
   c. Other talc-bearing materials.

3. No mechanical beneficiation should be considered at present, except the temporary problem of lime scale. (11/8/49.)

References

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(6) U.S. Bureau of Mines *Report of Investigations,* 3397.
(7) *C.S.I.R. Ore-dressing Report* 152.

Chapter 5

PETROLOGY OF THE MOUNT FITTON TALC DEPOSITS

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(MINERAGRAPHIC INVESTIGATIONS OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH—REPORT No. 370)

INTRODUCTION

A petrological study of the talc deposits near Mount Fitton, at the northern end of the Flinders Range, was undertaken at the request of the Director of Mines, South Australia, as part of the programme of the Mineragraphic Section of the Council for Scientific and Industrial Research. Brief descriptions of the talc and associated rocks from this area have been given previously in *Mineragraphic Reports* Nos. 318 (1944) and 330 (1945). The observations that follow are based upon the examination of a suite of specimens collected during a visit to the talc deposits in company with the Director of Mines in conjunction with the specimens reported upon in *Mineragraphic Report* No. 330.

Talc deposits (Mineral Lease 2876, etc.) occur along the margin of a folded belt of dolomite marble. One group of deposits, south of Billy Springs on Moolawatana station, are located in zones of strongly sheared schistose dolomite marble that are parallel with the axes of minor anticlinal folds occurring along the gently dipping northern limb of a westerly pitching anticline. Other deposits (Mineral Leases 2892, 2889) on Mount Fitton station are known along the northern limit of a synclinal fold of the dolomite marble. These were not visited but specimens of the talc were obtained.

The dolomite marble is overlain to the west by a competent, dense black hornfels, devoid of cleavage or crumpling; and is underlain to the east by tillite. It is part of a folded sedimentary series which has been intruded by a granite which forms an extensive outcrop to the north-east. The black hornfels and the dolomite marble appear to be products of contact metamorphism, and the mineralizing solutions that converted the dolomite marble to talc are probably related to this granitic intrusion.

At the time of the visit two of the talc bodies south of Billy Springs were being quarried on a commercial scale, and several others had been opened by small excavations. A number of others remain to be developed.

THE PETROLOGY OF THE TALC DEPOSITS

The Talc

The talc occurs as irregular, strongly cleaved lenses generally elongate parallel to the vertical or nearly vertical cleavage, which in turn is parallel to the axis of the enclosing fold. In places it appears intercalated with bands of chlorite schist and of schistose dolomite marble, or it grades through the schistose rock into massive dolomite marble. Veins and bands of coarse-grained carbonate frequently traverse talc-dolomite rock and the schistose dolomite. At the No. 5 deposit a band of coarsely crystalline carbonate, in which the individual crystals are up to 6in. across, forms a prominent wall-like margin on the northern side of this talc-bearing zone.

The talc is massive and extremely fine-grained (figs. 1 and 2) and ranges in colour from snow-white to grey-white. Occasional bands are pinkish, and where it is contaminated with chlorite it is greenish. Pure-white talc predominates in the Nos. 1, 2, 3, and 4 deposits, as at present developed. Off-white to grey talc forms the bulk of the exposed talc in the No. 5 body. In places in the No. 4 deposit thin bands and wisps of chlorite suggest relic bedding planes, often severely crumpled. At the No. 1 deposit comparable banding or bedding can be recognized occasionally in hand specimens of relatively pure talc. Occasionally, as in the western cut in the No. 5 deposit, veins up to 1in. wide of coarsely crystalline talc, grown columnar fashion from the walls towards the centre of the vein, transect bodies of massive fine-grained talc.

CHEMICAL ANALYSIS OF TALC

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
SiO_2	62·16	59·06	58·46	60·52	58·74
Al_2O_3	0·61	1·81	1·97	1·56	2·73
Fe_2O_3	0·13	0·16	0·33	0·14	0·37
FeO	0·45	0·45	0·42	0·40	0·47
MgO	32·06	33·12	32·56	32·39	31·59
CaO	nil	nil	0·28	0·06	nil
Na_2O	nil	nil	0·18	0·01	0·05
K_2O	nil	nil	nil	nil	nil
H_2O at 100°C	0·11	0·10	0·01	0·11	0·02
H_2O over 100°C	4·51	5·17	5·36	5·17	5·72
TiO_2	0·02	0·21	0·30	0·10	0·15
P_2O_5	nil	0·08	n.d.	0·16	0·10
	100·05	100·16	99·87	100·62	99·94

1—No. 4 deposit, best quality snow-white talc. (Analyst, T. W. Dalwood).
2—No. 5 deposit, best quality off-white talc. (Analyst, T. W. Dalwood).
3—Talc, Mineral Lease 2892, near Mt. Fitton station. (Analyst, T. R. Frost).
4—Talc, Mineral Claim 986, near Mt. Fitton station. (Analyst, T. W. Dalwood).
5—Talc, Mineral Lease 2889, Leslie Bros. (Analyst, T. W. Dalwood).

The chemical analysis of the talc from the No. 4 deposit (No. 1) indicates a high degree of purity. Thin sections of this talc show that it consists of a felted mass of fine interlocking needles and plates of colourless talc, up to 0·15 mm. long, but frequently much smaller (fig. 1). The only other minerals observed are minute grains of apatite (fig. 2) and rutile which occur as grains 0·02 mm. or smaller, very sparsely distributed through the talc. The apatite grains which are distinguished from talc by their low birefringence and higher refractive index sometimes occur in clusters which may be as large as 0·15 mm. across. If the powdered talc is boiled with concentrated nitric acid, the resulting solution gives a chemical test for phosphorus with ammonium molybdate. The distribution of apatite in this talc appears to be variable as no phosphorus is reported in one analyzed sample.

The titania in the analyses is accounted for by the small particles and prisms of yellowish rutile, from 0·005 mm. to 0·01 mm. long, included in the talc. In the purest talc from the No. 4 deposit these inclusions are extremely few and minute and the titania content is only 0·02 per cent. The rutile grains are more numerous in the talc from the No. 5 deposit with 0·21 per cent TiO_2. The grains are not always evenly dispersed through the talc and in some specimens it is segregated along dark lines or bands. When sufficiently abundant it can produce a talc with a dirty grey colour.

The analyses reveal that the talc contains small amounts of alumina, ferric and ferrous iron. The discovery and examination of minnesotaite—an iron

Fig. 1

Fig. 2

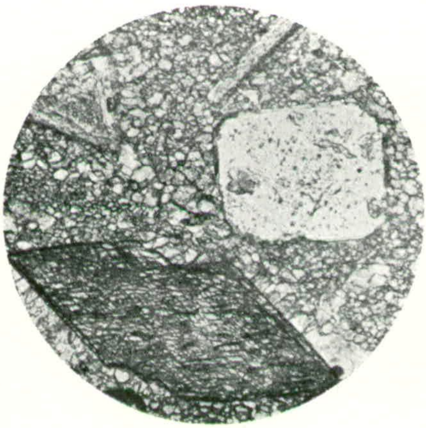

Fig. 3

Fig. 4

Fig. 1.—Typical talc showing fine-grained texture, No. 4 deposit (analyzed specimen)

Fig. 2.—Fine-grained talc with a crystal of apatite in best quality talc from No. 5 deposit (analyzed specimen)

Fig. 3.—Dolomite with plates of talc, a rectangular cross-section of scapolite, and a six-sided cross-section of tremolite with characteristic cleavage, near No. 4 deposit

Fig. 4.—Schistose talc-dolomite in a 5-ft. band between talc and coarse dolomite, south wall, No. 4 deposit

talc—by J. W. Gruner* has shown that ferrous iron can occur in large excess over magnesia in a mineral which is closely similar to talc in its molecular structure, and that small amounts of alumina and ferric iron in minnesotaite can replace silica. The universal presence of small amounts of alumina, ferric and ferrous iron, in all known analyses of talc indicates that similar departures can occur from the theoretical composition of talc, *i.e.*, that small amounts of ferrous iron can replace part of the magnesia and that small amounts of alumina and ferric iron can replace part of the silica.

In this case, analysis No. 1—talc from the No. 4 deposit—represents an exceptionally pure talc. The amount of alumina is much greater in analysis No. 2—from the No. 5 deposit—and the increase can be attributed to the presence of traces of chlorite which can be detected with the aid of a Berek compensator. The small amount of chlorite also lowers the silica content and increases the magnesia and water, relative to the pure talc of the No. 4 deposit.

Analyses Nos. 3, 4, and 5 are of material from the second group of talc deposits on Mount Fitton station. The talc is of similar quality to that which is being exploited near Billy Springs, except that the lower silica and higher water indicates stronger traces of chlorite which can be detected in thin section.

Chlorite and Bands of Chlorite Schist

The masses of white talc merge in part into talc with obvious impurities. The presence of chlorite in abundance in the talc bodies can be recognized by a greenish colour in the hand specimens. In places the white talc encloses intermittent wisps and thin bands of greenish talc, some of which have crumpled structure, suggestive of relict bedding. Two bands of dark-green chloritic talc about 6in. wide, extend for the exposed length of the No. 4 talc body, in its northern wall, intercalated with a brown band, about 12in. wide, of friable talc-dolomite rock. Such bands may possibly represent original sedimentary beds of different composition. A polished section of a chloritic band shows lenses of white talc about 1in. to 5in. long, arranged *en echelon* in the dark-green material.

In this section the chlorite, when abundant, can be readily detected by its low polarization colours (birefringence 0·007), as compared with the talc, and by its slightly higher refractive index. The chlorite is practically colourless and becomes difficult to recognize when sparsely distributed in the better quality talc. A ready distinction is afforded, however, by using a Berek compensator to determine the optical character of the principal zone which is positive for talc and negative for chlorite. By setting the principal zone, *i.e.*, the direction in which the fibres are elongated parallel to the slow direction of the compensator, all fibres or blades that blacken when the compensator is turned are chlorite, whereas all fibres or blades that darken when set at right angles to the slow direction of the compensator are talc. In this way it is possible to detect a distinct amount of extremely finely divided chlorite in the dark-grey talc from the No. 5 deposit, and in the greenish or off-white talc from the eastern end of this deposit. Even so, no chlorite has been detected in the best quality talc, such as the analyzed white talc from the No. 4 deposit.

One band of chlorite at the No. 4 deposit contains large numbers of minute crystals of rutile evenly dispersed through it. There is, however, a scarcity of this rutile in the second chloritic band which contains numerous rhombs of carbonate and a few crystals of apatite, 1 mm. to 2 mm. long, along the cleavage planes of the chlorite. This chlorite schist also contains a small nodule 1 cm. long with a rim of coarse apatite and a core of talc and apatite with numerous small crystals of rutile in both the rim and core. Sometimes the chlorite at the No. 5 deposit is so crowded with small rutiles that the chlorite patches within the talc assume a dirty greyish colour.

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* Gruner, J. W., *Amer. Min.* 29, pp. 363-372, "The Composition and Structure of Minnesotaite, a Common Iron Silicate in Iron Formations", 1944.

Carbonates

Selected samples of talc have shown that the acid-soluble material in the talc varies from 0·1 per cent to 0·3 per cent. This is due to traces of either carbonate or apatite. In some portions of the bodies the amount of carbonate is greater, and it occurs as occasional isolated rhomboidal crystals and as irregular grains up to 0·2 mm. across, but generally smaller, and less commonly as sparse coarse crystals up to 5 mm. across. There is a tendency for the amount of such carbonate to increase in the chloritic talc bands and in their vicinity.

At the east end of the No. 5 workings blebs and veinlets of carbonate occur in the talc. The carbonate sometimes occurs as the nuclei of tremolite "stars" in the talc.

Along the northern margin of the No. 5 deposit there is a belt of coarse dolomitic calcite, about 4ft. to 35ft. wide, with individual crystals up to 6in. across, marking the margin of the altered areas. It forms a distinct line of resistant rock across the country and can be followed along its strike for several hundred feet. Similar coarse dolomitic calcite occurs as irregular patches and veins of lesser dimensions, in the altered tremolitic dolomite east of the No. 4 deposit and in the vicinity of other talc outcrops. A chemical analysis of the dolomitic calcite from the northern margin of No. 5 workings gave 69·8 per cent $CaCO_3$, 27·2 per cent $MgCO_3$, and 2·3 per cent $FeCO_3$.

