AN INTRODUCTION

TO

GRANITIZATION AND HYBRIDIZATION

AT ROSETTA HEAD.

by

D.R. BOWES, B.Sc.

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Supervisor: Sir Douglas Mawson

1.

I. INTRODUCTION.

The occurence of granite in the Encounter Bay Area, has been a subject of interest to all South Australian Geologists. The granite outcrops at Port Elliot, Granite Island, Victor Harbour and also at Rosetta Head (commonly known as The Bluff).

A number of unusual rock types (as well as the granite) occuring at Rosetta Head were first described by W. R. Browne in his paper entitled "The Igneous Rocks of Encounter Bay, South Australia." (1) The most prominent of these was his "albite mica syenite" which does not outcrop anywhere else in this area.

Browne's general description of this rock is....."the relative proportions of the main constituents vary considerably from place to place and there are likewise textual variations. Sometimes the rock is porphyritic and at other times phenocrysts are absent. For the most part mica is subordinate, but near the contact with the schists it increases in amount until it predominates over the feldspar and in places the syenite actually appears to merge gradually into the country rock."

This description makes it appear that the rock is not typically igneous. The outcrop of the "syenite" follows the granite - country rock (a hornfels type) contact and this suggests that the rock is not solely of igneous origin, but is due to the mixing of the granite with the country rock.

Browne also described "Impregnation near the Syenite Contact." Here there are tongues and stringers of "syenite" and granite running through very highly altered country rock. The "syenite" itself as well as the country rock becomes very micaceous. Browne considers that "the albite syenite was first injected with accompanying veins and veinlets, the country rock being impregnated with albite and to a less degree, with rutile, zircon and apatite. Subsequently circulating solutions, still magmatic in character attacked the biotite of both igneous rocks and schists, converting it to chlorite."

Also described were a cordierite mica schist and an andalusite mica schist from Petrel Cove. These were described as contact metamorphic features.

The area around Rosetta Head has been mapped, a series of rocks analysed and a number of slides examined. The auther feels that these unusual types can be ascribed to segregation (and granitisation) and hybridisation. This is the object of the thesis.

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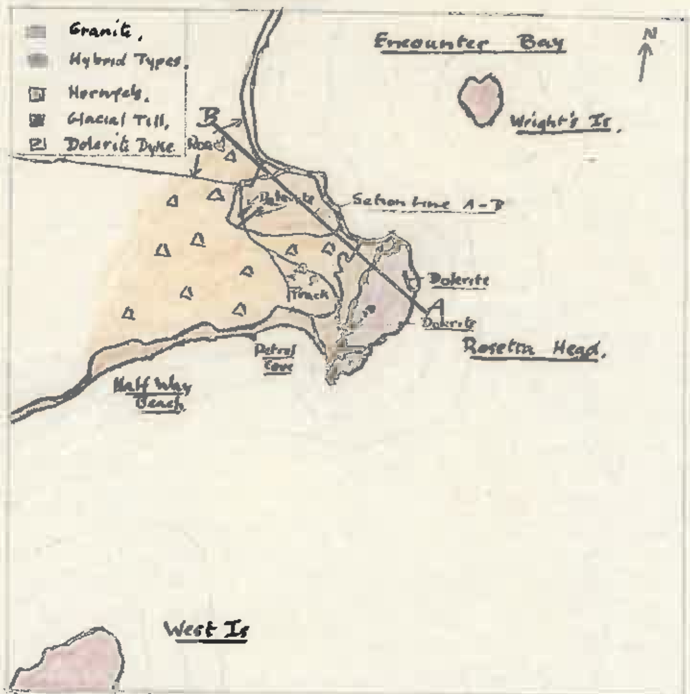
(1) W.R. Browne "The Igneous Rocks of Encounter Bay South Australia". Transactions of Royal Society of South Australia, Vol XLV., 1920.

II. GENERAL GEOLOGY AND PHYSIOGRAPHY.

Fig. I



At the western extremity of Encounter Bay is the large promontory, Rossetta Head (or better known as "The Bluff"), which juts abruptly out of the sea to the height of approximately 320' above sea level.

The seaward end of this headland is composed of a large granite mass which has been intruded into a gently folded series of hornfels.

