THE VICTORIA CREEK MARBLE,

WITH OBSERVATIONS ON THE GEOLOGY OF AN AREA NORTH-EAST OF

WILLIAMSTOWN, SOUTH AUSTRALIA

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HONOURS THESIS

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INTRODUCTION:

A small area immediately north-east of Williamstown, South Australia, has been mapped in considerable detail, with the intention of studying, in particular, outcrops of white marble, to be called the Victoria Creek marble. Also the rock types of this metamorphic province have been listed.

Rocks of the area have been subjected to fairly intense deformation, and fracturing. Metasomatic alteration and retrograde metamorphism is apparent in several localities. Consequently, and together with confinement of mapping to a small region, limitations must be realised, in applying the collected data to the regional geological picture.

Finally, an effort is made to compare observations with the more recently presented geology of the Barossa Ranges.

Previous Work

Several workers in the past, including Howchin (1926), Hossfeld (1934), and Campana (1953) have taken in this area in their regional mapping of the Barossa and Mt. Lofty Ranges. They have outlined the broad structural and stratigraphic relationships, and described surface trends and outcrops. Miles (1950) has worked in more detail in the South Para gorge region, whilst the Warren metasomatic zone has been fully described by Alderman (1942).

There is lacking on record a detailed petrological and mineralogical account of the Victoria Creek marble, neither is there any systematic petrographic report on the lower metamorphic sequence.

To facilitate the understanding of this paper, there follows a brief description of the regional setting of the Williamstown area, taken from the Report of the Geological Survey of South Australia, No. 4 (Campana 1953).

All the rocks in the South Para Gorge - Williamstown - Lyndoch region are considered to belong to the Lower Adelaide System, but the Lyndoch - Williamstown fault throws up the schistose block on the east, against the phyllitic shaly series on the west. The (Aldgate) sandstone in the vicinity of the recreation ground forms the core of the north-pitching major Williamstown anticline, which is obliquely cut off by the

Lyndoch - Williamstown fault. Then the schist - marble - quartzite succession is the normal sequence on the eastern limb. The Victoria Creek marble is correlated with the Castambul Dolomite of the Adelaide region.

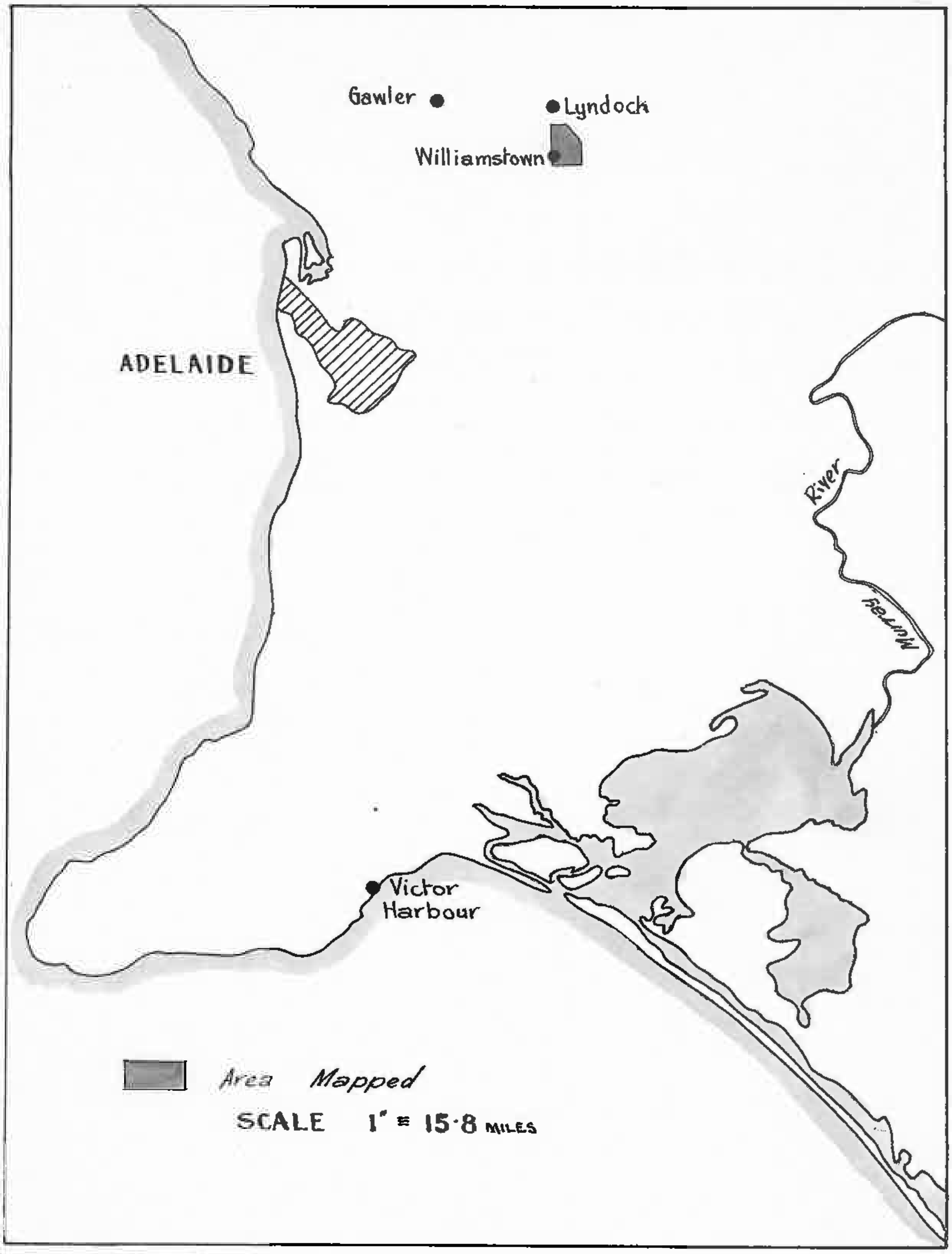
Scope of Field Work

Outcrops were inspected over an area of about 10 square miles, beginning from the township of Williamstown, and extending northward for three miles to a wide alluvium covered valley (Tweedie Gully). Mapping was carried eastward to the first perched thick Quartzite ridge, and westward to the Williamstown - Lyndoch road, where the phyllitic series of the Lower Adelaide System outcrops. The southern extent is the approach to the complex South Warren metasomatic zone, rocks of which have not been examined.

Procedure in Field Mapping

Aerial photographs from Gawler Runs 20, 21, 22 and 23 were used to construct a base map by slotted template method, at a scale of 20 chains to 1 inch.

All outcrops in the area were inspected, and plotted on the base. The quaternary alluvial deposits have not been mapped as geological units. Generally outcrops are very poor on a predominantly soil-covered surface. In all but the mid-year months, mapping is impeded by a lush growth of grass. Some of the country mapped is shown in Plate 3.



Locality plan of Williamstown area, (Approx. 25 miles N-E of Adelaide).

GEOLOGY:

1. VICTORIA CREEK MARBLE.

Marble[1] outcrops conform to three different lines, trending about 150°(west of north.) Each horizon is incomplete in outcrops, and varies in thickness from place to place. The best exposures, including those along Victoria Creek, are seen along the eastern horizon. The middle one seems to follow the line of the Enterprise Fault, whilst the western marble is located a quarter of a mile further west, and passes northwards into a crush zone. A single marble outcrop occurs less than $\frac{1}{4}$ mile south-east of Mattner's Homestead, on the strike of a calc-silicate bed.

The finest exposure of marble in the area is found as a dip-slope in the south bank of Victoria Creek[2], close to Mt. Crawford road and about 350 yards east of Ross' Bridge. Outcrops away from the creek are poor, seldom projecting much above soil level. They form hard white patches, or powdery travertinous crusts, in the shape of rounded knolls.

The thickness of the marble is variable and no figure can reasonably be inferred. In some parts, the bed pinches out and disappears while in others it may apparently swell to some 200 feet. These thickenings may sometimes be emphasised by contortion, as is the case in the outcrops in the creek $\frac{1}{2}$ mile north-west of Mattner's Homestead. Here several tight drags are sheared up against one another. (see diagram)

The disjointed and incomplete nature of the marble outcrops, largely prevents the closer study of variations in section and space.

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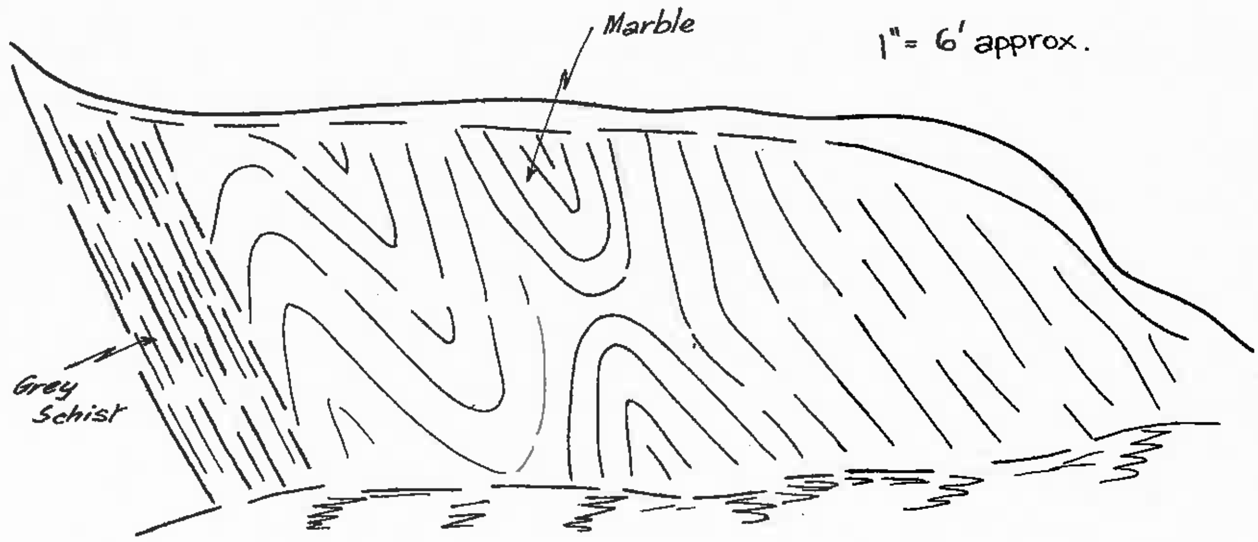
(1) "Marble" henceforth refers to the white crystalline dolomitic marble.