Pyrite

Pyrite appears generally absent from the talc, but in the talc at the eastern end of the No. 5 deposit, several bands of greenish talc are spotted with small crystals of pyrite, generally less than 2·0 mm. across. Much of the pyrite is weathered to limonite pseudomorphs, but occasional unaltered crystals remain. The talc in the immediate vicinity of the pyrite has crystallized into relatively coarse blades (as seen in thin section), and the later limonite tends to fill the interstices of the blades, forming a brown halo around the original pyrite crystal or residual cavity. Frequently crystals of carbonate are associated with the pyrite or the limonite pseudomorphs. In some specimens the pyrite cubes, with or without associated carbonate, form the nuclei of star-like radiate clusters of coarse tremolite crystals up to 5 cm. long.

Magnesian Clay

In the upper part of the No. 4 deposit there are seams of a white magnesium-rich clay mineral—probably attapulgite—in fractures and joints. These seams are only 2in. to 3in. wide and do not persist in depth. The clay substance is too intimately associated with residual talc to determine its composition.

Tremolite Rock

Large irregular bodies of massive tremolite rock occur in the vicinity of the talc bodies, sometimes near their margin, and sometimes tremolite is enclosed by talc. The tremolite rock passes outwards rapidly to schistose dolomite marble or apparently coarse granular dolomite with scattered prisms of tremolite.

The tremolite rock consists essentially of radiating clusters of blade-like crystals of tremolite, up to 1 cm. long, with interstitial talc, quartz, and carbonate, and occasional clusters of chlorite rosettes. The tremolite is colourless, optically positive with refractive indices from 1·615 to 1·645. It has perfect prismatic cleavages inclined to each other at about 55deg., and has an extinction angle up to 19deg. on the c-axis.

The interstices between the tremolite blades are commonly filled with quartz, individual quartz crystals being 1 mm. by 1 mm. In some sections the quartz predominates to the relative exclusion of carbonate and talc. In others, carbonate is much more abundant than the quartz. With increasing amounts of carbonate the rock passes abruptly into tremolitic dolomite. Frequently the quartz and tremolite are intimately intergrown. Tremolite blades end as ragged fringes and the needles and shreds are embedded in quartz. Talc, when present in the interstices, is commonly in the form of coarse plates, but it tends to make the rock friable. Much of this talc has a faint pink coloration in the hand specimen.

The chlorite occurs as clusters of colourless rosettes, with characteristic low polarization colours. Its refractive index is distinctly less than that of the tremolite.

One specimen was found consisting of rosettes of tremolite—about 2 cm. across—some of them enclosing a core of milky quartz, isolated in a base of coarsely crystalline quartz. A second consists of successive bands of radially grown tremolite, separated by a band of milky quartz, simulating crustified vein-growths.

Dolomite Marble

The host rock to the talc deposits is a white to grey dolomite marble, which in the vicinity of the talc deposits often contains tremolite and scapolite (fig. 3). No analysis is available, but qualitative tests on a number of specimens has proved the presence of abundant magnesium. In the immediate vicinity of the talc deposits it is converted to a schistose dolomite or talc-dolomite rock (fig. 4), the planes of schistosity being parallel to the prevailing cleavage direction in the talc.

The massive dolomite marble appears coarse-grained in the hand specimen with sparse to numerous crystals of tremolite and scapolite distributed through it. These can be distinguished from one another in the hand specimen if a cross-section of the crystal is visible. In thin section the scapolite is readily recognized by its square cross-sections, absence of cleavage, traces of alteration, straight extinction, and a uniaxial negative interference figure. The tremolite shows more or less diamond-shaped cross-sections with two cleavages at 55deg. parallel to the crystal outlines. Longitudinal sections are distinguished by the straight extinction of scapolite and the oblique extinction of tremolite. Both tremolite and scapolite are much coarser-grained than the enclosing dolomite which forms interlocking grains about 0·05 mm. to 0·1 mm. diameter.

Much of the dolomite marble contains grains of more or less rounded quartz, and are about 0·1 mm. diameter, presumably a constituent of the primary sediment.

Some bands of dolomite contain small flakes of mica which is pleochroic from colourless to pale-brown and, like biotite, is nearly uniaxial. This is presumably phlogopite.

Occasional crystals of apatite have been noted in the massive dolomites, but they are not abundant.

In the schistose dolomite the dolomite crystals are distinctly elongated parallel to the banding. One specimen contained coarse crystals of tremolite, over 1 cm. in length, parallel to the banding. Others have numerous small crystals of scapolite parallel to the direction of elongation of the dolomite crystals.

Specimens of schistose dolomite commonly contain a varying proportion of plates and needles of talc interleaved with the dolomite and scapolite crystals. The talc always shows pronounced elongation parallel to the prevailing planes of schistosity. The grain size of the dolomite crystals in these rocks tends to be much finer than in the massive dolomite.

Silicified Dolomite Rocks

The introduction of the siliceous solutions to form talc from dolomite has been accompanied or succeeded by considerable siliceous replacements of dolomite of varying character.

Associated with the schistose dolomite close to the south edge of the No. 5 talc deposit, where the road crosses the talc body, is an outcrop of hard siliceous rock containing a proportion of talc. The soft talc has been worn away, leaving a rough nodular surface. A thin section (20) reveals that the rock consists essentially of grains of quartz about 1 mm. to 2 mm. across, together with some talc and chlorite. The talc occurs partly as coarse patches, 1 mm. to 5 mm. across, in the interstices of the more or less pea-shaped bodies of quartz, and partly as myriads of fibres of talc shot through the individual quartz grains. In places the quartz has been fractured and the fractures are healed with veinlets of later quartz. The chlorite occurs in much the same way as the talc and, in addition, there are minute patches of a brownish material which may be iron oxide.

A bold outcrop immediately south of the road at the No. 5 talc deposit is generally similar, but the talc fibres and plates (13) occur only in irregular areas that include adjacent parts of several crystals of quartz, but not the whole of any given grain. Small residual particles of carbonate occur throughout enclosed in quartz.

In the hand specimen these silicified rocks show a granular texture that suggests the texture of the dolomite; and the intimate intergrowth of talc and quartz in thin section leaves little doubt that they are metasomatic rocks formed by the siliceous replacement of dolomites.

Other occurrences have the fine-grained character of jasperoids. An outcrop near the No. 5 deposit (10) is extremely fine-grained rock with minute needles of talc dispersed through finely crystalline quartz. It contains in places patches of coarser-grained quartz enclosing minute yellow to brown grains of rutile.

A small body of dark finely banded jasperoid was observed near the No. 4 deposit, apparently *in situ,* enclosed within a mass of tremolite rock. In thin section (4) it is seen to consist of quartz and carbonate, minute needles of talc, and an occasional blade of tremolite. Most of the quartz is speckled with minute dark specks which are probably rutile. The varying intensity of concentration of these dark specks is responsible for the banding of the jasperoid.

Another specimen from near the No. 4 deposit has the appearance of a grey slate and is related to the jasperoids on the one hand and to the altered dolomite on the other. In thin section (30) it is seen to consist of minute interlocking quartz grains, innumerable small prisms of rutile, and small fibres of talc. It contains strings parallel to the original bedding of relatively coarse grains of a bright yellowish-green mineral of high relief, which is probably vesuvianite. The crystals are short stout prisms with high refraction, though considerably lower than rutile, togther with weak double refraction and straight extinction. A weak pleochroism can be detected, and there are sometimes anomalies between crossed nicols in that different interference colours appear in different parts of the crystal. This identification, if correct, clearly links the rock with a recrystallized dolomite.

Several patches of grey to bluish quartz were exposed in the talc on the southern wall of the No. 4 deposit. The patches tend to be lens-like and the largest was about 3ft. across. The individual blebs of quartz are up to 2 cm. across. A thin section (22) shows that the quartz blebs consist of irregular grains 0·5 mm. to 1·0 mm. across, with interlocking crenulate margins. In places the coarse grains are replaced by mosaics of smaller grains. Many of the quartz grains are separated from one another by films or seams of talc in which the individual talc crystals are grown columnar to the bounding quartz grains. Some of the quartz grains have been shattered and the fractures are filled with veinlets of talc. The quartz grains are speckled with innumerable dust-like inclusions which tend to occur in parallel strings within a given grain. The orientation of these strings of inclusions varies with the grain. The silicification of the dolomites has its final expression in patches of quartz which has similarities to vein quartz.

Black Hornfels

Overlying the dolomite-marble is a dense finely bedded hornfels which is very tough, and rings when struck with a hammer, but is soft enough to be scratched with a hammer. The black hornfels shows prominent fine-grained relict bedding and includes bands of tillite, grit, and conglomerate in its basal beds.

Thin sections show that it is essentially a very fine-grained aggregate of biotite, quartz, and carbonate. The dark colour of the rock is due to the abundant biotite which is pleochroic in greenish-browns; the darker bands in the bedding are due to greater concentration of biotite within these bands. A notable amount of pyrrhotite is evenly dispersed through the rock, forming irregularly shaped grains which are associated with coarser crystal growths up to 0·2 mm. across. Plates of chlorite, zoisite, and grains of carbonate are sometimes enclosed by pyrrhotite. The zoisite is readily recognized in clear areas with a trace of cleavage, straight extinction, and very low polarization colours. In part the zoisite has a greenish cloudy appearance, with a trace of pleochroism and higher polarization colours, indicating a passage towards epidote. The pyrrhotite is also often associated with fringing granular areas, characterized by very high refractive index and high birefringence. Similar material also occurs in a lesser degree through the base of the rock. In rare instances such areas yield an uniaxial figure and then appear to be siderite, a carbonate with a much higher refractive index than the carbonate grains in the base of the rock, and presumably introduced at the same time as the pyrrhotite. In other cases sphene and less often epidote are probable components.

It is clear that the parent rock of this hornfels was an argillaceous rock and at the same time slightly calcareous. Its transition to ill-sorted conglomerate at its base, and the presence of tillites in the district, suggests that this hornfels may be a fluvio-glacial deposit associated with some tillite.

ORIGIN OF THE TALC

The metamorphosed character of the hornfels and the dolomite marble, coupled with the presence of granite in the vicinity, suggests that the talc deposits were formed by a localized metasomatic replacement of the dolomite marble succeeding the contact metamorphism of the area. The mineralizing solutions that led to the formation of the talc were presumably guided and localized in the highly cleaved belts or shear zones that cross the limbs of the main folds.

The reaction of the siliceous solutions with the dolomite has produced either tremolite where the lime is retained or talc under conditions when the lime was removed. In places early formed tremolite was subsequently replaced by talc. The accumulation of talc in relatively large bodies has been accompanied by the removal and exclusion of all impurities as well as the lime, and the purity of the talc body depends on the perfection of the process. The production of the schistose talc-dolomite on the margin of the talc bodies can be regarded as the stage in which the reactions involving the formation of talc have been incomplete.

In view of the general absence of alumina-bearing minerals it seems likely that the mineralizing solutions contained little or no alumina, and that the alumina in the chloritic bands adjacent to the talc is residual, being derived from impurities in the dolomite. The abundance of rutile in the chlorite bands supports this view since rutile has previously been shown to be a residual product of the alteration of biotite in the Gumeracha talc deposits.

No soda or potash was introduced with the siliceous solutions in view of the complete absence of these substances from the talc.

The final effect of the introduction of the siliceous solutions has been the replacement of the dolomite by quartz, the formation of the jasperoids, and the development of masses of quartz. Since the jasperoids represent silicified talc-dolomite rocks, the formation and deposition of talc must have been arrested before the development of the jasperoids and quartz. (5/9/47.)

PART IV

TUMBY BAY DISTRICT

Chapter 1

TUMBY BAY TALC DEPOSITS

BY

E. BROADHURST, M.Sc., B.M.E. (GEOLOGIST)

Situation:—Sections AN, AS, 28, *and* 46, *hundred of Yaranyacka, county of Flinders. Mineral Lease No.* 2676, *held by Minerals Pty. Ltd.* (*sub-leased to Tumby Bay Talc Co. N.L.*), *and Mineral Claims Nos.* 444 (*H. C. Beaty*), 522 (*C. J. Partington*), 639 (*A. F. Chambers*), *and* 726 (*Tumby Bay Talc Co. N.L.*). *The deposits are situated about* 8 *miles north of Tumby Bay, a shipping port on Eyre Peninsula, and about* 2½ *miles west of Lipson.*

PREVIOUS REPORTS

Review of Mining Operations 14, p. 42, 1911 (Matthews).

Review of Mining Operations 20, pp. 34-36, 1914 (Ward).

Review of Mining Operations 24, p. 63, 1916 (Jones).

Geol. Surv. of S. Aust. Bulletin 13, p. 40, 1928 (Jack).

Mining Review 78, p. 86, 1943 (Dickinson).

INTRODUCTION

The deposits are situated on the hills rising from the coastal plain at Tumby Bay. The relief is moderate. The main deposits are situated on hill-slopes which have an average grade of 1 in 7, and which become as steep as 1 in 4. The deposits are about half a mile from the main road, and an all-weather road, leading to them, has been made.