Permian glaciation has determined the present topography. The present seaward end of The Bluff (and also the neighbouring islands, Wright's Is. and West Is.), being composed of granite, offered great resistance, and so the ice rode over the top of these cupola like masses and carried away any sediments that may have been covering the granite at the time. On encountering the soft hornfels on the landward side, the ice carved down deep, and so left the large granite mass elevated above its surroundings.

Glacial till was dumped by the ice, and this unconsolidated material covers a large area in the immediate vicinity. The main erratics are of granite, and with the erosion of the softer, finely ground, material, these granite boulders have been left studded about the fields.

Howchin[1] has described the glacial deposits of this area, and as their occurrence does not affect the problem under discussion, no more will be written concerning them.

Fig. II is a diagrammatic section from A-B of Fig. I. Broad details only are given and the vertical scale is exaggerated.

Fig. II

W. Howchin.
(1) Transactions of the Royal Society of South Australia., 1904, 1906, 1910 etc. "Geology of South Australia"

In the above section the hybrid types occurring at the contact has been omitted.

Plates III and IV of Howchin's paper[1] and Fig. 2, Plate III of Browne's paper[2] give a good idea of the general physiography of the headland.

The granite has made its way up along the bedding planes of the hornfels which are dipping (at the contact) at approximately $35-40^{\circ}$ ↦ S. In the field there seems to be no flow structure or alignment of phenocrysts in the granite mass, but the aerial photograph seems to indicate some alignment in the direction perpendicular to the seaward face of the mass.

Wright's Island, The Bluff and West Island show definite alignment - this corresponds approximately with that of the regional cleavage ($20-25^{\circ}$ E of N). Probably the regional cleavage, as well as the bedding, was a factor in determining the direction of intrusion.

These three granite outcrops have the appearance of being cupolas of an underlying batholith. The Bluff itself has the appearance of being a roches moutonnées.

The granite made way for itself, in this upper part of the batholith, by piecemeal stoping of the country rock. Numerous inclusions of stoped blocks that have been soaked in granite 'juices' outcrop within the granite mass itself.

The folded series of metamorphosed sediments that comprise the landward side of the headland have been termed hornfels. Actually, throughout this area they show a definite preferred orientation, and in parts a definite banding, so probably a better term would be quartz-biotite-schist.

The general strike of the beds is $50-60^{\circ}$ E of N, but the dip varies due to the beds being folded into synclines and anticlines which pitch gently towards the south-west.

The regional cleavage of the area is approximately $20-25^{\circ}$ E of N, but it varies to about 35° E of N around towards Half-Way Beach. The dip of this schistosity is approximately 70° ↦ S.

Along the coast from Petrel Cove to Half-Way Beach there is a wave cut platform of metamorphosed sediments. The face of the cliffs are also of the same rock. Outcropping on top of these cliffs and back inland is Permian Glacial Till. There are also a few small patches of Kunkar.

Bands of both cordierite and andalusite (knotted) schist outcrop on this platform, especially in and just to the west of Petrel Cove. These bands (up to 20' across) seem to cut across both the regional cleavage (which strikes 25° E of N and dips 70° ↦ S), and the bedding (which strikes 60° E of N and dips at about 30° ↦ S). The bands of knotted schist mainly run in the direction 45° E of N, and all dip ↦ S.