(2) Plate 1.



Contorted marble N-W of Mattner's - looking north.

Contacts with the metasediments are seen in only two places, and one of these is a shear contact.

For convenience in description, the marble may be divided into two groups.

1. Typical white or grey marble, which is considered the simple primary metamorphic product of a slightly impure dolomitic limestone facies.
2. Marbles associated with faults or shears, in which there is evidence of hydrothermal activity leading to retrogressive metamorphism.

Calc-silicate rocks considered to be facies equivalents of the marble are discussed later.

Simple White Marble.

Mineralisation -

The small amount and lack of variety of primary metamorphic minerals in the marble suggests the original sediment was a fairly pure dolomitic limestone. (Of course, degree of metamorphism is also an important factor with respect to the nature of the metamorphic assemblage). Aluminosilicate impurity as clayey or micaceous material must have been negligible, and remains now as sporadic flakes of phlogopite, and then only in isolated occurrence. Silica was the only noteworthy impurity, which results in almost ubiquitous tremolite throughout the marble. A very minor quantity of amphibole is possibly produced by secondary silica, when it is seen to form preferentially in fracture cracks.

Tremolite may be seen in all its forms - clear bladed prismatic crystals; minute acicular needles, either disseminated or arranged in radiating aggregates; or fibrous asbestos-like material. It also occurs as large clots and streaks of the order of two feet in thickness. These may be seen in Victoria Creek about 120 yards east of Ross' Bridge and again on the hillside 600 yards west of the bridge.

Pyrite is seen quite commonly, most likely as a primary mineral, and its frequent association with higher tremolite proportions, suggests a more plentiful source of sulphide in the impurer sections of the rock.

Zircons as original detrital grains are occasionally recognised.

Secondary minerals found in the marble are serpentine (probably both antigorite and chrysotile), talc and calcite, although some of the latter two, is no doubt of primary origin. Hematite is common as a product of surficial weathering of sulphide.

It may be pointed out here that primary quartz has not been identified in any specimen of marble. Its quantity must have been small enough, to be used completely in the earliest stages of decarbonation.

Texture -

Notable about these marbles in general is their almost universally uneven texture and rather small grain-size, as seen in thin section. Both these features may be correlated with low grade metamorphism. Inconstant grain-size can possibly also be attributed to strong differential stress.

Texture of the type dolomitic marble may be described as poorly granoblastic. Dolomite crystals are moderately well-developed, but often have wavy boundaries, or an incipient interlocking relationship. The mortar texture which can be anticipated in sheared crystalline carbonate rocks, is not common but has been recorded in one section. It is often difficult to decide which are the effects of crushing, and which the effects of reaction, in the rocks.

Of some twenty five sections in which crystals were measured, grains exceeding 2 mm. are rare. In the white marble, mean grain size is 1 to 1.5 mm, with almost always gradation down to a fraction of a millimetre. The marble of the shear zones seems generally to be of still finer grain-size.

In the most northerly outcrops, there is a coarser creamy-white marble(1) with crystal grains averaging about 3 mm, the largest ranging up to 5 mm.

Composition of the Marble -

Samples taken at intervals along the strike of the marble were investigated by optical and X-ray methods. No chemical analyses have been carried out. As a result it seems the marble is largely dolomitic.

No specimen of a simple calcite marble has been encountered, but one specimen(2) taken at the Enterprise Mine proved to be crystalline magnesite. This specimen is discussed in detail further on.

Values of refractive indices vary a little from place to place, but mean values are

E	1.530	
W	1.695	
E'	1.585	(Value of E taken on the cleavage rhomb.)

These values indicate dolomitic composition which was confirmed with X-ray photographs.

A bluish-grey marble(3), often with strongly developed singular tremolite crystals, is found at intervals along the two westerly horizons. This has been x-rayed as dolomite.

Following is the description of the typical white dolomitic marble.

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(1) A133/141

(2) A133/139 - see "Hydrothermal Alteration".

(3) A133/11, 169.

Specimen No. A133/13

Location - 600 yards W. of Ross' Bridge (on hillside)

Hand Specimen - A compact creamy white medium grained marble.

Thin Section - Irregularly shaped dolomite (1) grains ranging in size from about 2.5 mm downward give it a rather uneven texture. Most dolomite crystals especially the larger ones, show an elongation in one direction producing a rough foliation, which is accentuated by the alignment of tiny tremolite needles. Rhombohedral cleavage of the dolomite is readily observed, and twin lamellae, sometimes in two or three directions in the one crystal, stand out as thin coloured intersection bands.

Powdery carbonate fills thin flat zones, presumably along which movement has rolled and crushed the crystals.

Clear tremolite needles or long slender prisms occur mainly at the intercrystal boundaries of dolomite. An occasional crystal is included in a carbonate grain. Tremolite shows amphibole cleavages and cross-sections, the diamond outline being quite customary. 2V is always very high and the interference figure biaxial - ve with moderately strong colour rings. Extinction angle taken of the prism edge is 17°. The prismatic crystals frequently grow into and across one another, and generally have ragged ends. Tremolite in the marbles is always clear and colourless, indicative of the iron-free magnesian end member of the series.

Mica flakes occur occasionally, having very low 2V, parallel extinction, and length-slow character. This is most likely phlogopite though there is no pleochroism. (Difficulty has been experienced in distinguishing between talc and near colourless phlogopite in thin section. Where convenient, x-ray determination has been used).

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(1) The term "dolomite" will be used for grains of carbonate described in thin section, unless otherwise stated.

A133/128[1] A white medium-grained crystalline marble studded with pale honey-brown mica flakes, which have been x-rayed as phlogopite. The rock also contains talc, tremolite, hematite and a little serpentine. The carbonate shows indications of being stressed. Talc-tremolite are associated in tiny cracks. The tremolite often has ragged ends, but in general, seems to be in equilibrium with the talc.

Altered Marble

The marble has in many places undergone local alteration, due mainly to the introduction of aqueous solutions carrying silica and in some parts magnesia. Some of the effects of this hydrothermal activity are discussed and demonstrated in the following descriptions.

Serpentine marble

Specimen No. - A133/127

Location - Victoria Creek, 350 yards E. of Ross' Bridge.

Hand Specimen - A pale green very compact serpentine marble. One of the (? joint) surfaces of the specimen consists of a thin layer of seemingly solid serpentine, studded with minute silvery flecks of talc. Serpentine occurs also as clots in the marble[2], which remains as prominent nodules on the weathered surface. Fresh pyrite grains are dispersed throughout the rock.

Thin Section - The serpentine mineral occurs chiefly as patches of clear criss-crossed fibres, or tiny fibrous bundles, with the physical appearance of chrysotile. However, serpentine from one of the clots was x-rayed as antigorite. It has low birefringence, showing first order greys and yellows, and often shows undulose extinction. Serpentine is also recognised, as a few tiny platy crystals with very dark grey interference colours.

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(1) See Plate 11

(2) See Plate 6

Relation of serpentine to carbonate

Serpentine wisps and fibres are intergrown within some carbonate crystals[1], often parallel to cleavage directions, but sometimes interwoven at random. No doubt this accounts for the more or less green tinted rock. Nearer the serpentine clots, the amount of serpentine in the carbonate increases to such an extent, that though most carbonate grain-forms are preserved, the grains are actually an interlocking bundle of serpentine fibres. The relationship is well demonstrated in the photograph at the end of the paper. The clots themselves are traversed by thin discontinuous strands of cloudy brownish carbonate.

Talc as small highly birefringent flakes is either intimately associated with the serpentine or else lodged amongst the carbonate grains.

Concerning magnesium enrichment, and the origin of serpentine.

From the vicinity of the serpentinised rocks, there extends southward a narrow zone of metasomatised rocks, which has been examined for about $\frac{3}{4}$ mile south of Mt. Crawford road. Rocks noted especially were:-

1. Kyanite rock - masses of very large pale blue kyanite, probably associated with pegmatite A133/96.
2. Kyanite bearing pegmatites.
3. Pale green massive damourite replacing kyanite. This damourite resembles serpentine in the marble.

All these three have been fully described in an earlier paper (Alderman, 1942).

Also 4. Masses of coarsely crystallised pale green fibro-lamellar serpentine A133/99.

5. Cherty siliceous material with veinlets of coarse fibrous serpentine (asbestos) A133/95, almost certainly a solution mineral.

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(1) See Plate 7

Thus, the zone contains in addition to abundant alumina, noteworthy amounts of hydrated magnesium silicate, and it is reasonable to postulate the activity of aqueous solutions containing silica and magnesia. There is no clue as to the origin of the magnesia in solution. It may be taken locally from dolomitic beds, or less likely, it may have some magmatic source. The introduction of magnesia as a component of late stage soda-rich granitic residual liquid is, rightly or wrongly, not favoured by Stillwell in his report on the Gumeracha Talc Deposits. Both he and Campana record soda metasomatism in the Northern Mt. Lofty and Barossa Ranges, manifest in a general preponderance of albite, and in cases of locally albitised rocks.

Perhaps, then some of the serpentine has crystallised from solutions replacing the carbonate, though it would be unwise to say without further analysis, that some or even most of the magnesium has not come from the dolomite. The nature of the serpentinisation, as seen in thin section seems one of diffusion along favourable cleavage planes, rather than wholesale interaction between crystal grain and solution.

There is an alternate possibility that local serpentinisation in the marble, could result under conditions of retrograde metamorphism of forsterite marble. There is however no indication that the metamorphic conditions for the development of forsterite were ever fulfilled. Forsterite is not known to have been recorded in this area.

Asbestos marble A133/103

Found in Victoria Creek, west of the bridge is a fine-grained greenish grey marble containing sheaves of silvery-grey asbestos shown by x-ray to be serpentine. In thin section, the asbestos is seen to grow at random in amongst the carbonate mass. Here there is no interaction between dolomite and serpentine, neither is there evidence of solution channels.

The occurrence of talc in the marble.