GENERAL GEOLOGY

The rocks in the district are of pre-Cambrian age, with a strike about N.30°E. and a steep dip to the east. Most of the rocks are mica schist. The talc deposits are associated with a bed of dolomite, which has an average width of 1,200ft. The dolomite has an irregular thickness of outcrop, and lenses out to the north. The shape of the outcrop suggests that it may be occupying the axis of a fold, but no direct evidence of folding could be obtained.

The beds could easily be overturned in such a steeply folded area, and the outcrops of dolomite have been converted largely to travertine. The steep dips are preserved in the travertine, but rarely are flat dips, and as a result any fold axes are difficult to find. Under these circumstances it is difficult to decide whether a structure is folded or not, but finally the opinion was formed that the structure was unfolded and that the lensing out was due to faulting or to an original structure.

The rocks have all undergone considerable alteration. At the south of the mapped area intense silicification has altered the rocks beyond recognition in the field. In the schist on either side of the dolomite, opposite the talc deposits, numerous pegmatitic veins occur. A zone of intense alteration occurs between the dolomite and the schist.

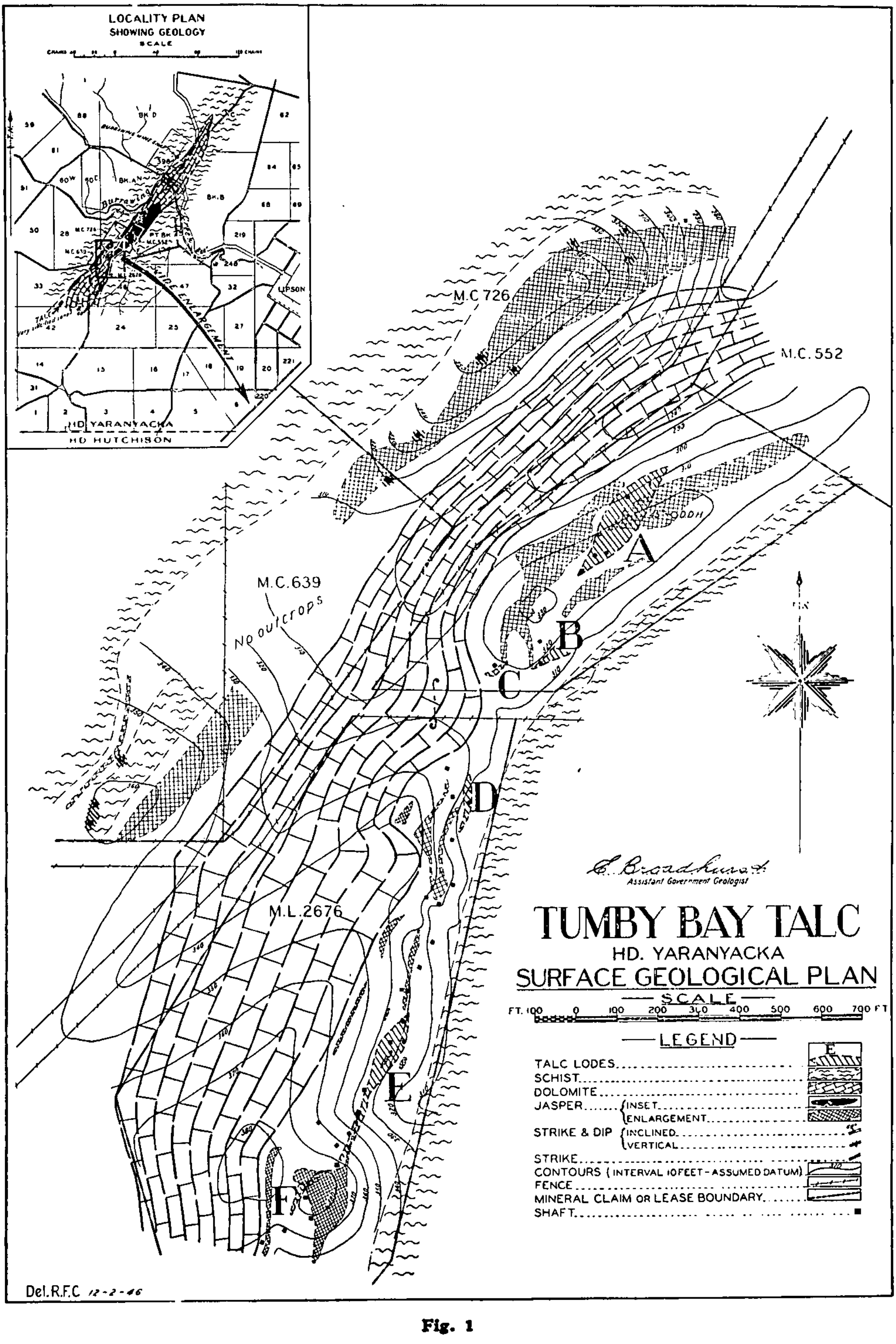
LOCALITY PLAN
SHOWING GEOLOGY
SCALE
HD YARANYACKA
HD HUTCHISON
UPSON
M.C 726
M.C. 552
M.C.639
No outcrops
M.L.2676
A
B
C
D
E
F
C. Broadhurst
Assistant Government Geologist
TUMBY BAY TALC
HD. YARANYACKA
SURFACE GEOLOGICAL PLAN
SCALE
FT. 100 0 100 200 300 400 500 600 700 FT
LEGEND
TALC LODES
SCHIST
DOLOMITE
JASPER { INSET / ENLARGEMENT
STRIKE & DIP { INCLINED / VERTICAL
STRIKE
CONTOURS (INTERVAL 10FEET - ASSUMED DATUM)
FENCE
MINERAL CLAIM OR LEASE BOUNDARY
SHAFT
Del.R.F.C 12-2-46

Fig. 1

Although it is usually associated with the dolomite, jasper also seems to be formed along lines of faulting in schist. Thus, on the western side of the dolomite bed on Mineral Claim 639, the jasper occurs in schist, although admittedly it is not far from the dolomite at this point.

The copper deposit worked in the Burrawing mine, 1½ miles NE. of the talc deposits, occurred in a vertical bedded fissure just to the west of the dolomite bed.

GEOLOGY OF THE TALC DEPOSITS

The talc is generally associated with a silicified zone between the schist and the dolomite. (Dr. F. L. Stillwell terms the rocks in this zone jasperoids, but in this report the field term of jasper will be retained.) This is not always the case, as in Mineral Claim 639 the talc is associated with jasper which occurs in schist. Although they are generally associated, the talc bodies do not seem to form any definite structural relation with the jasper bars. The jasper bars, although having fairly regular strikes, seem to form and reform in an indefinite manner. They show numerous signs of crumpling. At the south end of Mineral Lease 2676, the strike of the vertical bedding planes is very contorted, showing the effect of crumpling due to NE.-SW. (the general direction of the strike of the dolomite) pressure.

On the surface plan of the workings, no definite contact is shown between the jasper and the dolomite on one side and the schist on the other. This is partly due to lack of outcrops, but also due to the fact that a gradation exists between the jasper and the dolomite which occurs in the centre of the original bed. The process of silicification appears to have been concentrated in certain centres. There is a suggestion from the observed strikes that the centres of silicification may have been determined by horizontal crumpling, but the evidence is not definite enough to prove anything on this matter.

The talc lodes themselves seem more regular than the jasper bars. The lodes of talc are shown on the plan. Other lodes of impure talc also occur, but since they have not been worked their size and form have not been disclosed by mining. The talc lodes, shown by cross-hatching on the plan, represent the development of the purest bodies of talc. Even these have a large proportion of impurities, which will be discussed later. Some seams of almost pure talc—up to several feet wide—do occur, and these are the veins on which most of the mining has been carried out so far.

The talc in these deposits, unlike that in the Gumeracha and Mount Fitton deposits, is very fine and is only loosely coherent. When picked from a mine face for bagging it forms piles like soft flour. The lodes are traversed by numerous smooth joint-planes. Impurities consist of:

(*a*) *Earth Staining.*—This is a surface effect, apparently due to staining by vegetable matter from roots traversing the joint-planes. This earth staining persists to an average depth of about 20ft.

(*b*) *Jasper Bars.*—The jasper, as well as forming solid masses in the vicinity of the talc bodies, also occurs as bars in the talc bodies themselves. They are often 3ft. wide. Their attitude is usually steep, but their dip sometimes becomes as flat as 30deg. It is noticed that the best talc often occurs adjoining the jasper bars.

(*c*) *Rubble.*—This consists of talc with fragments of jasper scattered through it. The proportion of jasper fragments passes through various stages. Some rubble consists of a jasper bar which has been broken by minute fracture planes which have been filled with talc, giving a mass, consisting mainly of jasper, which can be broken up by the fingers. At the other end of the materials classed as rubble there is talc which contains too many jasper fragments to be economically hand-picked at the face.

(*d*) *Discoloration.*—This effect usually occurs in layers, often apparently parallel to the walls of the talc body. The materials forming the discoloration range from jasper bars to soft chloritic or clay layers. Usually an increase in the amount of discoloration is a sign that the extremity of the talc body is being approached.

Another form of discoloration is red staining, which consists of uniform ferric iron staining throughout the talc. It is associated with red jasper. Many of the talc bodies are reported to have passed into red stained material in winzes below the main workings. The red staining is not a surface effect, although it is probably due to oxidation.

Other impurities consist of various minerals throughout the talc, usually all grouped under the term "discoloration." One mineral—which Stillwell determined as sepiolite—resembles dolomite, and is termed such on the field, and occurs in masses up to a foot in largest dimension.

PRESENT WORKINGS

At present, prospecting is carried out by selecting spaces between the jasper bars on the surface. These are tested by vertical auger-holes, and, if the material appears suitable, shafts are sunk.

Most mining is being done at present from old shafts; the material mined being that which was formerly left as pillars or which did not previously appear to be of suitable quality. The workings are very tortuous, and in traversing them headway can often only be made on hands and knees. As a result, only seams of good talc are followed, and it is uneconomical to mine material where a large proportion must be rejected. It is even more difficult to put a prospecting drive through a wall of unsuitable material in search of further talc. There has been no attempt to fill the stopes and continue working overhead. All the working has been downwards, and with the bad walls this practice has become too dangerous to continue for very long.

Under these circumstances the future supply is very limited. Only a very good orebody could stand such treatment and still give a good output.

ORE DEPOSITS

The difficulties of estimating the amount of talc which can be obtained from the orebodies are numerous. The mapping of the outline of the bodies in plan presents considerable difficulties owing to the tortuous nature of the workings both in a horizontal and vertical direction. Another difficulty in mapping is due to the fact that often only the talc between two smooth walls, say, 4ft. apart, in the talc body was removed, owing to the difficulty of working a larger stope. In such a case the thickness of the lode might be estimated by projecting the limits of the talc body from points where it has been observed. In all cases the mapping of the lodes was difficult, and often a large amount of conjecture was used. Some of the shafts were inaccessible. However, the plan which has been prepared is intended to be the best interpretation of the data available. Since most of the shafts opened out at about a depth of 30ft., owing to the presence of earth staining above that level, the mapping was done on a plane about 30ft. below the surface.

The dip of the lodes could not be definitely determined owing to the imperfect exposures. The orebody "A" appears to dip to the east at 45deg., and the others seem to have an easterly dip.