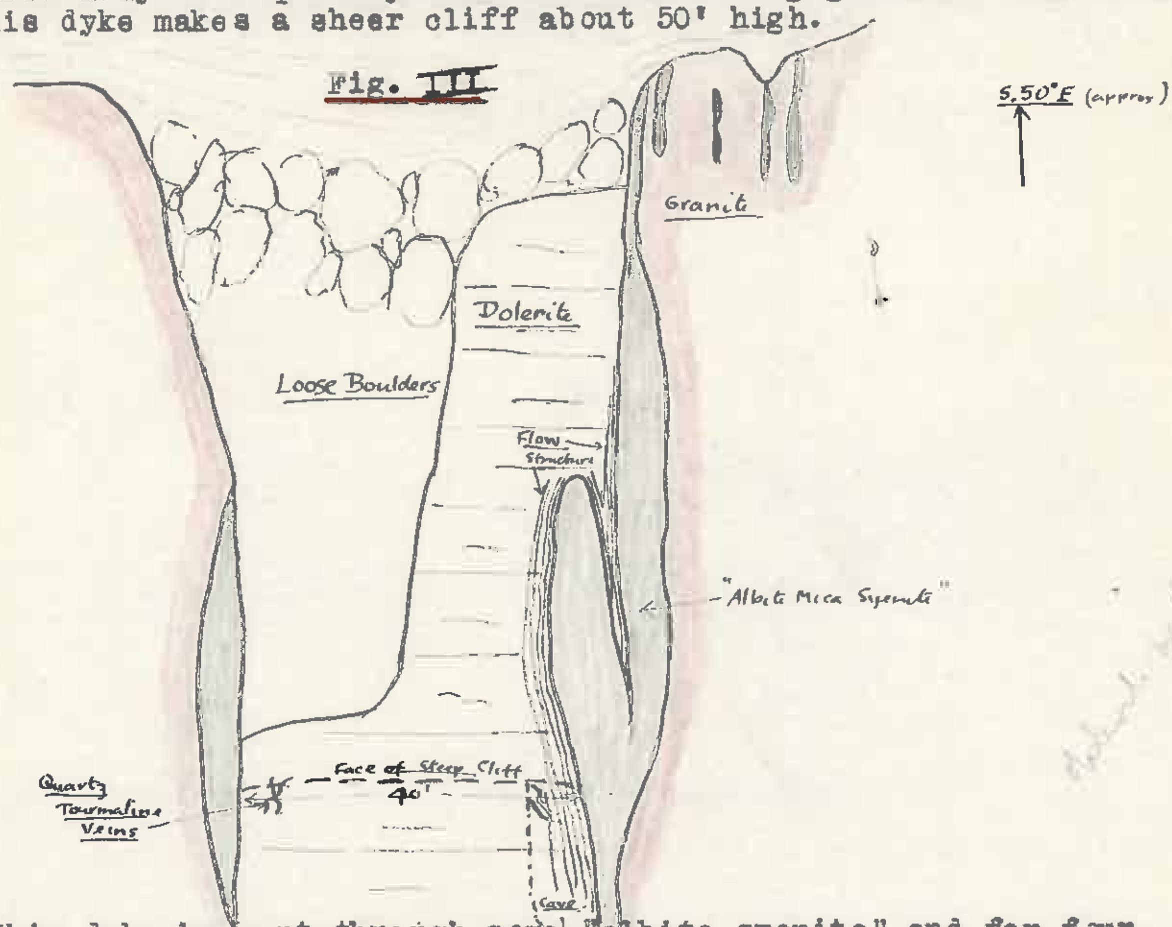
Much difficulty was experienced in determining the dip and strike of the sediments owing to the metamorphism that they had undergone. The presence of all numerous joints as well as pegmatitic and quartz veins made the task even more difficult.

Occurring at Petrel Cove, Half-Way Beach, and sandy points in between, are patches of reddish coloured gem sand. This sand is made up mainly of red garnet, black magnetite and clear quartz. Accessory minerals (zircon, rutile etc.) are also present. The mineral grains have been derived from the hornfels, and also from the overlying till.

(1) W. Howchin op. cit 1910.
(2) W.R. Browne op. cit

A number of dolerite dykes outcrop within the area mapped. One occurs on the seaward (eastern side) of the Headland. Here a bay has been formed due to the fact that the dolerite has been weathered away more quickly than the surrounding granite. The face of this dyke makes a sheer cliff about 50' high.

Fig. III



This dyke has cut through some "albite syenite" and for four or five inches from the contact parallel flow banding is shown by the dolerite.

Cut in at the bottom of the cliff of dolerite is a cave, in which can be seen quartz-tourmaline veins that cut the dolerite.

The dyke runs in from the sea in the direction 55° W of N - this is one of the main directions of jointing in the granite. About 40 yards inland the direction of the dyke changes to an approximately northerly direction - another of the directions of jointing in the granite - and runs for a further 60 yards. It is hidden in parts by granite and fallen granite boulders. The dyke is approximately 75' wide when it enters the sea, but tapers down to about 30' inland.

Another dyke is seen on the western side of The Bluff where the path crosses the hornfels - granite contact. The dyke is bearing 60° W of N and is 40 yards long and 18' wide. It is bounded on one side (~~western~~ southern side) by "albite syenite" for most of the way. At the top end it is bounded by granite, but it cuts through the contact into the hornfels.