Though generally widely distributed in the marble, talc does not occur in much quantity. In two localities, there are surface indications of fairly pure steatite - both on the hillside 600 yards west of Ross' Bridge. One is a small adit, the other a costean, and both showing that the talc is a very localised body.

Specimen No. A133/122 - Talcose marble.

Location - Victoria Creek, close to the serpentine marble,

Hand Specimen - A fine-grained white marble with greenish bands containing talc. Lustrous flecks of talc appear throughout most of the rock. Hematite pseudomorphs of pyrite cubes up to several mm in size are common, especially along the predominantly talcose bands.

Thin Section - Carbonate has a relatively uniform grain-size, though crystal relations vary. In some parts of the section, crystals are tending idioblastic whilst in others, the boundaries are interlocking with notable suturing. Talc is seen all through the section but especially so in certain parallel layers traversing the rock. It appears talc has crystallised side by side with the carbonate, and there is no obvious evidence of reaction. Talc forms idioblastic stumpy crystals, or as patches of minute flakes, some of which are crowded with minute indeterminate inclusions all with high relief. The talc is colourless, or may show the slightest tinge of green. Extinction is parallel to the one perfect cleavage.

Of somewhat different character is the talc marble A133/132, found close to the Enterprise Fault, not quite ½ mile south-east of Enterprise Mine. This marble is bluish green in colour with white blotches of carbonate, and is very fine-grained and compact. In thin section, the carbonate has a mortar structure. Random groups or singular crystals of clear dolomite with sharp but often rounded outline, are found in a mass of very fine-grained carbonate, showing no crystal structure. Disseminated throughout the rock are tiny idioblastic flakes of talc. These flakes seldom reach 0.5 mm in size and show strong pleochroism, from deep bluish green, to greenish-yellow, with grey to bluish-grey and yellow-interference colours. The mineral has one perfect cleavage (resembling mica), and some flakes are bent. Twinning or interleaving results in clear lamellae which show very high interference colours. The figure is negative with very low 2V, and strong colour rings. There is tendency for the grains to show hexagonal outline. They often form as strings of crystals, or elongated groups. Talc is also seen in occasional shapeless patches up to 10 mm in diameter, where thin fibres of serpentine are entangled with the talc crystals, which here are almost colourless, in contrast to the blue-green ones described above. An x-ray showed the acid residue of this rock to be talc-serpentine - magnesite, which is decidely a retrograde assemblage in dolomitic marble.

The Origin of Talc.

Talc in this region is always associated with dolomitic marble. (The only exception is a small quantity in an outcrop along the Enterprise Fault, and there, the talc cannot be shown to be related to a different rock-type). It may be safely concluded that talc is derived by the metamorphism, probably in part progressive as well as retrograde, of the dolomitic limestone. It is thought most of the talc is formed by hydrothermal activity of silica-rich aqueous solutions penetrating fractures andcracks in the carbonate rock. Talc is most abundant in zones where effects of shearing and high stress are obvious.

In the normal marble, talc may crystallise side by side with, or rarely, included in, the dolomite grains, which may be a simple metamorphism. Even so, talc tends to form along tiny cracks more favourable as solution channels.

A simple equation for the alteration of dolomite to talc is

$$\underset{\text{dolomite}}{3\,CaMg(CO_3)_2} + \underset{\text{silica in solution}}{4SiO_2} + H_2O$$

$$\underset{\text{talc}}{Mg_3(Si_2O_5)_2(OH)_2} + \underset{\text{calcite}}{3CaCO_3} + \underset{\text{carbondioxide}}{3CO_2}$$

An example of hydrothermal alteration of magnesian carbonate.

Specimen A133/139[1] found on the dumps at Enterprise Mine, has its main value in that it visibly exemplifies hydrothermal reaction, and the alteration of the marble. The specimen is supposedly a breccia block

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(1) See plates 8, 10

which has been engulfed by solution. The core of the block is a fine-grained greenish white marble, crystals from which have been x-rayed as magnesite. The relatively pure carbonate is enclosed by a highly altered outer zone in which coarse crystallised talc, very fine carbonate (calcite?), and serpentine are seen. The two zones are separated by wavy surfaces of alteration, the inner of which is a thin-band of brown calcite. Calcite suggests that the marble was at least in part dolomitic. Perhaps the calcite has acquired small amounts of iron in the breakdown of dolomite, producing the brown tint.

Three flat parallel green talcose bands traversing the marble may represent layers of originally higher porosity, more penetratable by the reacting material. Photographs of the specimen and its thin section may be seen at the end of the paper.

Further alteration of the marble

1. East of Ross' Bridge in the bank of Victoria Creek, there is marble sheared up against grey laminated schists. A localised zone of alteration extends a few feet on either side of the contact, especially along joints and foliation in the schist. Pale green actinolite, goldy brown phlogopite flakes and hematite (after pyrite) are abundant in the altered rock.

In the centre of the zone, following the bedding plane of the marble is a thin pegmatitic stringer carrying a few beautifully formed deep green actinolite prisms, some nearing and inch in length, intergrown with coarsely crystallised pink calcite.

It may be that here, the actinolite and mica have formed by diffusive interaction of marble and schist, in response to solutions passing along the shear.

2. Talc-Tremolite Schist[1] A133/138

On the dumps at Enterprise Mine is found a dark greenish rock, consisting of a mesh of fibrous tremolite crystals, filled in with dark green talc. By combined x-ray, optical and thin section work, the rock is shown to be essentially talc-tremolite with minor carbonate. Bent tremolite prisms and the overall schistose nature of the rock attest to strong deformation. The rock appears to be the product of bulk alteration

(1) See Plate 5

of a tremolite marble.

3. Tremolite - SiO_2 Rock A133/93

From the metasomatic zone comes a brown rock composed of jaspery material in which white tremolite prisms are embedded. The rock has not been fully studied, but most likely it represents an advanced silicification of the marble.

4. Tremolite Rock A133/142(1) - not a certain equivalent of the marble. Predominantly a tremolite rock, in which cherty siliceous material presumably is reacting with and replacing carbonate.

Other Rock Types

1. Arkosic (Basal) Sandstone.

The arkosic sandstone outcrops largely as the rugged hills enclosing, and south of, Williamstown recreation ground. The composition of these sediments is variable but feldspar (sodic plagioclase and subordinate microcline) is an abundant constituent whilst mica appears in minor quantity. Seldom is there a simple quartz sandstone. Layers of hematite grains define bedding planes, and frequent current-bedding in the sandstones. West of the Reservoir road, hematite may become so concentrated, as to form black banded hematite layers several feet in thickness. Sometimes, hematite has passed into solution and recrystallised along joints.

In several parts, in the vicinity of pegmatite veins, the arkose becomes fairly coarsely recrystallised with the production of large muscovite flakes sometimes showing wavy lineation. The connection between these micaceous zones and the pegmatites has not been closely studied, but it may be a pointer to the origin of the pegmatite bodies.

There are also outcrops along the western portion of the area, and further north, of laminated micaceous sandstone and sandy schist which are more argillaceous facies along a constant strike in the sandstone. Also in this vicinity, and again south of the oval, are layers of pebbly conglomerate. The boulders are mostly quartzite; well-rounded and sometimes elongated or lenticular, up to 4" in length, and usually embedded in a micaceous matrix.

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(1) See Plate 8

Metamorphism of the arkosic sandstone has left no conspicuous effects, except where mica forms in clayey facies, and possibly in pegmatisation. From thin section it is obvious that some degree of recrystallisation has taken place; it is most apparent in the purer sandstones, where a firm though porous rock remains (A133/32). Else the felspathic and arkosic sandstone have well preserved sandy texture, and may remain quite friable.

The most nor-westerly outcrops of sandstone occur in a shear zone, where they are brecciated, jointed and microfaulted, with quartz veining, solutionand recrystallisation of heavy mineral. A133/37 is a hematite quartzite (?) which appears to be a completely crushed and recrystallised hematite rich sandstone.

250 yards west of Enterprise Mine, a strong band of felspathised rock transgresses the calc-silicate horizon,and may be followed southward for about $\frac{3}{4}$ mile where it ends abruptly in the arkose. It also outcrops northward to Hausler's Mine. The hand specimen (A133/9) is a very hard compact rock, with feldspar porphyroblasts, and fairly plentiful sulphide. In thin section, the rock is obviously much altered. It may be the recrystallised breccia of an old fault line, as later faulting seems to have occurred along it at several places. Otherwise the band is difficult to explain.

Finally in this summary of the sandstones note is made of outcrops which have been strongly stressed. These are schistose or gneissic rocks with quartz lenses and stringers, coarse mica and pseudomorphed pyrite (A133/39) found in the western outcrops, about 1 mile north of the oval.

Several instances of an actinolite (tremolite) - albite (oligoclase) rock have been found. It outcrops persistently, though at intervals, as a thin horizon between the quartzite and the "blue" schist. Also in an area round about the turn of Victoria Creek, north of the oval. The rock is mostly weathered, and difficult to work with.

A133/130 from just north of Enterprise mine is a banded specimen with alternating amphibole and feldspar-rich layers. The structure is predominantly diablastic, with large actinolite crystals enclosing tiny feldspar grains. Albite is the predominant feldspar, with some microcline.

Quartz may be present, but is outwardly identical with the albite.

A133/19 is a similar rock, but more massive, and contains more quartz. Further west is a rock (A133/7) in which actinolite appears to have been mobilised (c.f. amphibolites), and crystallised as fibrous veinlets in fractures.

In the past the problem of these soda-rich (albitic) rocks has been answered by soda-metasomatism, and probably there is good evidence for doing so. The rocks just described contain at least, 50% albite. However, evidence from the basal sandstone and arkose shows that in the source material, there must have been an abundance of sodic plagioclase. If the original sediments were rich in albite, these actinolite albite rocks could be metamorphosed dolomitic arkose in which magnesium and quartz have produced the amphibole, and albite only recrystallises.

There is a possibility that the marble can be correlated with these rocks.

2. Pegmatites

Numerous pegmatite veins have been mapped, some reaching ¼ mile in length. The trends seem to follow those of the sandstone. In a couple of places the veins tend to follow around the lines of minor folds, but there is no sure evidence that their emplacement predated the folding.