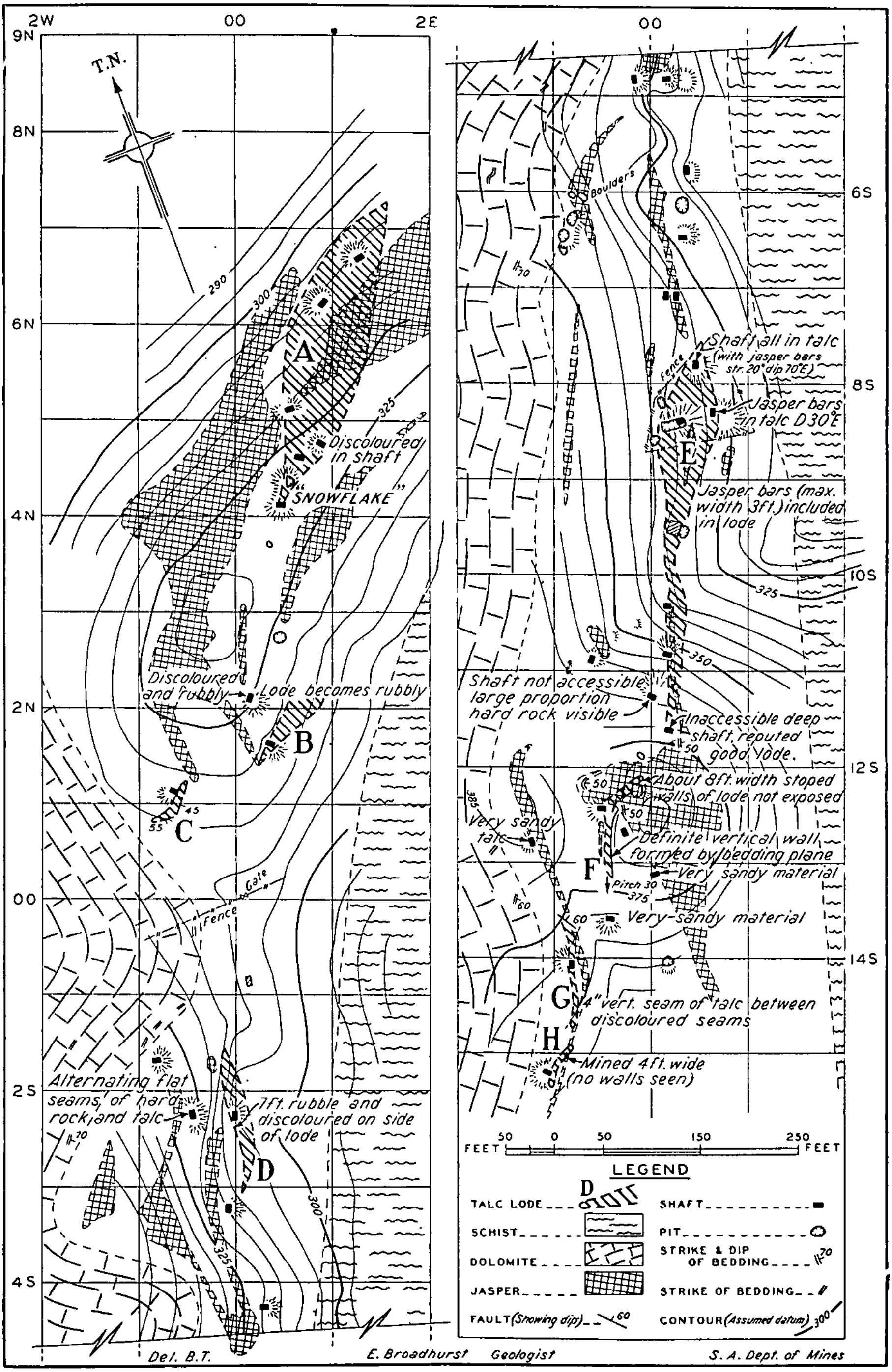

Fig. 2.—Plan of Tumby Bay talc deposits, showing geology

The talc bodies, as shown on the plan, do not consist entirely of talc, but contain impurities such as jasper bars, rubble, and patches of discoloration. Of these impurities the jasper bars and the discoloration would be left in place as pillars. Portion of the rubble could be treated to remove the impurities from the talc if it is found economical to do so, and experiments are being carried out at the Bonython Laboratory to investigate the methods by which this separation can be carried out. On the absence of any sections through the lodes only a rough estimate of the various proportions of the impurities can be arrived at. This estimate is that the amount of talc that can be hand-picked and bagged in the stopes, the amount of rubbly material that can be treated to recover the talc, and the amount of waste that will be left behind in the stopes as pillars or filling are in equal proportions, each one-third of the total.

The extension of the talc bodies in depth is uncertain. Where winzes have been sunk below the present workings, it has often been reported that the lodes passed into red discoloration. This may be an effect of the deeper zone of oxidation; but again it may be due to a primary structural characteristic of the orebodies. No definite prognostication of the behaviour of the lode in depth can be made, and it is only by development that this can be ascertained.

All the lodes of known dimensions are on the eastern belt of lodes. Some lodes have been opened up on the western belt; but, except for the lode near the boundary between Mineral Claims 726 and 639, they are small and do not seem to persist.

The lodes on the eastern belt are given in the following table:

Lode	Area, sq. ft.	Tons per vertical ft.
A	17,480	1,247
B	992	71
C	384	28
D	1,952	140
E	9,838	702
F	880	63
G	624	44
H	240	17

Assuming that only one-third of these quantities is recoverable, and that the other two-thirds are to be left behind in the stopes as filling, the amounts recoverable from the lodes are as follows:

Lode	Tons
A	418
B	24
C	9
D	47
E	234
F	21
G	15
H	6

These figures neglect the strong possibility that an economical process will be found to treat the rubbly material and recover most of the talc in it.

MINING

Near the surface much of the talc has been left in place, due to the presence of earth staining. It is possible that there would be a market for this talc if it were produced cheaply enough. The earth staining is due to vegetable matter which would probably disappear on ignition, and thus the talc would be suitable for ceramic uses. The open-cut method of mining would have the big advantage of cheapness, and it is the only practicable way of cleaning up the old workings.

In the old workings much good talc has been left as pillars, and probably some new seams of good talc would be uncovered. The rubbly material which had previously been left could be removed and treated also. The disadvantages of open-cut mining are found largely in the nature of the wall rock. For instance, in orebody "A", the lode probably dips at 45deg. E. under a hanging wall of hard jasper, which is very hard and would be expensive to remove. In some cases, as in the orebody "E", this jasper hanging wall apparently does not occur, but then the wall would probably be broken and jointed and a batter of 45deg. would have to be maintained. The choice of open-cut mining depends largely on the demand for the talc obtained near the surface. If this can be sold, then some open-cut mining could be carried out. However, considering the nature of the walls, it is probable that it could not be carried to a depth of more than 40ft.

The talc lodes are apparently suited to flat-backed stoping with filling and temporary support by timber bulks. The large proportion of waste in the lode could be either left in place as pillars or broken and put under foot for filling. If any extra waste were required for filling the spoil from the open-cut workings might be used, so that the two could be used together advantageously. When the orebodies are opened up systematically it may be found necessary to use other methods of mining; but on present indications the method described above seems to be the best.

DEVELOPMENT

In proposing any development, it must be remembered that the primary object of development at this stage is to investigate the behaviour of the lode at depth and to prove tonnages of ore. Further development will have to be carried out before stoping operations can begin. However, the prospecting development will serve as a necessary part of the stoping development. If the nature of the talc continues to be satisfactory at depth, most of the development work would be carried out in talc and it would be a less expensive way of obtaining the talc than the present method of mining.

Since practically nothing is known of the behaviour of the lodes at depth, it would be preferable to start on the big orebodies since a greater tonnage of talc can be proved from them. The biggest orebodies are "A" and "E", and of these it would be preferable to concentrate on "A", the bigger of the two.

Development would consist of sinking a shaft to about 100ft. below the present workings. The shaft from which present work is being being carried out (co-ordinates 6·22N-0·90E) could be enlarged, and sinking continued to a depth of 140ft. Sinking would probably be done on the underlie on veins of suitable talc, which underlie to the east. At the bottom of the shaft cross-cuts would be put out to the limits of the orebody. The best veins of talc encountered in the cross-cuts would be selected and drives extended both ways along these veins, which would be along the length of the orebody. At 100-ft. intervals along the drive other cross-cuts would be put across the body, and in this way the size of the body could be determined.

If the orebody maintains the same size as that where it is worked near the surface, the amount of development would be as follows:

Sinking	100ft.
Cross-cutting	200ft.
Driving	300ft.

CONCLUSIONS

1. The ore which can be obtained from the present system of mining is becoming very limited, and more and more costly to raise.

2. Some open-cut mining may be carried out on the surface, depending on whether a market can be found for the earth-stained talc.

3. The large size of the talc orebodies warrants a development programme to prospect and prove the amount of talc which can be obtained. It is realized that a large proportion of these bodies are inclusions of mullock or are unsuitable for bagging; but even if one-third of the lode is payable talc the rest could be used for filling the stopes, and thus the cost of mining would not be increased. The cost of stoping should be about £1 per ton.

4. The suggested development is to test orebody "A" at a depth of 100ft. below the present workings. The mapping indicates that, with only one-third of the talc recoverable, this lode would give about 400 tons of talc per vertical foot. The development is designed to give definite evidence of the capacity of the orebody.

5. To satisfactorily carry out this purpose, a total of 600ft. of development is considered probable. (18/1/46.)

Chapter 2

PETROLOGY OF THE TUMBY BAY TALC DEPOSITS

BY

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(MINERAGRAPHIC INVESTIGATIONS OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH—REPORT No. 336)

INTRODUCTION

The following observations on the petrology of the talc deposits of Tumby Bay are based on the study of a collection of specimens gathered during a brief visit to the deposits at an early stage of their mapping, supplemented by some additional specimens supplied by E. Broadhurst.

As indicated by Broadhurst, in his report on the talc deposits, the talc occurs in elongated lens-like bodies in two zones of altered rocks on either side of a belt of dolomite, about 1,200ft. wide, the altered zones being flanked by dolomite on one side and mica schists on the other. The production of talc has as yet been limited to the eastern zone (*see* fig. 1).

PETROLOGY OF THE TALC DEPOSITS

The Dolomite

A specimen (No. 23) of the dolomite taken from the vicinity of the Burrawing copper mine—about 1½ miles north of the talc deposits—is a crystalline rock consisting of interlocking, equidimensional grains of dolomite, averaging between 0·25 mm. and 0·5 mm. across. The texture is comparable with that of a fine-grained marble. In addition to the carbonate, a small amount of colourless tremolite is present and tends to occur as strings of small irregular grains in the grain boundaries of the carbonate, and as occasional prismatic grains up to 1 mm. long, intergrown sieve-fashion with the carbonate.

The dolomite (Nos. 21 and 22) adjacent to the talc deposits is generally similar in mineral composition, but differs markedly in texture. It shows a pronounced mortar texture, with isolated equidimensional grains of dolomite, 0·25 mm. to 0·5 mm. across—which show crenulate edges—distributed through a matrix in which the carbonate grains are 0·01 mm. to 0·05 mm. across. This establishes the fact that this section of the dolomite has been subjected to strong shearing.

Tremolite is practically absent from some sections, but in others it is locally abundant, in bands and elongated clusters or sheaves of crystals. These bands are probably elongated parallel to original bedding planes. In addition to the tremolite, some sections contain plates of a colourless mineral that is identified as talc. It occurs generally as tabular crystals with high birefringence, a good cleavage parallel to the length of the crystals, and straight extinction. An occasional grain gives an optically negative biaxial figure with 2V about 10°, which distinguishes the mineral from muscovite.

Mica Schists

The mica schists are lustrous, moderately coarse-grained, highly schistose rocks. They are characterized by an abundance of biotite and muscovite—sometimes intergrown—and the micaceous laminae alternate with laminae of granular, interlocking quartz and felspar. The amount of felspar relative to quartz varies in different specimens. Most of the felspar is untwinned, though lamellar twinning occasionally appears. Untwinned grains have a refractive index close to 1·535, indicating albite.

Some of the schistose layers contain coarse lenticular bundles of sillimanite which pass at their margins or along their length into isolated needles of sillimanite embedded in quartz or muscovite. Small pink garnets, up to 0·5 mm.

across, occur at intervals along the micaceous bands. Small crystals of greenish-brown tourmaline, sometimes with bluish cores, are unevenly distributed, and occur along some of the micaceous laminae. The ragged relic appearance of the sillimanite areas suggests that much of the muscovite has been derived from sillimanite in the final alteration accompanying the introduction of the tourmaline.

One specimen (No. 5) from the marginal zone represents, however, an altered mica schist in which the mica appears to be partly replaced by talc. This specimen is a finely bedded greenish-grey rock with segregations and lenses of fine-grained secondary quartz along the bedding planes. It consists of bands of interlocking quartz grains associated with traces of clear felspar, interleaved with narrow, irregular bands of fine-grained talc or mica with occasional plates of relatively coarse talc. Some of these bands consist largely of chlorite, but small flakes of chlorite appear through the rock as well. Many of these flakes of chlorite are associated with opaque particles of leucoxene which are buff-coloured in reflected light and are sometimes segregated along the cleavage planes of the mica. They appear to represent titania, which has been discharged in the alteration of biotite to chlorite. Strings and clots of brownish tourmaline crystals lie more or less parallel to the bedding in parts of the section which is transected by a series of more or less parallel fractures oblique to the bedding.