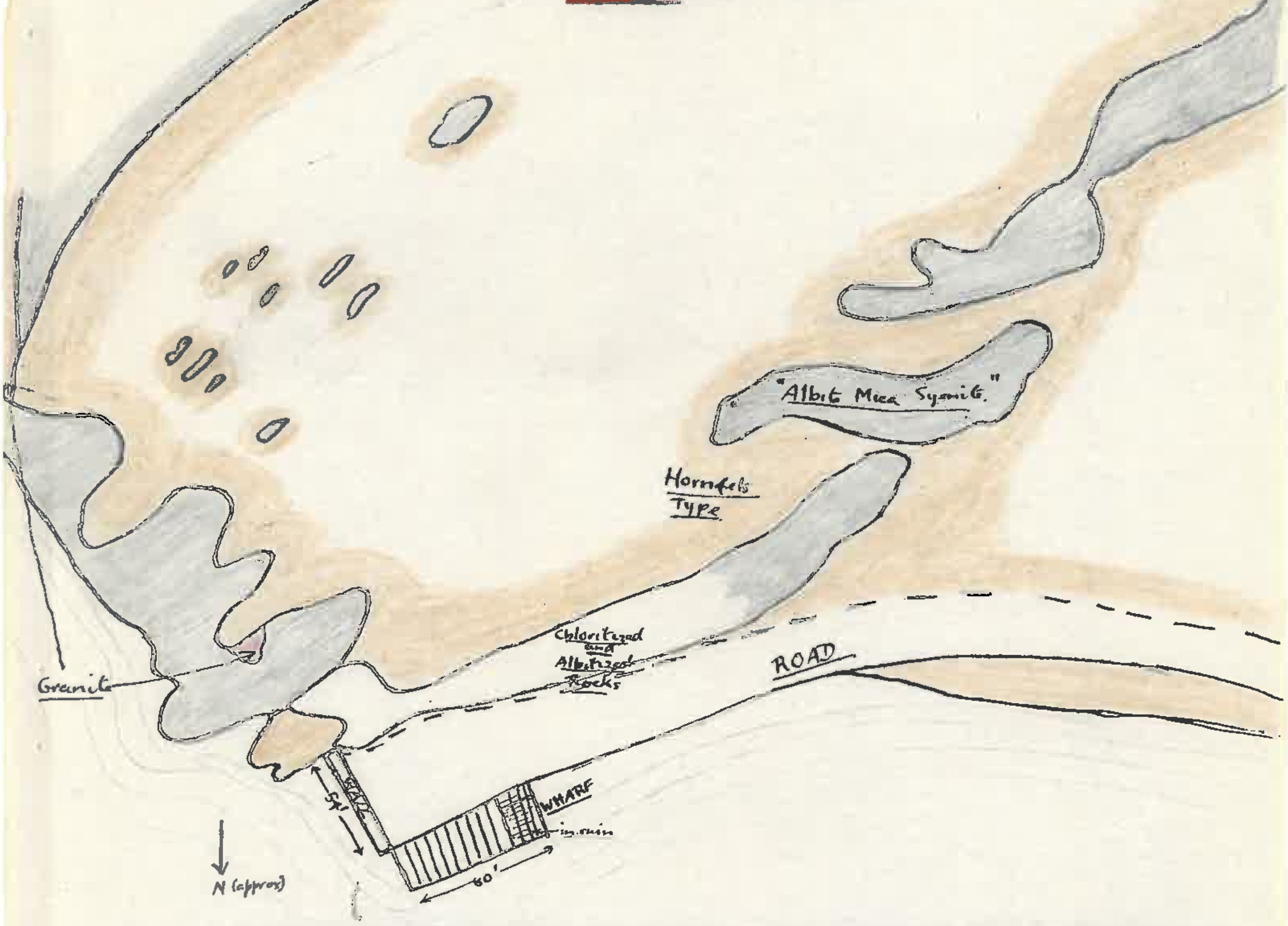
Two other parallel dykes running in the direction 30° E of N are found about 600 yards north of the granite-hornfels contact. The one nearest the headland outcrops for 80 yards and is 15' wide. About 20 yards further north is a parallel dyke that outcrops for 24 yards and is 36' wide.