It is important to note that at least in this area, pegmatites are confined to the sandstone or its metamorphosed equivalents. This may have bearing on the genesis or age of the pegmatites.

Texture of the pegmatite varies considerably from very coarse grain, to that of a granite. Some pegmatite resembles an aplite. Mineralogically, the rock is composed of clear quartz, yellow-ish pink feldspar, and muscovite predominating over biotite. Tiny fractured bluish-green apatite crystals, and yellow green beryl are quite common, but a brownish-black tourmaline is rarer.

Mention has already been made of the asbestos and kyanite pegmatites of the Warren metasomatic zone.

The pegmatites in the field appear to be of normal magmatic origin. However it may be suggested at this stage, that they could have been fluid phases initiated in a rock (arkose), which must compare closely in chemical composition with the pegmatites themselves.

Several quite large quartz veins in the area, are considered directly related to the main north-south faults.

3. Quartzites

The quartzite horizon which is at or near the top of the basal sandstone outcrops as three distinct persistent bands.

The central and eastern quartzites are very similar, in that they are rather felspathic and massive. The western band is a purer quartzite, which north of the Enterprise Mine, becomes a porous saccharoidal rock, bespecked with hematite. As this band nears the Enterprise Fault (near Victoria Creek) it becomes mylonitised, and rich in pyrite. Most of the quartzite contains appreciable pyrite.

The "Thick Quartzite" forming a ridge onthe eastern edge of the map is a massive fairly pure saccharoidal rock.

4. Calc-silicate Rocks.

Calc-silicate rocks are plentiful and varied in this region. They form thin layers right through the section. Those lying stratigraphically above the "blue" schist are fairly straight-forward, and can be treated separately from those below. The epidote-hornblende rocks which may be equivalent to the marble, have been studied more closely than the others. This aspect is discussed under stratigraphy.

Epidote-hornblende - plagioclase rocks, and amphibolites.

Rocks of this group outcrop in a band extending from east of Enterprise Mine, southward to, and along Victoria Creek. They pass below Ross' Bridge and appear to merge into the metasomatic zone. Some rock-types here are amphibole schists and gneisses, amphibolite, epidote-quartz feldspar rock, epidote schist, chlorite hornblende-muscovite schist.

Stringers, lenses and clots of milky to clear quartz are common throughout the band, and malachite staining from weathered sulphide, is seen in several places.

These rocks most likely originated from a predominantly calcareous clayey facies, rather arenitic in parts. Similar rocks may be expected in the low grade regional metamorphism of basic igneous rocks, but there is no indication of intrusion phenomena.

The relation between these calc-silicates and the other rocks, in particular, the basal series, is not plain in the field, and remains a debatable problem.

There seem to be three possibilities.

(1) In two localities (just west of Enterprise, and again ½ mile south along the strike) these hornblende-epidote rocks are underlying cross-bedded sandstones which are not overturned. The two seem to be conformable. The idea of the calc-silicates being unconformably pre-Adelaide (Hossfeld, 1934), though well justified, is not desirable.

(2) The calc-silicate may be a transition zone in time at or near the top of the arkose. This is unlikely, in considering the first possibility.

(3) The calc-silicate may be a facies variation within the sandstone beds.

This seems most favourable. In places a quite sandy feldspathic rock is seen to develop epidote, biotite and hornblende.

Further evidence comes from thin section work.

A133/155 A specimen chosen to demonstrate the apparent change from a recrystallised felspathic sandstone to a quartz-hornblende - biotite rock. There is no sharp transition - merely the appearance of random grains of hornblende increasing fairly rapidly to give a hornblende rich zone. Iron-ore mineral is disseminated in abundance throughout the whole section.

A133/151 A felspathic rock with random epidote and hornblende, and abundant heavy mineral, some of which roughly defines bedding planes. Thin Section - Texture is variable throughout the rock - of medium grain-size, and poorly granoblastic.

Albite is the chief constituent mineral, estimated at 45% of the section. It occurs in patches of closely interlocking crystals, each one almost invariably bespecked by a host of minute inclusions.

Multiple twinning is not common, but several grains give a maximum extinction angle 001 of 17°. 2V is high, and the interference figure is biaxial +ve.

Scapolite is seen as inclusions in the albite. It has low second order interference colours, and a uniaxial -ve figure.

Chlorite occurs as small pale green pleochroic grains amongst the albite; it has characteristic bluish interference colours, and often wavy extinction. Chlorite is also intimately associated with hornblende. There appear to be two amphiboles - one the blue-green hornblende and the other closely resembling actinolite seen in nearby rocks.

Epidote is scattered throughout the whole section as large crystals associated with the amphibole, or as tiny disseminated grains, or inclusions in the albite. The epidote is strongly pleochroic from yellow-green to yellowish white. Sphene occurs in unusual abundance. The formless grains are brownish and faintly pleochroic. Sphene is distinguished by its extreme birefringence, high relief and +ve biaxial interference figure with 2V of about 35°.

Iron-ore mineral is dispersed through much of the rock, and appears to have recrystallised in places. It has been x-rayed as hematite. Some larger subhedral crystals have epidote and sphene inclusions.

Biotite and zircon are in accessory quantity.

Some other rocks in this horizon are; A133/156 Amphibolite, located in Victoria Creek due north of the oval. It is almost a pure amphibolite, consisting of 95% or more dark green hornblende with small interstitial crystals of feldspar and a scattering of tiny hematite grains. Cutting the amphibolite are veins of pale green secondary actinolite, strongly fibrous perpendicular to the plane of the vein.

A133/40 - Epidote Schist.

Location - 750 yards due south of Enterprise Mine,

Hand Specimen - A fine grained epidote-green rock, consisting largely of epidote, but with darker zones of increased proportion of hornblende. Small segregations and thin stringers of quartz and epidote are seen parallel to, or cutting across fine planes of schistosity. The rock is weakly lineated.

Thin Section - Epidote constitutes at least 80% of the rock section, with quartz and hornblende the other important minerals. The rock has a granoblastic texture, but a decided grain orientation of slightly elongated epidote and quartz crystals produced a schistosity, which is accentuated by parallel hornblende prisms.

Epidote, as sharply outlined grains of moderately high relief is pleochroic from yellow-green to yellow-white. Interference colours range up to lower third order, whilst the interference figure has strong colour rings, -ve sign, and estimated 2V of 80-85°. Most grains contain numerous minute inclusions - tiny epidote nucleii, or magnetite; some are probably quartz and many are indistinguishable.

Quartz crystallises as grains in amongst the epidote, or occurs as thin veinlets of flattened crystals. A segregation of larger quartz crystals is seen cutting acorss the general schistosity of the rock. Hornblende of the deep blue-green variety typical of this facies occurs as strongly aligned prismatic crystals. Towards one margin of the section there is gradual increase in hornblende to about equal proportion with epidote. Hornblende contains small rounded inclusions of epidote and quartz.

Plagioclase - an occasional clouded crystal has a -ve sign, high 2V, and porrly developed multiple twinning. Composition has not been determined.

Zircon (?) - a few crystals with both high relief and birefringence, and a uniaxial +ve figure.

A rock related to the epidote schist, contains small amounts of biotite and microcline.

A133/42 Hornblende Gneiss.

A grey and greenish-black speckled rock with a crude gneissosity. Under the microscope, this rock is found to be quite complex.

Thin Section - Large porphyroblastic hornblende crystals are set in a groundmass of essentially felspar and epidote. Iron-ore mineral is disseminated throughout the entire rock. Hornblende constitutes at least 60% of the section - irregular interlocking crystals nearly always exhibiting diablastic structure, crowded with tiny grains of magnetite, epidote, feldspar and quartz (?). The hornblende is very strongly pleochroic, with deep bluish green colours typical of the low-alumina hornblende of low grade metamorphics - x = pale yellowish brown, y = deep bluish green, z = green. Interference figure gives 2V of 75°, with a -ve sign. An occasional twinned crystal may be seen.

The presence of albite-oligoclase is established. Crystals showing multiple twinning have 2V above 80°, but give both +ve and -ve signs. Extinction angles were not obtained. Yet other grains, still with multiple twinning, persistently show 2V of 45-50° and are +ve. There is most likely another feldspar, in a process of alteration.

Quartz is subordinate. Its resemblance to sodic plagioclase makes its proportion hard to estimate.

Scapolite appears as tiny elongate crystals showing high birefringence, straight extinction and length fast character. The scapolite is associated with altering material, perhaps plagioclase.

Sphene - brownish crystals of very high relief and extreme birefringence, either formless or approximating to rhombic section. An occasional biotite crystal of comparable size is associated with the hornblende. Small crystals of pale green chlorite seem to be related to the hornblende.

Epidote of faint yellowish green colour is common throughout the rock.

Many grains are too small for accurate identification but the majority of these are probably epidote, with a little sphene, but some may be zircon and apatite.

The original sediment is thought to be an argillaceous calc-arenite.

A133/47. Spotted biotite-quartz-epidote rock.

This is black schistose rock with whitish blebs of quartz, and notable absence of hornblende. In thin section, quartz, epidote and biotite are approximately equal proportion. They all tend to be idioblastic, giving the rock a granular texture. Quartz grains are equi-dimensional, individually small, but segregate in places to form smooth ovoid patches, averaging 2 mm in length, of interlocking crystals. Tiny inclusions, some biotite or zircon, and perhaps tourmaline, are seen in the quartz.

Biotite crystals are limited in size, and form segregated bundles or patches, which give the rock its coarse schistosity. Pale green epidote crystals, very variable in size, are scattered throughout the rock, and are packed with tiny inclusions of quartz, magnetite and possibly rutile.

Iron-ore mineral occurs mainly in segregations of grains associated with the biotite.

Tourmaline and zircon are distinguished also as individual grains.

One other interesting rock of thisfacies is a coarse actinolite-plagioclase rock which has completely recrystallised to a pegmatitic texture (A133/165).

Calc-silicates above the "Blue" Schist.

These are the rocks sometimes referred to as "dioritised sediments" - an undesirable term, as they only bear a vague mineralogical resemblance (plagioclase - amphibole) to the true diorite.