Rocks in the Zone of Alteration

Between the dolomite and the schists is a zone of intense alteration containing irregular bodies of highly siliceous rocks, which can be called jasperoids, and masses of talc. In addition, there are residual masses of sedimentary quartz schist, quartz-talc schist, and talc schist, which show gradation on the one hand to talc deposits, and on the other to jasperoids in which the banding of the schists is preserved in some degree. No complete section across this altered zone is available—either as outcrops or in the mine workings—and it is not possible to determine whether these zones of altered rocks originally consisted solely of schists or of included beds or lenses of dolomite intercalated with the schist.

The Talc Bodies

The talc in the several deposits is snow-white, and fine-grained; the individual crystals ranging from needles a few microns thick and 10 microns to 20 microns long to small plates 0·1 mm. across. Much of the talc is loosely coherent, and powders, on handling, to an impalpable dust. The refractive indices are α 1·540, γ 1·590, and platy crystals are optically negative with 2V about 5° to 10°.

ANALYSIS OF TUMBY BAY TALC

Analysis No.	A	1	2
SiO_2	63·50	61·26	61·08
Al_2O_3	—	1·76	3·11
Fe_2O_3	—	0·33 }	0·55
FeO	—	0·04 }	
CaO	—	nil	0·12
MgO	31·70	30·53	28·42
Na_2O	—	0·17	0·02
K_2O	—	0·10	0·10
Cl	—	0·30	0·01
H_2O over 100°C	4·80	4·90	5·55
H_2O at 100°C	—	0·22	0·73
	100·00	99·61	99·69

A—Theoretical composition of talc.
1—Sample face of drive, 38-ft. level, Tumby Bay talc mine, Mineral Lease 2676, section 46, hundred of Yaranyacka. (W. S. Chapman, analyst). *Mining Review* 78, p. 87, 1943.
2—First-grade talc from new prospecting shaft. Mineral Claim 498, section AN, hundred of Yaranyacka. (T. W. Dalwood, analyst). *Mining Review* 78, p. 87, 1943.

Analysis No. 1 (from the Tumby Bay talc mine) indicates a talc of high quality. A sample of similar talc from the Snowflake workings shows an excellent "slip" and leaves no grit or clayey residue when rubbed between the fingers.

Analysis No. 2 (from Mineral Claim 498) is less pure, and the higher percentage of alumina indicates the presence of small amounts of either a chloritic mineral or a clay. A sample of talc from the new shaft at the southern end of the ridge leaves small pellets of a tough, clay-like mineral, when it is rubbed between the fingers, and occasional grains of quartz. A small sample of the residual material gives a strong qualitative test for alumina after fusion with sodium carbonate. Its refractive index appears to be above 1·555, and it is stained by methylene blue but shows no evidence of base exchange after treatment with acid. The clay thus appears to be a kaolin rather than a montmorillonite.

Nodules and bands of a similar white clay also occur in the Snowflake workings. These also yield a copious precipitate of alumina after fusion with sodium carbonate, and staining tests with methylene blue suggest that the clay is a kaolin.

In parts of the workings, both in the Snowflake section and more particularly in the southern workings, narrow blue or yellow bandings can be traced on the margin of the talc bodies. This banding outlines the crumpled bedding or planes of schistosity of the rock that has been replaced by the talc (*see* fig. 2). The prevailing dip of the blue bands corresponds with the dip of the talc lodes and of the wall rocks, in which there is a marked but gradational increase in the clay content relative to talc. The blue bands, under the microscope, are seen to consist of numerous fine, opaque particles—0·01 mm. to 0·005 mm. across—dispersed through talc which, as far as they can be identified, appear to be particles of hematite.

The chief other impurities are nodules of white sepiolite and chert-like silica or jasperoid which is sometimes black and sometimes white. The sepiolite nodules are up to 6in. long, while the silica nodules are often larger. In places, the walls of a talc body consist of brecciated jasperoid or "gravel" embedded in talc. It appears as if a band of jasperoid has been shattered and the fractures filled with talc. The relative proportions of talc and jasperoid in these shatter zones is very variable.

Sometimes the coarser jasperoid "boulders" are surrounded by irregular lumps of limonite or limonitic clay, from an inch to a foot across. These bodies are usually lens-like, with their long axes more or less parallel to the strike of the talc seam, and they dip at about 70deg. E. The abundant limonite suggests the possible previous presence of pyrite, of which traces have been found in the sepiolite and jasperoid.

Clays

In addition to the clay which sometimes occurs in the talc, there are occasional exposures of clay bands in the walls of the talc bodies. Much of this clay is cream or pale buff; but at one point in the Snowflake shaft there is a large block of variegated yellow, pink, and brown clay, showing liesegang rings and similar staining textures. Its clayey character is established by a copious precipitate of alumina obtained from it after fusion with sodium carbonate. The clay appears to have a refractive index higher than 1·555, indicating that it is probably a kaolin, and this is supported by staining tests with methylene blue.

Sepiolite

Associated with the talc in the Snowflake workings are nodules—up to 6in. long and several inches thick—of a white magnesian silicate mineral closely allied to sepiolite and to talc. In the hand specimen the mineral is creamy white, and appears granular and homogeneous. It is distinctly harder than talc, but is readily scratched with a needle, and is brittle. Determinations of the specific gravity of several fragments vary between 2·27 and 2·35. In thin section (No. 7) the mineral appears less homogeneous. Three components can be distinguished. Cloudy fibrous areas, often with a more or less stout prismatic outline, form the bulk of the material. Numerous, small, clear prisms and plates are distributed through the wider, cloudy areas. The third component is a minor one and consists of interstitial areas or plates of an isotropic substance.

The cloudy component shows strong absorption and parallel extinction and has a comparatively low birefringence. The clear prisms show brighter polarization colours than the cloudy material, and also have straight extinction. The clear component is sometimes intimately intergrown with the cloudy component, and in places they seem to merge into one another, indicating that they may be different phases of the same substance. This is also indicated by the following determinations of the refractive indices by the immersion method.

Cloudy component—between 1·510 and 1·520, possibly less than 1·515.
Clear component—between 1·510 and 1·520, close to 1·515.
Isotropic component—between 1·520 and 1·530.

An analysis of a selected sample of the substance (made by T. W. Dalwood) is as follows, and corresponds approximately to the formula $2MgO.4SiO_2.H_2O$.

SiO_2	71·08
Al_2O_3	0·62
Fe_2O_3	0·24
FeO	0·09
MgO	22·14
CaO	0·14
Na_2O	0·22
K_2O	nil
H_2O over 100°C.	5·12
H_2O at 100°C.	0·99
TiO_2	nil
P_2O_5	tr
	100·64

There appears to be no recorded magnesian silicate of this composition; though some sepiolites, especially the dehydrated sepiolite II (Longchambon, 1935)* approaches it, with a SiO_2/MgO ratio of 1:8. It would, however, conform to the hypothetical $<$-sepiolite $3MgO.6SiO_2.nH_2O$ proposed by Efremov (1939)† as a probable end member of the sepiolite group.

The apparent lack of homogeneity finds a counterpart in many sepiolites, which consist of a mixture of an α form consisting of orthorhombic or monoclinic fibres, and a β form, which is isotropic and amorphous. The refractive indices of the components in the Tumby Bay material are of the correct order for comparison with these substances.

Since the data as yet to hand do not warrant the erection of a new mineral species, the mineral is tentatively regarded as sepiolite, or possibly as a dehydrated form of it, largely freed from zeolitic water, possibly as a result of the conditions attending its formation in a shear zone.

Some of the sepiolite (No. 6) encloses fragments of black quartz, resembling "gravel" in the talc. The quartz occurs as clusters of crenulate, interlocking grains, 0·2 mm. to 0·5 mm. across, and shows strain polarization. At the margin of the clots, the quartz tends to be finely intergrown with the isotropic component of the sepiolite.

* Longchambon, H., *Comptes Rendus Acad. Sci. Paris*, 200, 947-949, 1331-1333, 1935.
† Efremov, N. E., "On the Classification of Some Magnesial Silicates and Their Alumo-analogues", *Comptes Rendus (Doklady) de l'Acad. Sci. de l'URSS* 24, No. 3, 287-289, 1939.

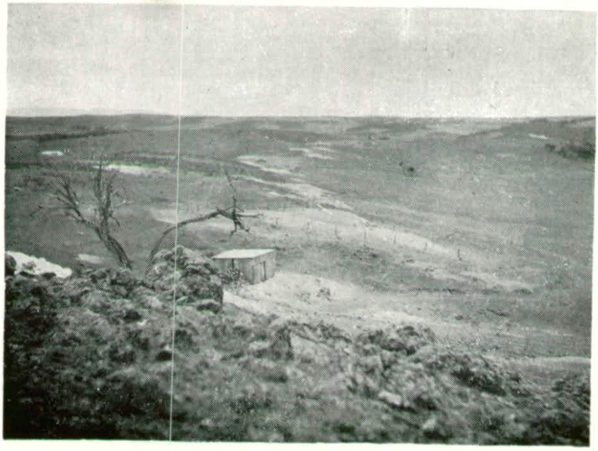

Fig. 1.—Tumby Bay talc deposits—Line of talc workings

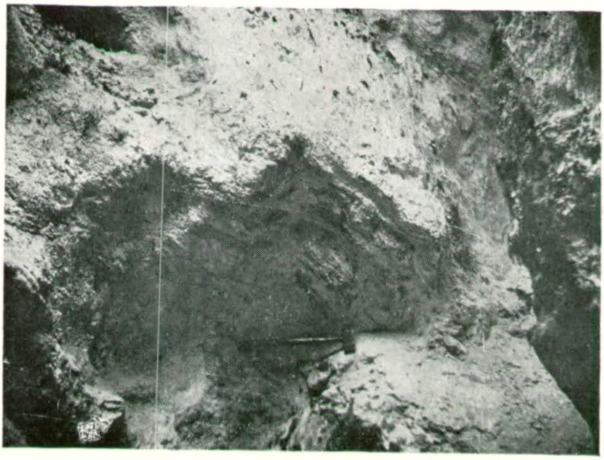

Fig. 2.—Tumby Bay talc deposits—Crumpling in schists which are largely replaced by talc

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The sepiolite also contains brown-stained patches, which extend outwards from central opaque areas, with a tendency to rectangular shape, suggesting the form of pyrite crystals.

Quartz Schists, Quartz-Talc Schists, and Talc Schists

Some of the rocks in the zone—as at the compressor site—are finely banded, pale-grey to brownish schistose rocks, which in thin sections are seen to consist essentially of quartz, talc, and minor amounts of chlorite, leucoxene, and tourmaline. The proportion of quartz to talc varies considerably from specimen to specimen. In one case (No. 2) augen of felspar, up to 2·0 mm. long, occur along the schistose planes.

The quartz occurs in small elongated grains, all with their long axes parallel to the banding, and are sometimes embedded in talc flakes which are similarly oriented. Refractive index measurements and optic axial angles distinguish the talc from muscovite. Occasional lenticles of chlorite are present, elongated parallel to the banding, and associated with numerous particles of opaque leucoxene. The rock is speckled with sparse, minute, brown tourmaline, and very occasional particles of pyrite, magnetite, or limonite.

As the proportion of talc increases, the quartz grains become smaller (0·2 by 0·05), and become isolated or interleaved with the talc. Chlorite disappears and strings and patches of leucoxene occur, chiefly with quartz, between the flakes of talc. Tourmaline prisms (0·1 mm.) tend to lie parallel to the banding. In one section (No. 26), the banding is crumpled—which gives the section the appearance of watered silk—and in this the quartz and talc flakes follow round the fold in the crumples, curving with them. The banding is crossed by zones of shearing oblique to the banding and related to the crumples.

Jasperoids

The term "jasperiods" is used in the sense defined by Holmes* for fine-grained quartz aggregate or chalcedony derived by the replacement of calcareous rocks.

The jasperoid rocks present a variety of types, all generally similar in that they are the product of silicification of pre-existing rocks in the zone of alteration. There is, however, no apparent sequence in the distribution of the various types, all of which are closely associated with the talc deposits. These various rocks form the chief outcropping portions of the talc-bearing zone.

Some of the jasperoids (No. 3) resemble dolomite in the hand specimen. They are buff-coloured and have a close, dense, texture. In thin section they are seen to consist almost solely of interlocking microcrystalline grains of quartz, with irregular coarser-grained patches dispersed through the finer quartz. Rare small grains of a colourless hornblende may be present. The buff colour is imparted by brown interstitial material, sometimes suggestive of altered biotite. In places there are discontinuous, parallel, narrow bands of very fine-grained talc or mica. This impersistent banding suggests a relict of a texture inherited from an originally banded rock.

Some patches of jasperiod (No. 8) associated with sepiolite nodules are greyish-white and sub-opaline. The jasperiod has a sharp but irregular junction with the sepiolite, and both are traversed by narrow veins of chalcedony. The jasperiod is so fine-grained as to appear almost isotropic, and much of it has a finely fibrous texture inherited from the replaced minerals. A partial analysis showed that this rock consisted of about 90 per cent silica.