The rock termed "albite mica syenite" by Browne is of quite common occurrence, but is mainly found in association with the granite - hornfels contact. This rock occurs between the granite and the hornfels practically all the way round the contact. It also occurs, but not showing any obvious relation to the hornfels in other parts, being present as outcrops surrounded by granite. There are a number of such patches between the wharf and the large dolerite dyke ~~and~~ on the east side of the headland. This dyke also cuts through some "syenite"; also, nearly around to the SW tip of the Bluff get another outcrop of "syenite" in granite.

The "syenite" also outcrops without any obvious relation to the granite in yet other parts, being present as outcrops surrounded by hornfels. Such outcrops are seen just south of the wharf in the large hornfels block that has nearly been cut off from the adjacent hornfels.

The following sketch illustrates the outcrops mentioned above:-

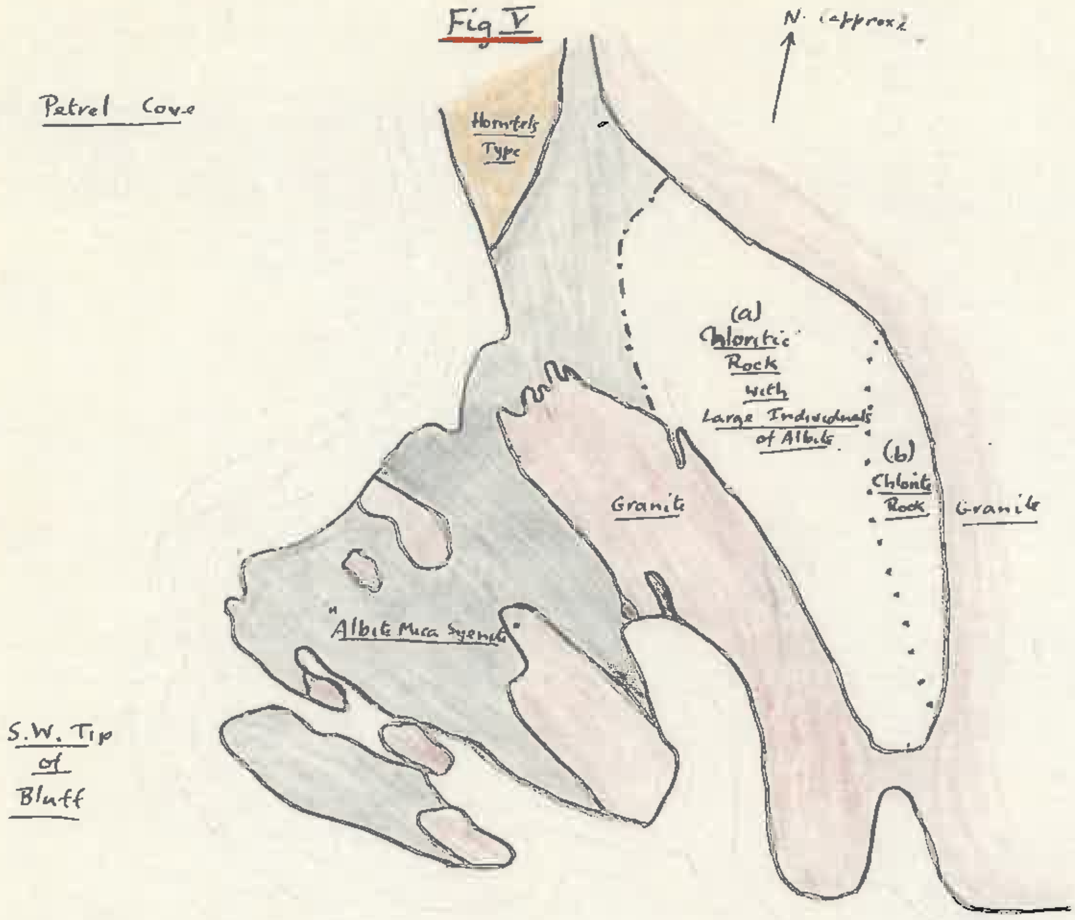
Fig. IV



Further to the south along this east coast of the headland occur what look like "tongues of syenite" running in direction approx. 80° E of S. There are a number of such "tongues". In the middle of one of these is a mass of chloritic material about 12 yards long by 2'6" wide.

The best exposed outcrops of the "syenite" are shown on the SW tip of the Bluff.

The following sketch shows these outcrops.