The rocks form thin bands in the brown schist into which they often pass gradually (c.f. actinolite biotite schist). This would confirm their origin as shaly or felspathic limestones interbedded with dolomitic shales and purer argillaceous sediments.

The calc-silicates are hard and compact, and often show a gneissic structure presumed parallel to original bedding.

With varying proportions of the essential minerals actinolite and sodic plagioclase, and to a lesser degree, epidote and biotite, a number of different calc-silicate and amphibolitic rocks are formed. Some are massive, other are banded, but all are closely related mineralogically.

The only exception is a most peculiar rock containing diopside. Large pyroxene crystals several inches in length form a frame-work which is filled in with solid, but very finely crystallised actinolite (A133/168)., as though it had formed from a liquid oozing in amongst the diopside.

In thin section, actinolite seems to be included in solid diopside, as well as form groups and lines of crystals along the boundaries of the diopside crystals. Calcite is often associated with the latter, which suggests the origin of the rock lies in some secondary, retrograde alteration. The rock is not in equilibrium, as quartz and calcite coexist - in one instance, a quartz grain is embedded in calcite - with diopside.

Schists - grey laminated type.

These schists form a band just east of the main marble horizon, and also outcrop at several places further west. Their oft banded and laminated nature is due to alterations in the proportions of quartzo-felspathic and micaceous material and almost certainly perpetuates the original bedding planes. Change of facies produces a fissile friable sandy mica schist which resembles the micaceous (pelitic) facies of the basal sandstone further south in the Warren area. (This will be used in evidence for the correlation of these grey schists with the basal arkosic sandstone, in the area north of Victoria Creek). Such a rock (A133/91) is essentially composed of quartz-mica-feldspar. Biotite predominates over muscovite, except in thin layers, which are tightly packed muscovite flakes. Individual mica flakes are relatively small, but strongly aligned. Equi-dimensional granular quartz and feldspar make up the bulk of the rock. Quartz is in excess of feldspar, which is mostly albite, with minor microcline.

Tourmaline as small subhedral grains, is pleochroic from greenish-brown to whitish brown. Apatite and zircon are distinguished as minute inclusions in the quartz and feldspar. Iron-ore grains are sparsely scattered in the rock, and hematite as an alteration product of biotite, is common.

"Blue" Schist A133/38

The "blue" schist is a thin bluish-grey resistent band, outcropping persistently, usually as an angular or humpy ridge. Here again, facies changes are quite apparent. Most of the "blue" rock is essentially a quartz muscovite schist, but it may change along the strike to a hard bluish quartzite. The distinctive blue colour is due to a very fine dissemination of heavy mineral, most likely hematite.

In thin section, biotite is only subordinate to muscovite, and an occasional grain of feldspar zircon or rutile is seen. The fabric is very fine-grained, fairly even, and strongly schistose due to near 100% parallel orientation of mica flakes packed in amongst the quartz.

This horizon has been used as the only consistent marker horizon in the area.

Brown Schist

The micaceous schists above the "blue" band are a typical grey-brown colour. They are derived from pelitic and magnesian argillaceous sediments. Their interbedded calc-silicate rocks have already been discussed.

The brown schists vary considerably - from plain fine micaceous rocks to coarse fissile garnet bearing types; crinkled schist; and actinolite schist transitional to the calc-silicate bands. Some of these are now described.

A133/84 Spotted actinolite-quartz-biotite-schist.

The matrix of this rock is composed of approximately equal parts of biotite and quartz, providing a fine granoblastic texture. The amount of feldspar is difficult to assess, but seems to be small. The biotite flakes are strongly aligned imparting a strong schistosity to the rock. Occasional chlorite flakes are interleaved with, or next to biotite, but muscovite has not been recognised. Rounded subhedral grains of greenish-brown tourmaline are present, with occasional hematite. Rounded acicular crystals are probably zircon.

Scattered in abundance are porphyroblasts of actinolitic amphibole, giving the rock its spotted character. Small actinolite crystals also occur in the matrix. The porphyroblasts are generally rounded or ovoid, often sheaf-like in form, but notably always ragged in outline. The actinolite is very pale green, faintly pleochroic, with a 2V approaching 90°.

Tiny formless grains of epidote are scattered sparsely throughout the section, but seem to be more concentrated in or about the actinolite crystals.

Such a schist could originate from a dolomitic shale, or argillaceous dolomitic sandstone.

A133/77[(1)] A coarser grained schist from a strip down the centre of the brown schist, which seems to be a purer argillaceous facies. The rock consists chiefly of biotite and quartz with chlorite, untwinned feldspar (albite), tourmaline and magnetite. There are a few crystals of garnet, which seem to be undergoing alteration.

Relict crystals, now a mass of fine interlocking micaceous (?) material, are elongated and show a strong cleavage perpendicular to the elongation. They seem entirely altered, but perhaps they were andalusite.

A133/78 is fundamentally similar to A133/77 but garnet here appears to be in equilibrium and the relict andalusite crystals are absent.

The brown colour of these schists is likely due to the preponderance of biotite mica.

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(1) See Plate 4.

STRATIGRAPHY:

None of the geological information collected in this project is incompatible with the correlation of these metamorphics with lower Adelaide System rocks. (Campana 1953). Campana strongly backs this view, taken from broad stratigraphic and structural relations, by observing further north in the Tanunda - Greenock area, the schistose rocks gradually passing along the strike into phyllitic and shaly Adelaide-type rocks. Accepting this correlation, there does remain some doubt as to the proposed equivalence of the Victoria Creek marble, to the Castambul dolomite of the Adelaide region.

The arkosic hematite sandstones are readily correlated with the Aldgate sandstone, and rocks above the Blue Schist likewise can be matched with the impure dolomites, dolomitic shales and pelites of the Lower Phyllite Series, thence leading up to the Thick Quartzite on the eastern edge of the map. The sequence below the Blue Schist is not at all clear in this area.

For the purpose of this paper alone, the structure and stratigraphy depend largely on a correlation of the grey laminated schist with the arkosic sandstone. This may appear unnecessary, but the writer feels justified in making this correlation when considering the rock-types and their possible structural relationships. Most previous authors have placed the marble and grey schist (in that order) above the basal sandstones. Admittedly one is immediately prompted to do this, when dealing with lower Adelaide rocks. Furthermore, Campana has extended the "South Warren metasomatic zone" northwards to include the grey schists of the Victoria Creek area, here mapped. There is no need for this, as there is no reason to postulate alumina metasomatism in rocks which are simple metamorphic products of sandy or felspathic argillaceous sediments. The writer feels that even in the micaceous schist zone of the South Warren, perhaps the metasomatic addition of alumina has been over-emphasised (Campana 1953).

If the grey laminated schists are to be considered equivalent to the basal beds, as they are in this paper, then they are merely rocks of a differing (argillaceous) facies.

At several points along the main grey schist beds, the rocks become very sandy, or micaceous and fissile. Not far south of Mattner's, there are outcrops, of sandstone in which bedding planes of heavy mineral have been recognised. Further evidence for a correlation is that the basal sandstone - quartzite - calc-silicate section underlying the "blue schist" north of the Enterprise Mine, compares with a similar section further east, in which the sandy and laminated schists underly the quartzite - calc silicate - "blue schist". (It is noted here that the schistose facies has been made a distinct unit on the fact map, but one and the same unit as the sandstone on the interpretation.).

There is no doubt that the main horizon of the Victoria Creek marble, underlies the laminated schists adjacent on the east. This means that the marble becomes an horizon within the basal series and as such could be correlated with the hornblende - epidote calc-silicate (see back for discussion). This relationship is supported by field association, as the two rock types seem to outcrop close together in several places.

This same sequence of rocks has been investigated on the western limb of the Williamstown Anticline in the South Para Gorge area (Miles 1950). A quick inspection of this part showed the marble lying between sandstone on the east and laminated schists on the west. Perhaps a structurally less complicated area such as this will with detailed mapping, give the true picture, in which we may expect the marble to be just overlying the basal sandstone.

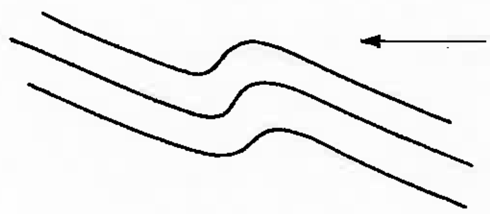
STRUCTURE:

Structural features observed in the field are listed and discussed. A structural section has been drawn, but is mostly based on interpretation

Folding.

The schists, marble and calc silicates are considered to form the east limb of the north-pitching Williamstown Anticline, which axis passes through the oval trending at about 330° (Campana). No actual turnover is observed in the area mapped, and the fold axis must pass into the Lyndoch-Williamstown fault-line further south. Facings taken on current bedded sandstones prove the beds to be right way up. Difficulties in mapping the sandstone structure arise from absence of any continuous horizon, and very weathered outcrops. Current bedding in small exposures may lead to quite large errors in dip-strike measurements.

It is apparent from visible outcrops and variable strikes and dips, that the sandstones are recurringly drag-folded, which would account for their seemingly great thickness. The drags imply an overthrusting from the east, producing asymmetric structures as shown.



The anticlines have extended easy limbs with short steeper west limbs.

The drag folds, which are also found in a number of places away from the sandstone, signify only moderately tight folding. The plunges of all lineations and smaller folds are generally inconsistent both in direction and magnitude. There is not sufficient data to make deductions based on the petrofabrics, but it can be noticed there are in a broad sense two groups of lineations, almost all of which are b - lineations. One set plunges consistently to the north-east, the other has a mean trend about 30°W of N., but may plunge either N or S. This could result from two separate phases of folding - note the gentle flexure trending due north through the centre of the map.

Beginning in the calc-silicate beneath Ross' Bridge, and closely following this band northward to the crush zone is a thin layer of intensely folded rock - sometimes in the calc-silicate, sometimes in the sandstone. Some of the folds a few feet in magnitude appear almost an echelon type - something to be expected in an area of combined thrusting and faulting and varied plunges. The unusual thing about this crumpled zone is that the plunges are near vertical, or steep either north or south. No explanation can be given for this zone, to fit the structural picture.

Lineations other than crinkles and microfolds are rare. A couple of measurements on aligned tremolite and hornblende needles were taken.