Much of the jasperoid is banded in light-grey or brown and dark-grey bands, in which fine crumpling and banded structures are preserved. Both light and dark bands consist chiefly of microcrystalline to cryptocrystalline quartz.

* Holmes, A., *Nomenclature of Petrology*, p. 127, 1928.

Frequently, there are more or less rectangular areas of quartz in which all the minute grains are elongated parallel to the length of the area. Films of brown stain between the quartz grains give these areas the appearance of good cleavage parallel to the length, and it is evident that they have been derived by the replacement of a well-cleaved prismatic mineral. The matrix between these areas shows no such orientation of the quartz grains. In the dark bands, the outline of the replaced crystals is more accentuated; and in some cases opaque limonitic cores occur within the replaced crystal. These banded jasperoids also contain a considerable proportion of a fibrous micaceous mineral which is probably fine talc.

In some specimens the jasperoid has been brecciated, and sufficient of the original banding is preserved by the quartz to outline the fragments. Some show a grading, along their strike, into talc-quartz schists, the gradation being a lit-par-lit section in which tongues of one rock give way to tongues of the other rock. In other specimens, the jasperoid occurs as ramifying bands about 2 mm. to 3 mm. thick, interleaved with bands of soft talc of about the same thickness.

It thus appears that the jasperoids replace rocks of varying composition. Some may replace dolomite, and some certainly replace schist. Much of it tends to grade into talc-jasperoid or talc-schist rocks, and so into the talc lodes.

CONCLUSION

Petrological examination of the rocks indicates that the talc bodies at Tumby Bay, and their associated jasperoids, occur in a zone of shearing and crumpling along the margin of a broad bed of dolomite. The shearing has given rise to granulation in the marginal part of the dolomite. The shearing and crumpling appears to have been most intense along the contact of the dolomite with the schists that bound it.

The development of the talc and the secondary jasperoids was associated with the introduction of siliceous solutions; possibly associated in origin with the pegmatite dykes that occur in the vicinity. The magnesia for the talc was derived presumably chiefly from the dolomite, but in part from the mica of the schists which have been replaced. The proportion of dolomite involved in the formation of the talc and talc schists cannot be established, but much of the banding that suggests replacement of schists may be a relict of replaced schistose dolomite. (19/3/46.)

PART V

MINOR TALC DEPOSITS

Chapter 1

TALC AND FELSPAR DEPOSIT NEAR LOBETHAL

BY

A. W. G. WHITTLE, M.Sc. (PETROLOGIST)

Situation:—Section 5083, *hundred of Onkaparinga, county of Adelaide. Private property with the minerals alienated from the Crown. Operated by Pyro-Meg & Felspar Co.*

LOCATION

The workings are in section 5083, hundred of Onkaparinga, 1½ miles east of Lobethal.

PRODUCTION

The approximate amount of material obtained from these workings since production commenced in 1932 is:

Felspar	656 tons—valued at £1,260.
Soapstone	3,347 tons—valued at £7,717.

NATURE OF THE WORKINGS

There is insufficient data on which to build up a complete picture of the geology, the only observations obtained being in the various pits. However, the general nature of the rocks is similar to that of the rocks in the Gumeracha district.

Quartzite

A little unaltered quartzite outcrops, but the greater part has been converted to a fine-grained white albite rock retaining the original bedding.

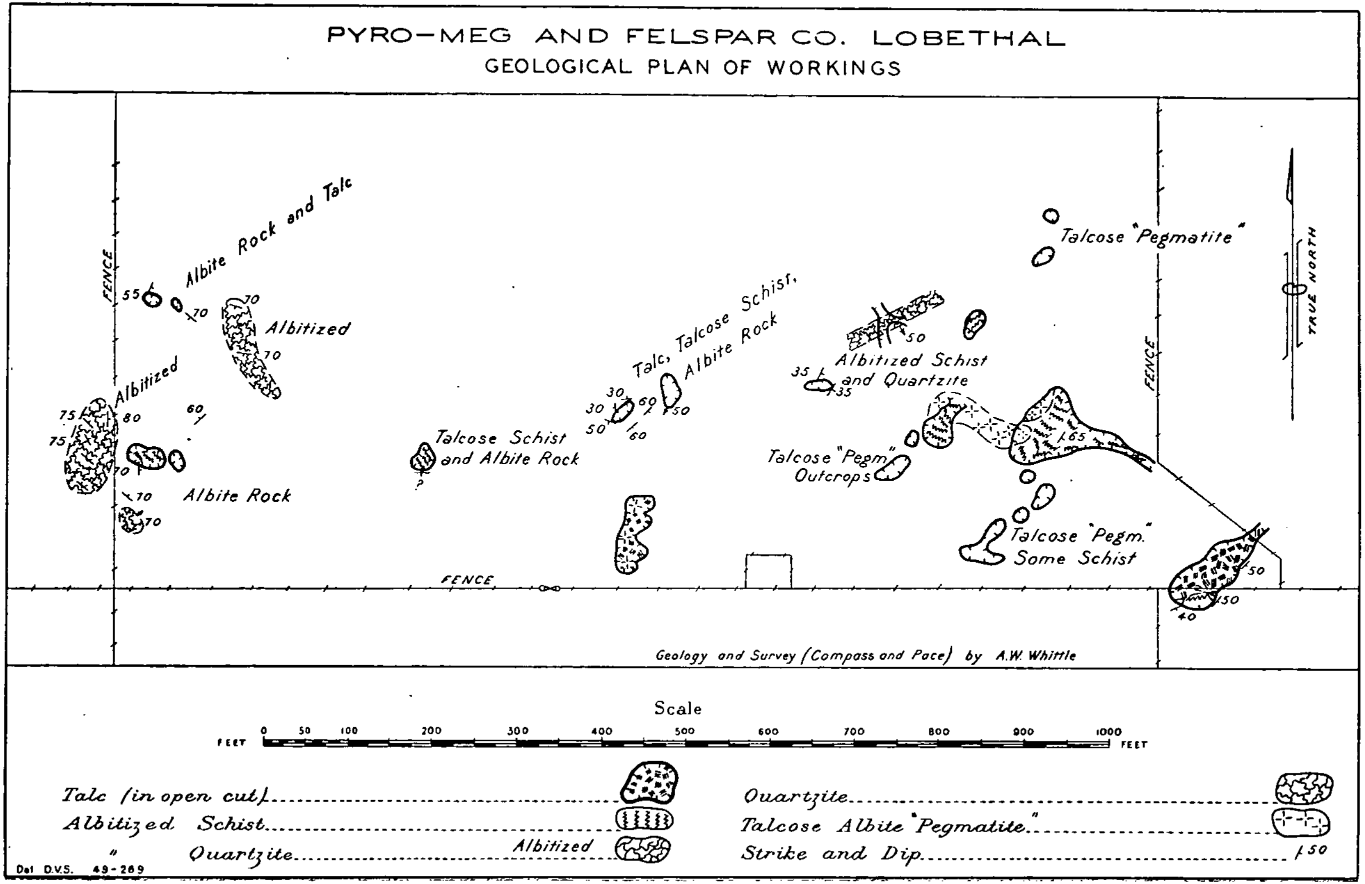
Schists

Brown mica schists are the prominent rock type. In most places where these occur they are rich in oriented talc flakes and often show evidence of albitization.

Talcose Pegmatite

The most interesting rock type is the *talcose pegmatite* from which the company obtains its felspar. This rock varies from a fine-grained talcose albite rock to a coarse pegmatitic-looking rock with large crystals of albite up to 4in. long showing multiple twin lamellae. The talc, in the coarser types, occurs in graphic intergrowth with the felspar. This is not a pegmatite in the true sense of the word, but is an altered sediment, *i.e.*, a completely albitized sediment. Where the rock is fine to medium grained it is comparable with the albitized quartzite at Gumeracha, whereas the very coarse types, suggestive of pegmatite, are comparable to the clay rock near Dunstan's mine. Under conditions favouring complete and undisturbed crystallization, large albite crystals could easily grow up to several inches in size.

The bulk of the talc obtained here is a fine-grained massive type, really a steatite or soapstone, generally badly stained by iron compounds. A considerable quantity occurs in the most easterly quarry. This quarry is only about 8ft. deep, but a shallow shaft sunk from the floor shows the talc to be continuing downwards. Schist is associated with the talc in this quarry at it is in others on the property. The talc is frequently quite clayey, due to the kaolinization of albite which is disseminated through it. The talc which occurs in graphic intergrowth with coarse-grained albite is a green, coarser-grained, flaky variety.


PYRO-MEG AND FELSPAR CO. LOBETHAL
GEOLOGICAL PLAN OF WORKINGS
FENCE
Albite Rock and Talc
Albitized
Albitized
Albite Rock
Talcose Schist and Albite Rock
Talc, Talcose Schist, Albite Rock
Albitized Schist and Quartzite
Talcose "Pegmatite"
Talcose "Pegm" Outcrops
Talcose "Pegm." Some Schist
TRUE NORTH
Geology and Survey (Compass and Pace) by A.W. Whittle
Scale
FEET 0 50 100 200 300 400 500 600 700 800 900 1000 FEET
Talc (in open cut)
Albitized Schist
" Quartzite Albitized
Quartzite
Talcose Albite "Pegmatite."
Strike and Dip
Del D.V.S. 49-269

CONCLUSIONS

There is quite a considerable reserve of felspar and soapstone, so that the quarries may yield a supply of the order of present production for quite some time. The shallow shaft extending below the floor of the eastern quarry indicates that talc free from iron staining is to be expected in depth.

Further occurrences of talc, for about ½ mile N. to the main road from Lobethal to Mount Torrens, indicates that some prospecting in this direction may be well worth-while.

The specialized use of soda-rich felspar in industry should make the exploitation of this deposit of albite felspar very attractive.

Plans showing the location of this deposit are printed on pages 8 and 19.
(30/9/49.)

Chapter 2

TALC OCCURRENCES IN THE LYNDOCH DISTRICT

BY

A. W. G. WHITTLE, M.Sc. (PETROLOGIST)

LOCATION

The principal talc bodies occur about 2 miles ESE. of Lyndoch, in hilly country which rises sharply from relatively flat rolling country at an average elevation of 900ft. The elevated country in which the talc is located varies from 1,500ft. to 2,000ft.

No registered claims have been taken out in this district for the workings are on private property and appear to have been worked by the property owners themselves.

PRODUCTION

No figures are available, but in any case the production would be of a very low order.

NATURE OF THE WORKINGS

In general, the workings are not advanced beyond prospecting holes. However, several small open cuts have been made, while in section 3133 there is a shaft (depth unknown) and an adjoining open cut from which possibly 50 tons of soapstone may have been removed.

GEOLOGY

The sudden change in elevation from 900ft. to 1,500-2,000ft. between the plains to the west and the hills in which the talc occurs is strongly suggestive of a major meridional block fault located no more than 1 mile W. of the talc orebodies. This faulting has no genetic relation to the talc formation.