Here there are extensive outcrops of the "syenite" and its relation to both the granite and the hornfels is well shown. In each case the contact is very sharp. The granite tongues in and out of the "syenite" as shown in the figure.

There are also outcrops of two unusual types -

(a) A chloritic rock containing large rounded individuals of albite (up to 1½" x 1½" x 1½"). The contact between the "albite syenite" and this chloritic rock is quite sharp. It is shown up well by the fact that there is a sharp cliff-like face at the contact. This chloritic rock with large albite individuals occurs at a higher level (above sea level) than does the actual "albite syenite" (in this area).

(b) A rock composed practically wholly of finely interwoven flakes of chloritic material. This type shows no large albite individuals. The contact between these two types ((a) and (b)) is not very sharply defined.

The cliff of chloritic rock with large individuals of albite looks like a basalt from a distance as the large albites drop out on weathering leaving a dark coloured rock riddled with holes.

By the wharf (on the opposite side of the headland) occur very dark greenish chloritic types. These are mixed with less chloritic rocks and rocks that are practically free from chlorite but very rich in fine grained albite crystals (so a white colour). There is a definite zoning of types.

In this area there are veins and tongues of both granite and "syenite" cutting through the surrounding rocks.

It is obvious that the geology of this area is very complicated.

III PETROGRAPHY.

A. THE HORNFELS.

A dark greyish coloured even grained rock of sedimentary origin that has undergone metamorphism of a regional nature. It would probably be better designated as a quartz-feldspar-biotite schist as it shows a definite preferred orientation. (This is the regional cleavage - approx. N20°E). A hornfels with its typical decussate texture is the result of thermal metamorphism.

I am indebted to my colleague, Mr. E. G. Robinson B.Sc., who has been researching on the hornfels, for the following description of a hornfels from near Rosetta Head.

The specimen is very fine and evenly grained consisting essentually of quartz and biotite. The quartz occurs in a granoblastic state of state of small clear and uncracked grains which undoubtedly have been recrystallised. They form a mosaic throughout which the other minerals are dispersed. The biotite is abundant and occurs as small flakes of highly pleochroic nature in light brown - dark brown. Aggregations are common and here the flakes exhibit a decussate texture and generally have a weakly preferred orientation. This is more noticeable because of the high pleochroism.

Some orthoclase is present as small grains toward which the quartz is idioblastic. A few clear grains of albite (Ab_{95} An_5) are present. Magnetite, with a little apatite and tourmaline are seen as tiny grains.

The rock is a quartz biotite hornfels that is weakly schistosic.

Rock III in Table I, which occurs about ½ mile north of Rosetta Head, differs from the above rock by having more pellucid grains of albite and by having quite a marked preferred orientation.

Rock I in Table I, which occurs 200 yards north of the granite contact contains much more biotite and also has a strong schistosity. The biotite flakes show up the preferred orientation. There are also a few muscovite flakes present. This rock has been called a schistose hornfels but would probably be better described by the name quartz, biotite schist as it does not show the typical decussate texture of a hornfels and also shows a marked regional cleavage.

The following table shows the analysis of hornfels of the area.

TABLE I

	I	II	III	IV
SiO_2	58.82	63.55	68.76	72.90
TiO_2	0.96	0.86	0.74	0.56
Al_2O_3	18.34	16.55	13.79	13.74
Fe_2O_3	0.96	0.97	0.66	0.04
FeO	5.93	4.67	4.60	3.29
MnO	0.05	0.09	0.07	n.d.
MgO	4.00	3.12	2.65	1.85
CaO	3.53	3.11	2.81	2.12
Na_2O	3.39	3.33	2.54	3.02
K_2O	3.28	3.24	2.29	1.99
H_2O+	0.27	0.50	0.53	0.46
H_2O- (110°C)	0.10	0.10	0.04	0.11
P_2O_5	0.19	0.19	0.21	0.15
ZrO_2	0.05	tr	0.19	n.d.
BaO	0.05	0.05	0.14	n.d.
S	0.03	0.19	0.13	n.d.
	99.95	100.52	100.15	100.23
Less O for S	0.01	0.08	0.05	---
Total	99.94	100.44	100.10	100.23

I Schistose Hornfels - 200 yards from igneous contact, Rosetta Head.
Anal. D. R. Bowes

II Hornfels Phase from Inclusion on Breakwater, Granite Island, Victor Harbour.
Anal. A. W. Kleeman. (1)

III Hornfels - ½ mile north of Rosetta Head
Anal. D. R. Bowes

IV Sedimentary Inclusion, Breakwater Quarry, Granite Island, Victor Harbour.
Anal. A. W. Kleeman. (1)

(1) A.W. Kleeman. "The Nature and Origin of the So-called Diorite Inclusions in the Granite of Granite Island" Transactions of Royal Society of South Australia. Vol LXI, 1937.