As the Thick Quartzite ridge is approached, the brown schist becomes entirely crinkled. This lineation is near horizontal, and may have been intensified by the over-riding quartzite.

FAULTING:

The Lyndoch-Williamstown Fault.

This fault has been placed along the join of the phyllitic series on the west, with the sandstone schist to the east. There is no contact visible in the region mapped. A fairly prominent scarp marks the line of the fault, for which there is no other direct evidence. Only the crush zone in the north and brecciated, ferruginised sandstones in the south can support its probable existence. In the South Para Gorge, Miles claims good evidence from conflicting structures on either side of the fault. In using this fault to explain the change of metamorphic grade from schist to phyllite, it should be pointed out that the change is not a big one, and could feasibly be progressive.

The Enterprise Fault.

There is no doubt about the existence of this fault. It looks to be a steep east-dipping reverse fault, which would imitate the Lyndoch-Williamstown Fault. The Enterprise Fault can be followed from Hausler's where it throws marble up against sandstone, through the Enterprise Mine, and south to Victoria Creek, whence it most likely passes over to the metasomatic zone. The fault is marked by a line of quartz veins, mineralised in places, and retrograde marbles. Perhaps the marble has served as a lubricant on the fault plane.

Strongest shearing seems to have occurred just west of the Enterprise Fault, and shows itself especially in the sandstone.

A fault outcropping along Victoria Creek is cut off by the Enterprise Fault. The former one itself, seems to truncate the small syncline just east of the Enterprise Fault.

Metamorphism

The schists and marbles belong to a regionally metamorphosed province of rather low grade. The epidote-hornblende calc-silicates belong to the albite-epidote amphibolite facies, and no other rocks in the area can be assigned to a more advanced metamorphic facies. Many rocks do not have distinctive assemblages.

The phyllitic shale series exists west of the schists, and is of somewhat lower grade, although there are calc-silicates (albite-actinolite rocks) within the phyllites, which are very similar to rocks in Victoria Creek.

Retrograde metamorphism has already been discussed in the marbles. Its effects are also seen in other rocks (e.g. breakdown of andalusite in schists; growth of porphyroblastic unoriented muscovite in schists; possible alteration of diopside in calc-silicates) and it is expected that an area folded and faulted, and close to a hydrothermal centre, will be particularly susceptible to retrograde processes.

ACKNOWLEDGEMENTS

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Dr. Skinner has introduced me to, and assisted me in, the various x-ray and photographic methods.

I also wish to thank Miss A. Swan for her willing advice in the preparation of maps.

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Verhoogen, J.

PLATE 1

Marble outcrop in south bank of Victoria Creek, east of Ross' Bridge.

PLATE 2

Outcropping marble in Victoria Creek. Note foliation, probably defining original bedding planes.

PLATE 3

Terrain mapped north-east of Williamstown.

PLATE 4

Typical ridge forming schists - here low dipping garnet mica schist.

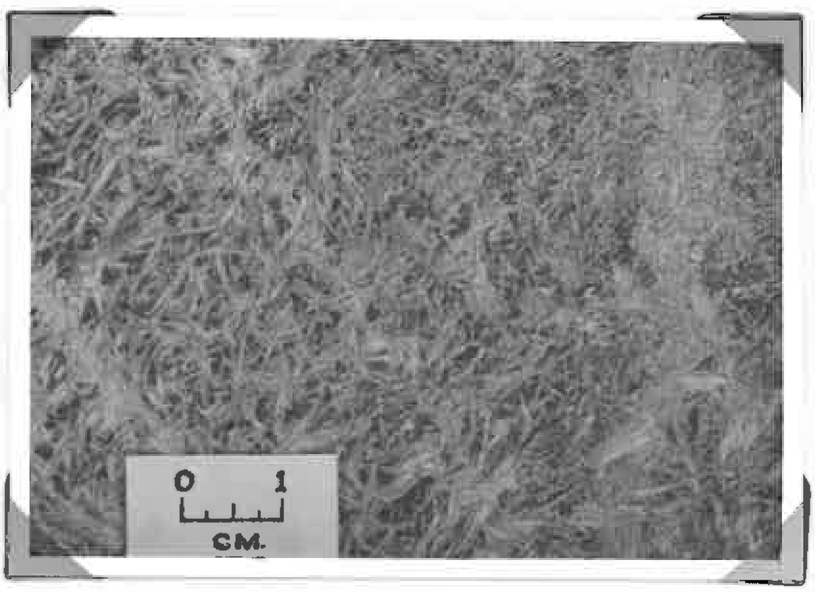


PLATE 5

A133/138 Talc-tremolite schist - Enterprise Mine.

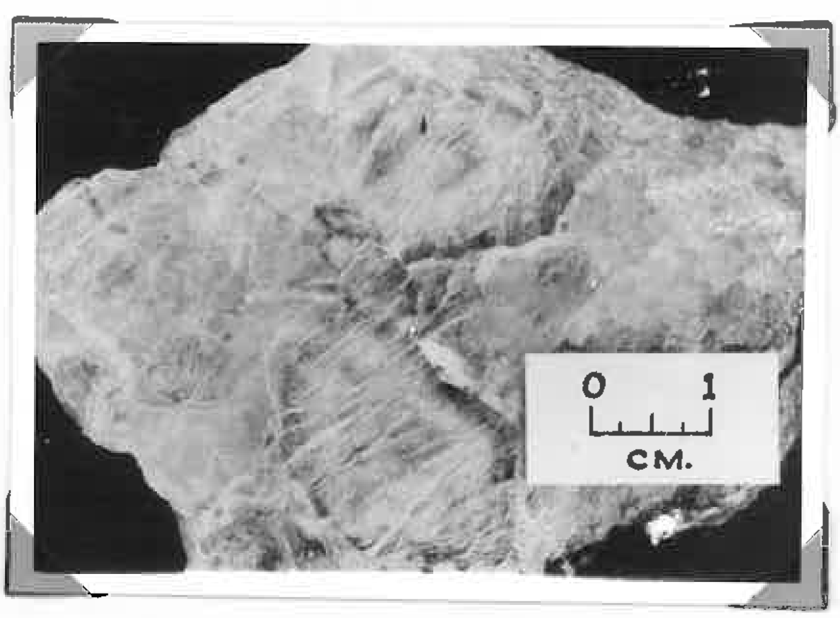


PLATE 6

A133/28 Serpentine nodules in marble (as for A133/127)

PLATE 7

A133/127 Dolomite grains showing the development of fibrous serpentine along cleavage planes. (x10).

PLATE 8

A133/13 Siliceous (cherty) material attacking and replacing carbonate in a highly tremolitic rock. Note the diamond shaped cross-sections of amphibole. (X10).

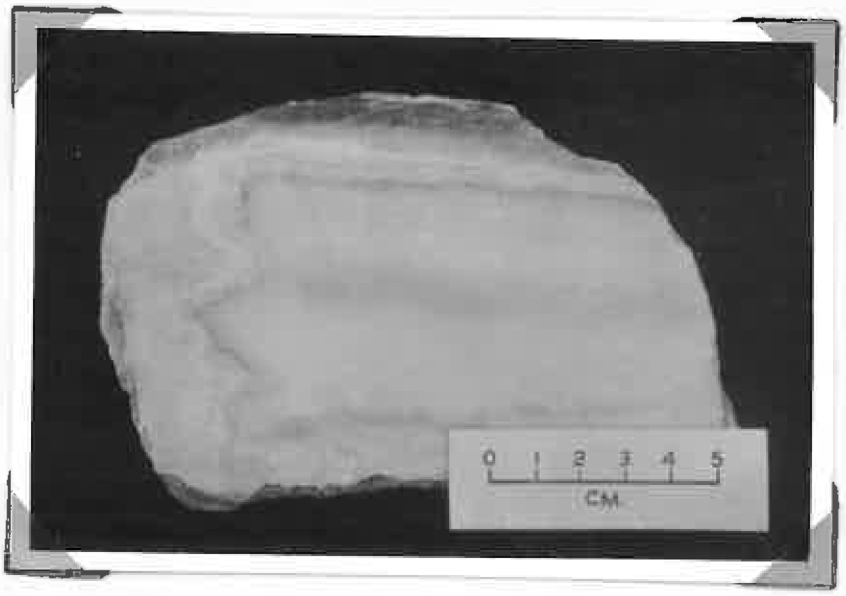


PLATE 9

A133/139 Hand specimen, showing the central crystalline marble, separated from the outer talc carbonate zone by a brown layer of calcite. Dark layer (at top) is serpentine.

Below is the photograph of thin section (X10) at the boundary of the brown calcite, and inner, relatively unaltered marble. The "reaction front" is advancing upward into crystalline magnesian marble, leaving behind it a texturally rather nondescript talc-carbonate mass. (lower half).

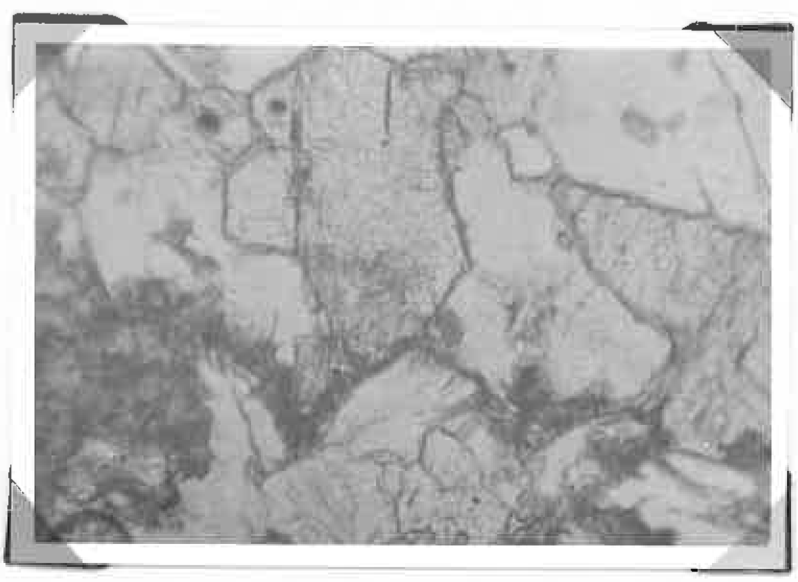


PLATE 10

PLATE 11

A133/128 Demonstrating local alteration in the white marble. A thin zone or "alteration channel" of talc-tremolite (diagonal across lower right corner) cutting crystalline dolomite. Note twin lamellae in dolomite grains (X10).