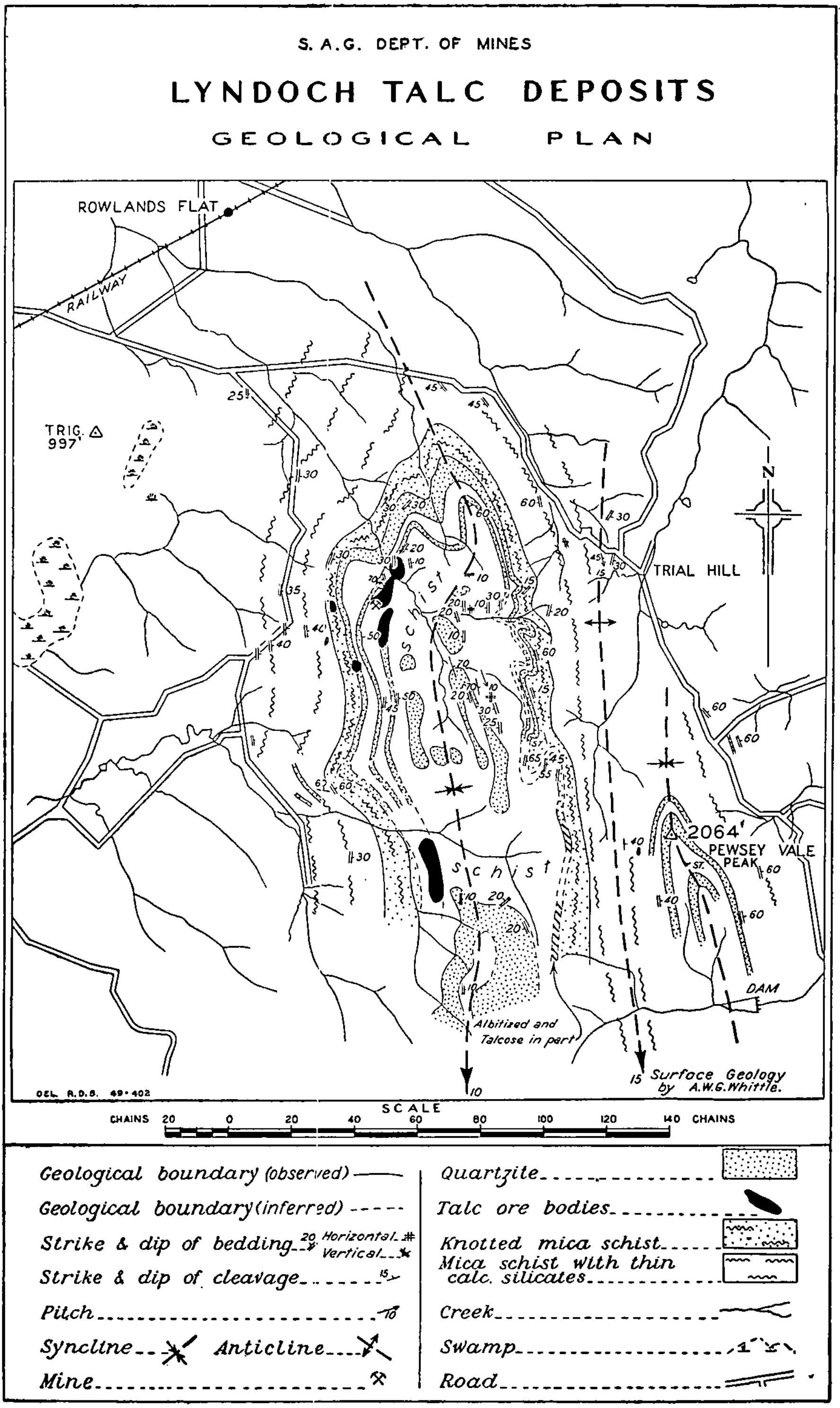
The significant local structural feature is the presence of a syncline, almost isoclinal in nature, striking approximately north and south. The syncline is overturned so that its axis dips steeply eastward. Its pitch is 10°S. It is in the western limb of this syncline that the talc orebodies are to be found.

There are two important rock types associated with the talc, namely, quartzite and muscovite-biotite schist, the latter frequently containing thin interbedded bands of calc-silicate rock. Albitized equivalents of these two country-rock types are of common occurrence both in association with the talc itself and elsewhere where no talc has been recorded, hence the general features are analogous to those of the main Gumeracha field to the south.

The talc orebodies are roughly lenticular in shape with their longer axes directed approximately parallel to the principal synclinal axis. Although the detail is often very obscure owing to intense local albitization or to lack of sufficient outcrops, it is obvious that the lenticles of talc occur in minor drag folds on the western limb of the main syncline where the quartzite has been albitized and the schists albitized, and, in part, converted to flaky talc. Occurrences of talc are distributed for at least 2 miles S. of section 3133, which is as far as this survey was extended. However, it is probable that they would continue even farther south towards Williamstown.

Along the eastern limb of the syncline there are no talc orebodies, but in places where drag folding is developed there are strongly albitized zones.

The talc itself is identical with that obtained at Gumeracha. It is a green flaky type with fine disseminated white crystalline albite, and it contains large boulders of albitized country-rock.


S. A. G. DEPT. OF MINES
LYNDOCH TALC DEPOSITS
GEOLOGICAL PLAN
ROWLANDS FLAT
RAILWAY
TRIG. 997'
TRIAL HILL
N
schist
schist
2064'
PEWSEY VALE PEAK
DAM
Albitized and Talcose in part
Surface Geology by A.W.G. Whittle.
DEL. R.D.B. 49-402
SCALE
CHAINS 20 0 20 40 60 80 100 120 140 CHAINS
Geological boundary (observed)
Geological boundary (inferred)
Strike & dip of bedding
Horizontal
Vertical
Strike & dip of cleavage
Pitch
Syncline
Anticline
Mine
Quartzite
Talc ore bodies
Knotted mica schist
Mica schist with thin calc. silicates
Creek
Swamp
Road

CONCLUSIONS

Future production of talc in this region is favoured by the close proximity of the railway which passes through Lyndoch, 2 miles away. However, factors against the development of this field are principally the small size of the talc orebodies and their location in steep hilly country. The general quality of the talc does not appear to be in any way inferior to that obtained in the Gumeracha district.

Plans showing the location of these occurrences are printed on pages 8 and 19. (5/12/49.)

Chapter 3

TALC OCCURRENCES IN THE VICINITY OF WILLIAMSTOWN

BY

A. W. G. Whittle, M.Sc. (Petrologist)

LOCATION

Talc is known to occur on sections 1180 and 1181 about 1 mile ENE. of Williamstown.

PRODUCTION

The only production recorded is 56 tons of soapstone obtained in 1944 from section 1181.

NATURE OF THE TALC OCCURRENCES AND LOCAL GEOLOGY

The workings are small. There is an adit, extending about 50ft. into the hill-side, in one place, while elsewhere there are small open pits.

The talc occurs amongst mica schists with minor marble and quartzite beds lying immediately above the ilmenitic basal grits which pass through Williamstown. The marble formations are strongly talcose, and frequently carry copper carbonate which is disseminated through the rock rendering the talc strongly coloured. The schist and minor quartzite intercalations are strongly albitized and in places contain some impure talc.

The association of talc with the carbonate rocks is purely fortuitous, *i.e.*, the talc cannot be regarded as derived from them because their magnesium content is very low, and the abundance of albitized country-rock locally, indicates that the genesis of the talc here is most probably the same as that at Gumeracha. There are insufficient outcrops in this locality to establish the structural control of the talc deposition.

CONCLUSIONS

The talc occurring in this locality is in small amount only and is very impure in quality. It is contaminated with copper carbonates, lime carbonate, and country-rock to such an extent that it would be difficult and costly to beneficiate the talc.

A plan showing the location of these occurrences is printed on page 8.
(7/12/49.)

PART VI

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RECORD OF TALC MINES IN SOUTH AUSTRALIA

(MARCH, 1949.)

Name	County	Hundred	Section	Mineral Claim or Lease	Remarks
1. B. Edwards	Flinders	Yaranyacka	—	MC. 10490, 10491	No returns; cancelled 1918
2. Burrawing copper mine	Flinders	Yaranyacka	403	MC. 11803	No returns; cancelled 1918
3. C. J. Partington	Flinders	Yaranyacka	A^S	MC. 10975, 552, 923	Small production, 1948
4. Tumby Bay Talc Co. N.L. (Minerals Pty. Ltd.)	Flinders	Yaranyacka	A^S, A^N, 46	ML. 2676; MC. 726	ML. 2676 chief producer at Tumby Bay
5. S.A. Mines Co.	Flinders	Yaranyacka	A^N, 28, 33, 42	MC. 638, 639, 444, 517-519	Small production, 295 tons 1943-44
6. John Dunstan & Son (W.A.) Ltd.	Adelaide	Talunga	6265, 6323, 6543, 6274, closed road	ML. 2777, 2514; MC. 559, private property	Chief producer at Gumeracha
7. Torrens Mining Co. Ltd.	Adelaide	Talunga	6268, 245, 6264, 6266, 6267, 6212-4, 6329	MC.14222-3; sections 6268 and 245, private property	Consistent production since 1929
8. J. Porter	Adelaide	Talunga	6213, 6214, 6212	Private property	Small production of asbestos and steatite, 1939-44
9. Talunga talc	Adelaide	Talunga	6274, 6275, 6380, 6384	MC. 559, 560, 640, 648, 779, 695	Mainly prospecting. Small production 1942-46
10. Fairview phosphate mine	Burra	Bright	4	Private property	By-product phosphate mining, G.S.S.A. Bull. 7
11. Minbrie mine	Jervois	Minbrie	110	MC. 345	Small production 15 tons 1929
12. G. Page	Jervois	Hawker	Pt. 171 and 172	MC. 614	No production, cancelled 1945
13. Tweedies Gully mine	Adelaide	Barossa	3131, 3133	MC. 618, 765, private property	Prospecting only, no recorded production
14. C. W. and L. C. Smith	Adelaide	Barossa	1180, 1181	MC. 622, 623, private property	Small production, 56 tons 1944

RECORD OF TALC MINES—*continued*

Name	County	Hundred	Section	Mineral Claim or Lease	Remarks
15. Lyndoch asbestos mine	Adelaide	Barossa and Nuriootpa	585, 1800	MC. 15237, 15322, private property	Small production, 40 tons 1937
16. Lobethal Soapstone and Felspar (Pyro-Meg & Felspar Co.)	Adelaide	Onkaparinga ..	5083................	Private property	Soapstone production since 1932
17. Flinders Talc	Out of counties N.E. division	—	(K4)................	ML. 2867 ; MC. 842, 839, 867 M.L.2876, 2877 ; M.C. 868, 890 ; M.L 2872 ; MC. 889, 891	Production since 1945, and increasing
18. Leslie Bros	Out of counties N.E. division	—	(K4)................	MC. 820, 979-989, 1051, 1064-9	Small production, 1946-47
19. John Dunstan & Son (W.A.) Ltd.	Out of counties N.E. division	—	(K4)................	MC. 900	No recorded production