TABLE II

NORMS OF ROCKS.
of Table I

		I	II	III	IV
Quartz		9.15	18.36	32.52	38.76
Orthoclase		19.46	18.90	13.34	11.68
Albite		28.82	28.30	21.48	25.15
Anorthite		16.96	14.18	13.34	9.73
Corundum		2.86	2.35	2.24	3.06
Zircon		0.18	---	0.37	---
	WO.	---	---	---	---
Diopside	FS.	---	---	---	---
	EN.	---	---	---	---
Hypersthene	Fs.	10.00	6.07	6.60	5.15
	En.	8.51	7.80	6.60	4.60
Magnetite		1.39	1.39	0.93	---
Ilmenite		1.82	1.67	1.37	1.06
Pyrite		0.12	0.38	0.24	---
Apatite		0.34	0.44	0.34	0.34

These hornfels are of wide occurence. They are known at Cape Jervois, Waitpinga, Encounter Bay and run around into the Mount Barker area.

Most of them seem to show the decussate texture typical of a hornfels formed under the influence of thermal metamorphism. In other parts the regional cleavage is well shown, indicating the influence of regional metamorphism.

It seems as if both regional and thermal metamorphism have played their part in the recrystallization of these rocks.

B. ~~THE~~ GRANITE.

The Porphyritic Granite from Granite Island has been described by Browne,[i] and a similar granite from Cape Willoughly, Kangaroo Island by C.E. Tilley.[ii] The granite at Rosetta Head is practically the same as these others that have been described.

It is a coarse grained, holocrystalline, porphyritic rock of ~~high~~ light colour. Large phenocrysts of orthoclase (up to 4 cm. X 3 cm.), rather tabular in habit and sometimes showing Carlsbad Twinning, are set in a medium grained mass of bluish opalescent quartz, orthoclase, plagioclase (recognised by its multiple twinning, and also sometimes showing zoning) and a dark blackish - brown biotite that is found in clusters of tabular crystals. Some of the phenocrysts are studded with small tabular biotite crystals.

The granite has the appearance of being contaminated. There are numbers of dark coloured xenoliths in all stages of disintegration and conversion to mineral composition that is in equilibrium with the magma. Similar inclusions on Granite Island have been described by A.W. Kleeman.[iii]

The porphyritic orthoclase (microcline microperthite) crystals seem peculiar and it seems certain that these were not the first products of crystallization. It seems as if they grew late in this process due to some special enrichment of the magma. ~~in potash (especially) and lime~~.

Under the microscope, the rock is a holocrystalline, hypautomorphic-granular, porphyritic rock consisting of large subhedral crystals of microcline microperthite, together with interstitial quartz, tabular laths of plagioclase, tabular crystals of biotite, and also muscovite, apatite, zircon, magnetite.

MICROCLINE MICROPERTHITE - Browne[iv] has given an accurate description of this. "A section parallel to (010) gives an extinction of 6°, and shows streaks of another feldspar in roughly parallel orientation with R.I. higher than that of the host....... The direction of the streaks makes and angle of 60° with the basal cleavage, which would make them parallel to (100)."

Measurements of optic axial angle of the mineral were made by L.A. Cotton and gave an approximate value of 76° for the 2V.[v]

Inclusions in the phenocrysts are biotite flakes (up to 2.5 mm in length), muscovite flakes, zoned plagioclase laths (up to 2 mm in length) and of composition about the oligoclase - andesine border).

The phenocrysts also often show a zoning effect as if the crystallization has been in two stages.