LOCATION OF SPECIMENS FROM WILLIAMSTOWN AREA COLLECTED BY

I. B. FREYTAG

(Thesis: "Victoria Creek Marble)

Accession No. 133

6 Pegmatite large outcrops ½ mile due north of Oval. Ref.899168

7 Actinolitic arkose 550 yards due north of Oval. Ref. 899168.

9 Altered rock from persistent band ¾ mile south of Enterprise Mine Ref. 896177.

11 Grey marble from Victoria Creek, 600 yards due west of Ross Brid Ref. 903167.

13 Dolomitic Marble from hillside 600 yards NW of Ross Bridge. Ref. 908169.

17 Tremolite clot in marble from hillside 600 yards NW of Ross Bri Ref. 908169.

19 Quartz-albite-actinolite rock from Victoria Creek, 330 yards we of Ross Bridge. Ref. 908167.

20 Mylonite(?) gneiss from sheared zone. Ref. 900167.

22 Chlorite-mica schist from vicinity of Ross Bridge. Ref. 91116

26 Tremolite marble from 400 yards east of Ross Bridge. Ref. 91416

28 Serpentine Marble from Victoria Creek, 400 yards east of Ross Bridge. Ref. 914163.

29 Banded serpentine marble from Victoria Creek, 150 yards east of Ross Bridge. Ref. 913163.

35 Laminated basal sandstone from ¾ mile south of Enterprise Mine. Ref. 897177.

37 Hematitic sandstone from 550 yards NW of Enterprise Mine. Ref. 893190.

38 "Blue" Schist from ¼ mile west of Mattner's Homestead. Ref.898193.

39 Schistose quartz-mica-feldspar rock from 950 yards south of Enterprise Mine. Ref. 895178.

40 Epidote schist from 950 yards south of Enterprise Mine. Ref.896178.

42 Calc silicate gneiss from 950 yards south of Enterprise Mine. Ref. 896178.

43 Magnetite schist from 950 yards south of Enterprise Mine. Ref. 895178.

47 Spotted calc-silicate rock. Ref. 904169.

69 Pyritic quartz-feldspar rock. Ref. 913168.

74 Calc-silicate rock. Ref. 915167.

77 (?) Andalusite schist. Ref. 917168.

78 Garnet schist. Ref. 917168.

79 Amphibolite. Ref. 917170.

82 Altered Andalusite(?) schist. Ref. 909183.

84 Speckly (actin.) schist from $\frac{1}{4}$ mile east of Mattner's Homestead. Ref. 905193.

91 Laminated sandy micaceous schist from 1000 yards NW of Ross Bridge. Ref. 905176.

93 Chert-tremolite rock from metasomatic zone 1000 yards S. of Mt. Crawford road. Ref. 912154.

95 Serpentine Silica rock from Metasomatic zone $\frac{1}{4}$ mile south of Mt. Crawford. Ref. 913158.

96 Kyanite from metasomatic zone 30 yards south of Mt. Crawford road (Hamiltons Property). Ref. 912163.

98 Serpentine Rock from Metasomatic zone 1000 yards south of Mt. Crawford Road. Ref. 912154.

99 Recrystallized iron ore mineral from Mausler's Mine. Ref. 895197

103 Asbestos Marble from Victoria Creek (Sharp turn $\frac{1}{4}$ mile approx. west of Ross Bridge). Ref. 907168.

113 Calc-silicate rock from $\frac{1}{2}$ mile north of Ross Bridge. Ref. 915173.

122 Talc Marble from Victoria Creek, 400 yards east of Ross Bridge. Ref. 914163.

124 Talcose Marble from Victoria Creek, 400 yards east of Ross Bridge Ref. 914163.

127 Serpentine Marble from Victoria Creek, 400 yards east of Ross Bridge. Ref. 914163.

128 Phlogopite Marble from $\frac{1}{2}$ mile south of Enterprise Mine. Ref. 896

130 Calc-silicate rock from $\frac{1}{4}$ mile north of Enterprise Mine. Ref. 898189.

132 Green marble from knoll $\frac{1}{2}$ mile south-east of Enterprise Mine. Ref. 899178.

135 Grey Marble from dumps at Enterprise Mine. Ref. 896185.

138 Talc-tremolite schist from dumps at Enterprise Mine. Ref. 8961

139 Altered Marble from dumps at Enterprise Mine. Ref. 896185.

141 Coarser Marble from creek 330 yards north of Hauslers Mine. Ref. 896200.

142 Tremolite-silicate rock from 350 yards south-east of Mattner's Homestead. Ref. 912154.

151 Sandy calc silicate rock from $\frac{1}{2}$ mile E. of N from Oval. Ref. 90216

155 Quartz-feldspar-hornblende rock from 650 yards W of S of Enterprise Mine. Ref. 895181.

156 Amphibolite from Victoria Creek, $\frac{1}{4}$ mile NE of Oval. Ref. 901163.

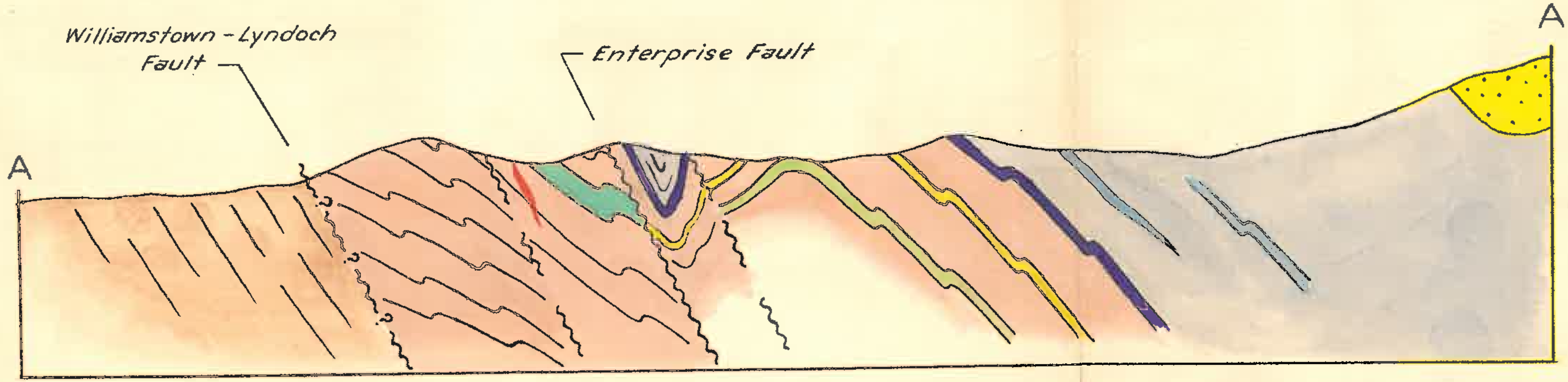
161 Calc-silicate rock from Victoria Creek, approx. $\frac{1}{4}$ mile due west of W-L Fault. Layers in the shales. Ref. 892161.

165 Pegmatitic actinolite-plagioclase rock from Victoria Creek, $\frac{1}{4}$ mile NE of Oval. Ref. 901163.

169 Marble from 500 yards W of N of Enterprise Mine. Ref. 895189.

168 Calc-silicate rock. Ref. 926162.

DIAGRAMMATIC INTERPRETIVE GEOLOGICAL SECTION A-A (LOOKING NORTH)

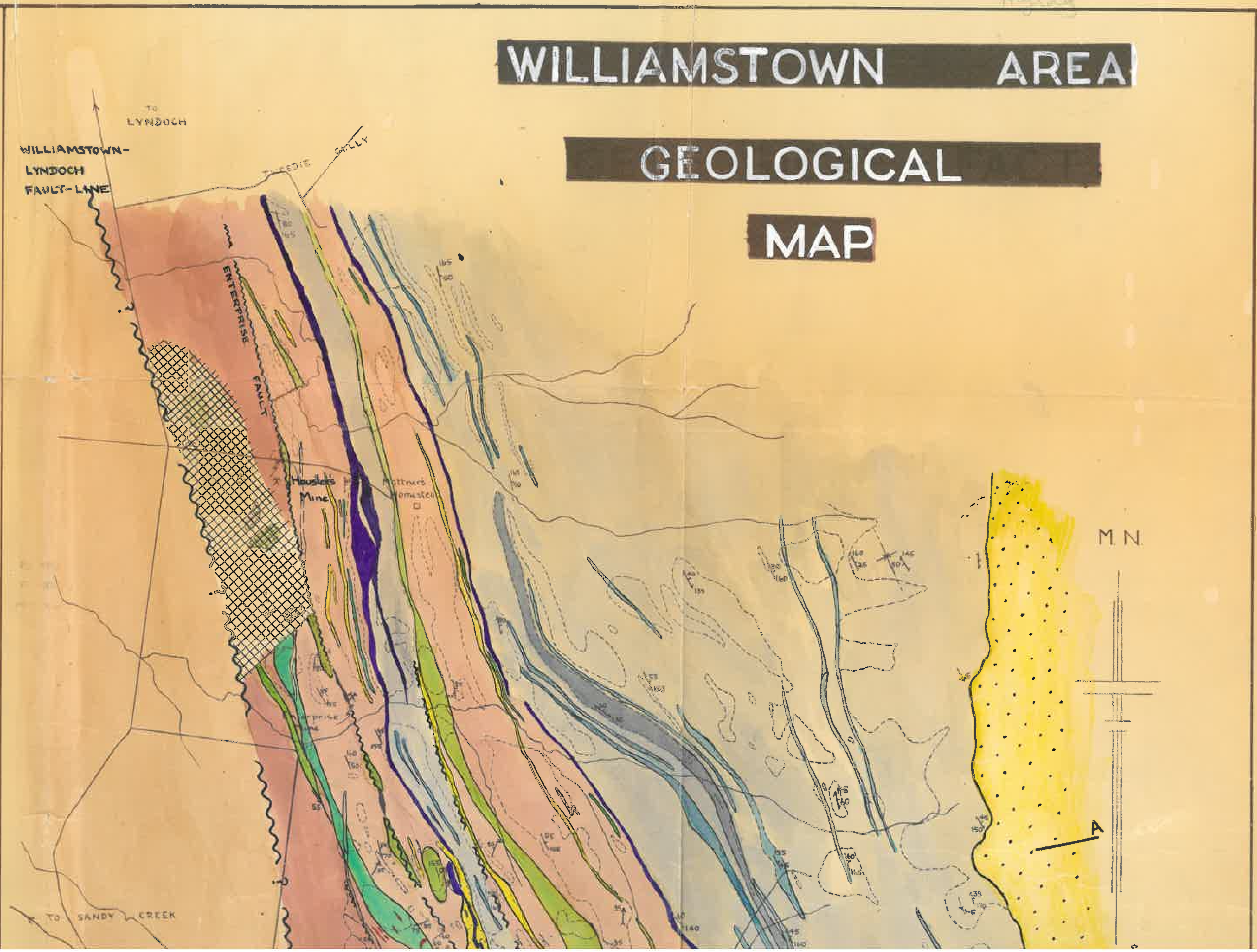


...oside type.

rock (albite-
rock.