PLANS AND ILLUSTRATIONS

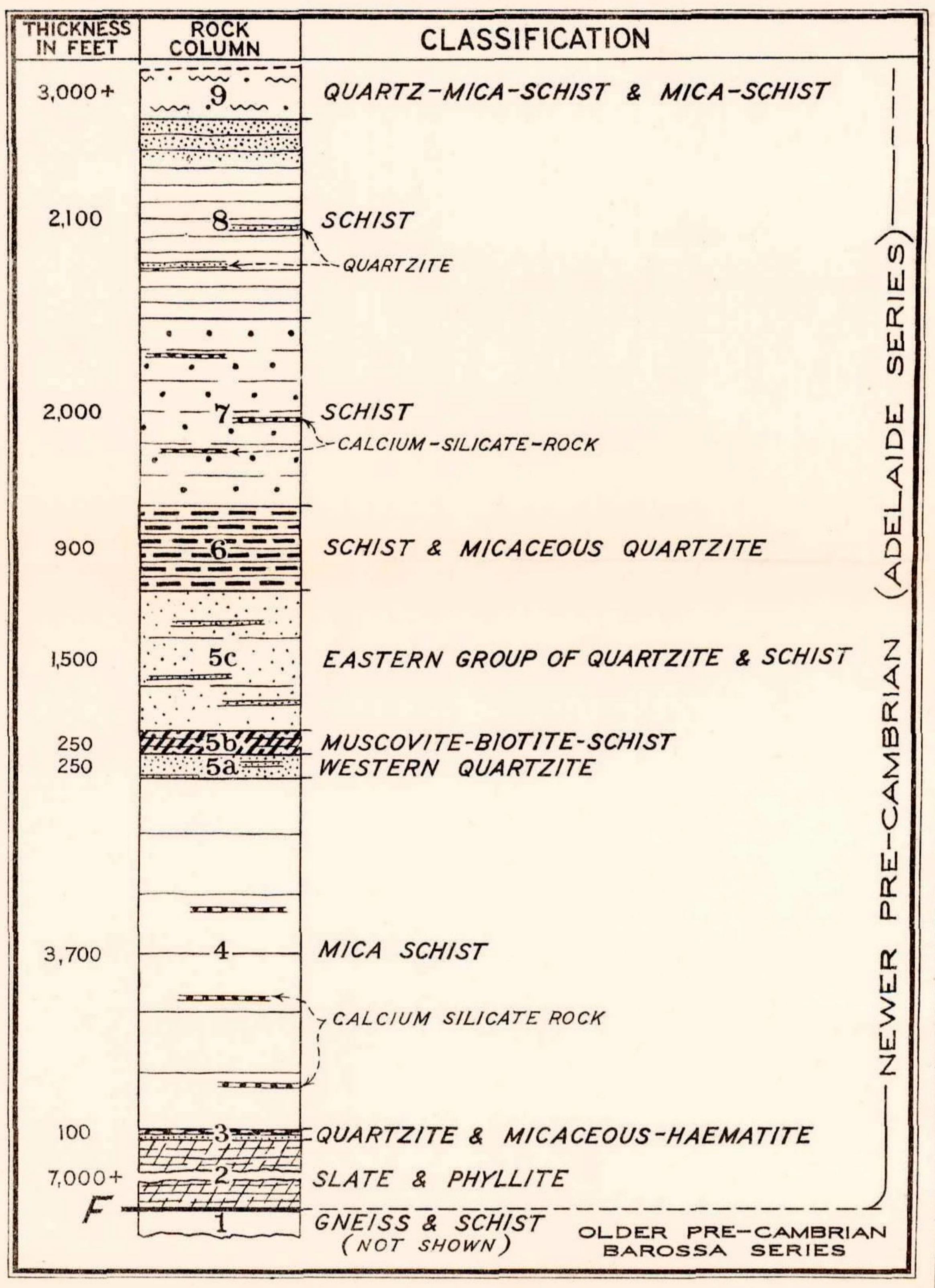
PLATE II

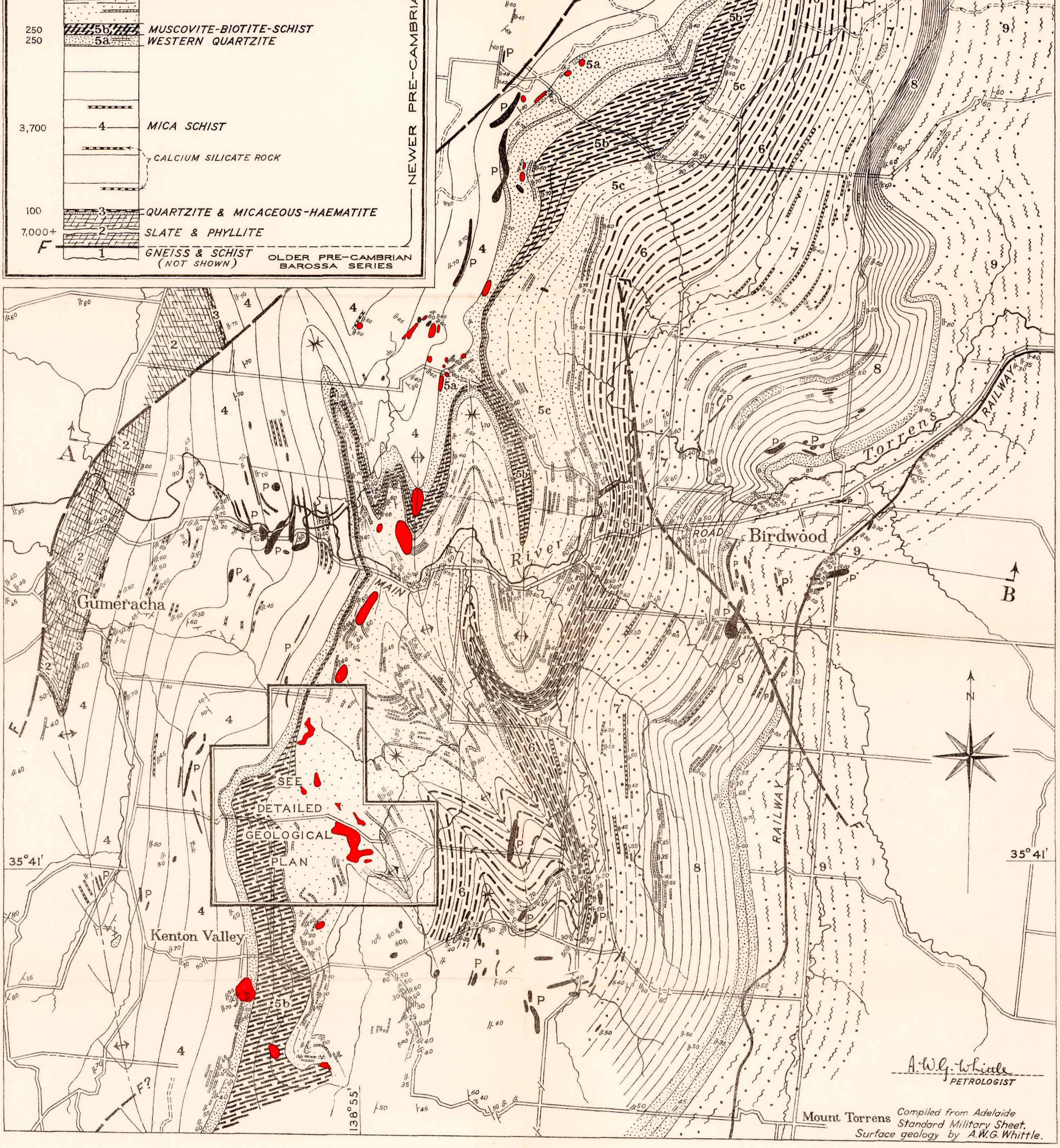
S. A. G. DEPT. OF MINES

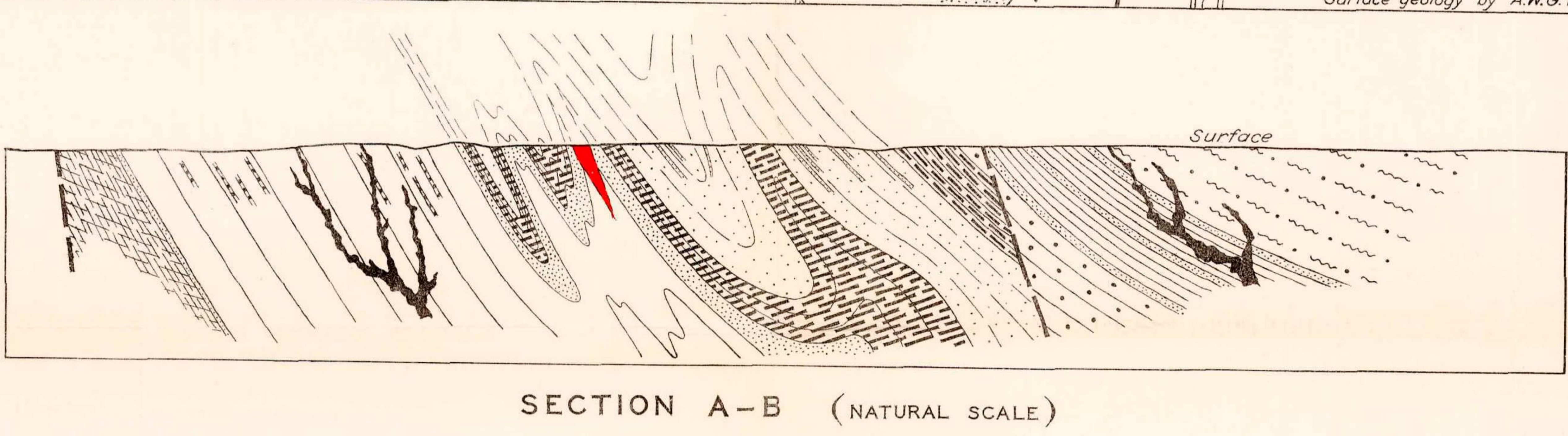
GUMERACHA TALC DEPOSITS.

HD. TALUNGA

REGIONAL GEOLOGICAL PLAN

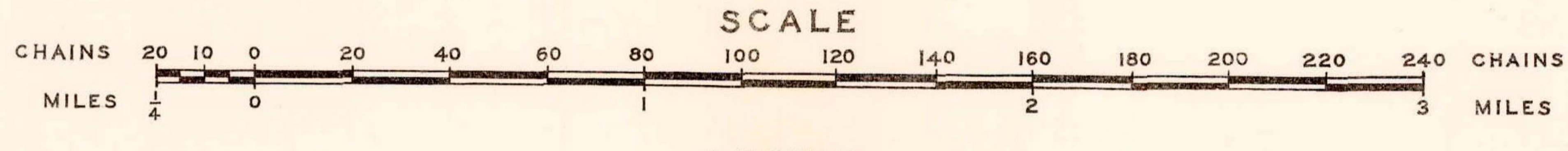






SECTION A–B (NATURAL SCALE)

SCALE



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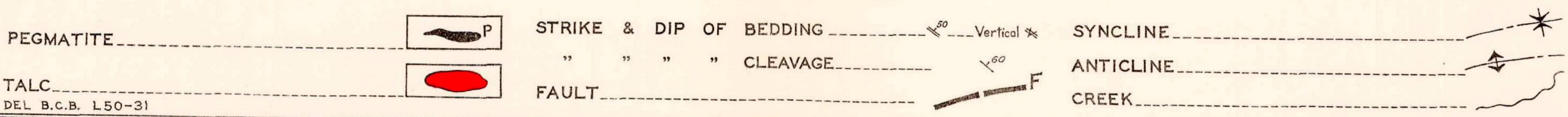
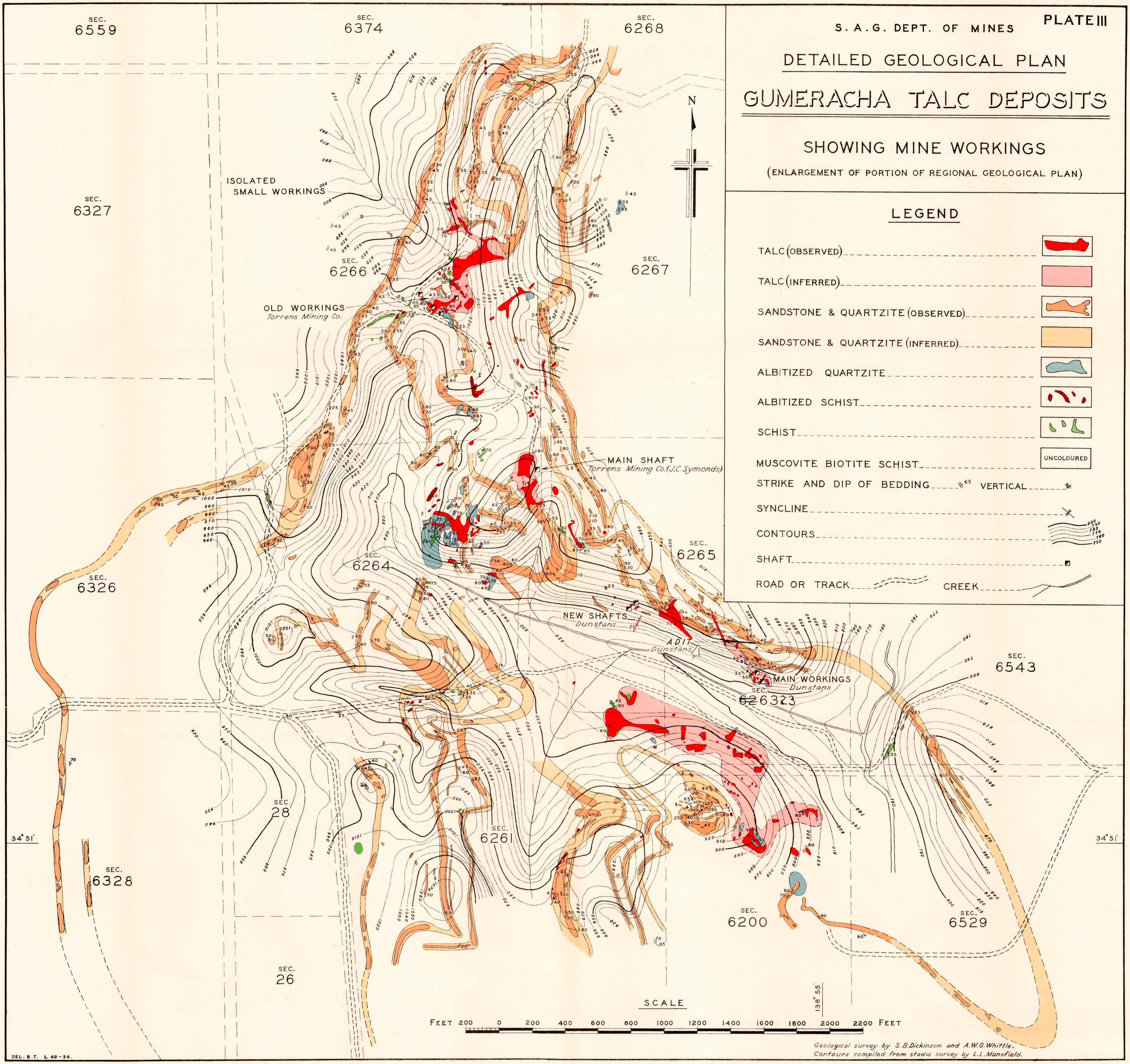


DEL. B.C.B. L50-31

M. E. SHERRAH GOVERNMENT PHOTOLITHOGRAPHER ADELAIDE



M.E. SHERRAH, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.