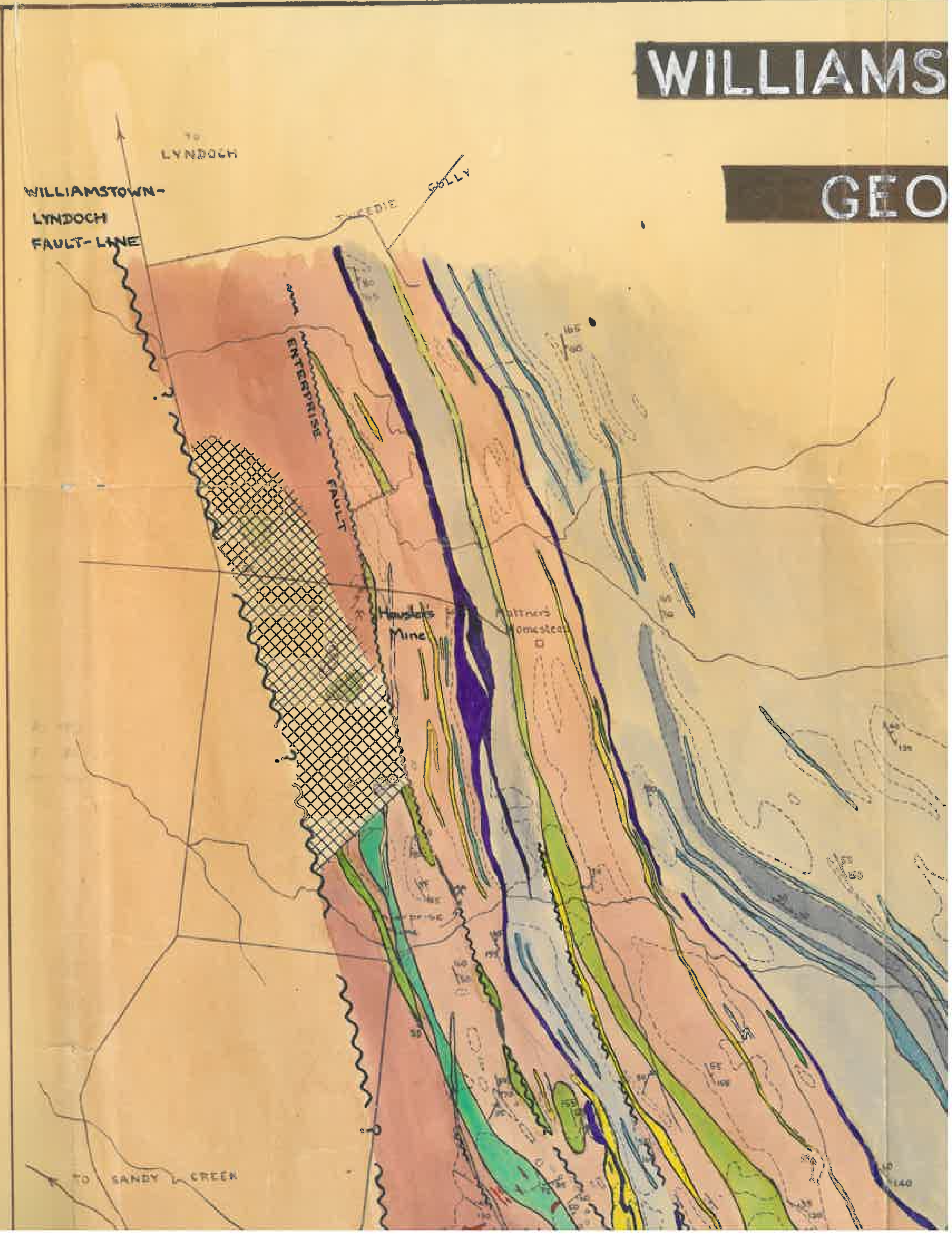
... sandstone;

WILLIAMSTOWN AREA GEOLOGICAL MAP



— LEGEND —

- "Thick Quartzite".
- Calc-silicate Rock — actinolite-plagioclase-diopside type.
- Schist — garnet andalusite? type.
- Schist — brown type; crinkly schist.
- "Blue Schist".
- Quartzite.
- Schist — grey laminated type.
- Victoria Creek Marble.
- Amphibolite; basic gneiss; calc-silicate rock (albite-epidote-hornblende type); albite-actinolite rock.
- Blue-grey phyllitic shale; dark grey shale
- Basal (Aldgate) Beds — cross-bedded hematitic sandstone; arkose; pebbly conglomerate; quartz schist.



Quartzite.

Schist — grey laminated type.

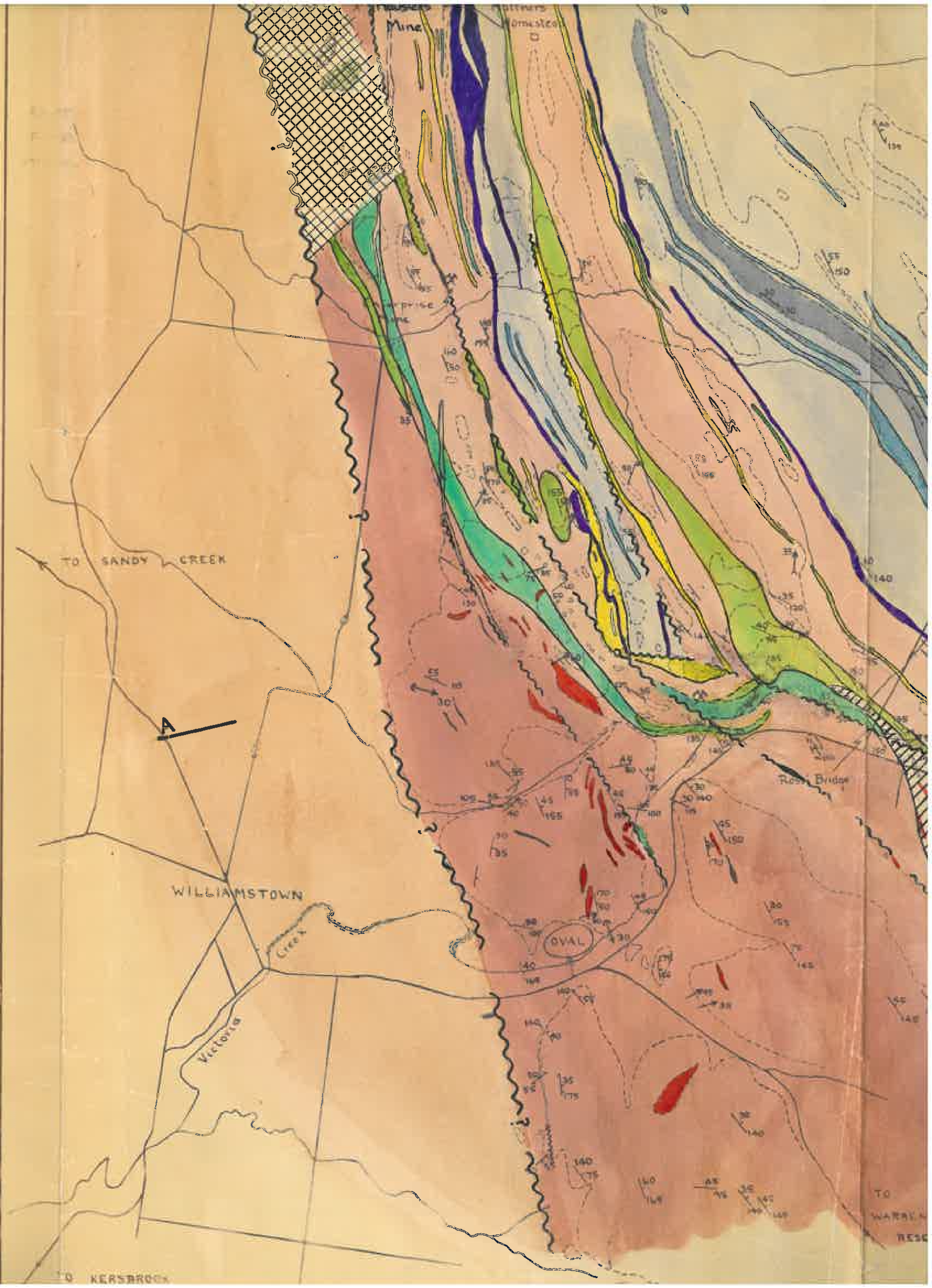
Victoria Creek Marble.

Amphibolite; basic gneiss; calc-silicate rock (albite-epidote-hornblende type); albite-actinolite rock.

Blue-grey phyllitic shale; dark grey shale

Basal (Aldgate) Beds — cross-bedded hematitic sandstone; arkose; pebbly conglomerate; quartz schist.

Pegmatite.
Quartz vein.
Metasomatic and pegmatized zone.
Crush zone.
Fault.
Bedding.
Schistosity.
Lineation, microfold.
Pitching syncline.
Pitching anticline.
Mine, pit



rock (albite -
rock .

sandstone;