(i) W.R. Browne. op. cit.
(ii) C.E. Tilley "The Petrology of the Granitic Mass of Cape Willoughby, Kangaroo Island – Part I". Transactions of Royal Society of South Australia, 1919. Vol XLIII
(iii) A.W. Kleeman. op. cit.
(iv) W.R. Browne op. cit
(v) Given by Browne

The following is an analysis of a phenocrysts of the granite at Victor Harbour by H. W. Gartrell.[1]

TABLE III

SiO_2	64.54
Al_2O_3	19.34
Fe_2O_3	tr.
MnO	tr.
MgO	tr.
CaO	1.24
Na_2O	2.88
K_2O	11.84
H_2O	0.58
Total.	100.42

The proportion of the various feldspar molecules calculated from the analysis are:-

Or	65.7	
Ab	22.9	34.3
An	11.4	

Browne compared this analysis with analyses of other perthites and found that the amount of lime is high for a microcline microperthite. It therefore seems that the plagioclase part of the microperthite is about oligoclase-andesine which is somewhat unusual.

There is also some microcline in the medium grained groundmass which for the most part is fairly free from inclusions.

QUARTZ - This mineral is very abundant, and is present as anhedral, interstitial crystals. It is clear with lines of fluid inclusions and also a few rod-like inlusions of rutile. It has the normal optical characters of quartz, but in the hand specimen it shows a peculiar bluish opalescence which is typical of all the quartz in the Victor Harbour Granite.

PLAGIOCLASE - is present as subidiomorphic crystals and irregular grains. It is twinned on the Albite and Pericline Laws, and in parts shows zoning, although this is not particularly noticeable under the microscope. The maximum extinction angle on a section parallel to (010) (symmetrical zone) is 21°. The R.I. is > balsam. This mineral is therefore andesine with a composition $Ab_{60}An_{40}$.

BIOTITE - tabular crystals present as a fitting between the large crystals. It is brown and strongly pleochroic. Basal sections show a poorly defined hexagonal outline. Sections at right angles to this are seen as broad tabular laths. Inclusions of apatite, zircon (with yellow pleochroic haloes) and magnetite can be seen. The biotite is sometimes in parallel intergrowth with muscovite. It is found as inclusions in the microcline microperthite.

MUSCOVITE is present as small tabular crystals with a perfect basal cleavage and showing high polarization colours. It is normally found in parallel intergrowth with biotite.

APATITE - small euhedral prisms with characteristic high relief, low D.R. and straight extinction.

ZIRCON - subhedral prismatic crystals found as inclusions in biotite and surrounded by pleochroic haloes.

MAGNETITE - irregular black grains and octahedra. Mainly found in association with biotite.

(1) H.W. Gartrell, Transactions of Royal Society of South Australia, Vol XXVII., 1903.

A bulk analysis of the granite from Rosetta Head was made, and this together with other analyses are given below.

TABLE IV.

S	I	II	III	IV	V
SiO_2	71.45	68.20	74.48	70.18	65.01
TiO_2	0.54	0.58	0.12	.39	0.57
Al_2O_3	13.78	15.99	12.99	14.47	15.94
Fe_2O_3	0.80	0.89	0.25	1.57	1.74
FeO	2.79	2.58	0.85	1.78	2.65
MnO	0.01	0.04	—	0.12	0.07
MgO	1.11	0.80	0.13	0.88	1.91
CaO	1.86	2.61	0.74	1.99	4.42
Na_2O	2.74	2.85	2.31	3.48	3.70
K_2O	4.35	4.60	6.06	4.11	2.75
H_2O+	0.48	0.64	0.60	0.84	1.04
H_2O- (110°C)	0.11	0.21	0.17		
P_2O_5	0.14	0.14	—	0.19	0.20
ZrO_2	0.12	p.n.d.	—	—	—
BaO	0.19	0.04	—	—	—
S	0.05	—	—	—	—
FeS_2	—	0.11	—	—	—
	100.52				
Less O for S	.02				
	100.50	100.28	99.70	100.00	100.00

I. Porphyritic Granite, Rosetta Head (Bulk Analysis). Anal. D.R.Bowes.
II, Porphyritic Granite, Granite Is, Victor Harbour. Anal, W.R.Browne.(i)
III. Even Grained Granite, Port Elliot. Anal. W.R. Browne.(i)
IV. Granite of all periods, Daly's average of 546 analyses.(ii)
V. Granodiorite. Daly's average of 40 analyses. (iii)

(i). W.R. Browne - op. cit.
(ii) R.A. Daly "Igneous Rocks and the Depths of the Earth" (1933) p.9.
(iii) R.A. Daly " " " " " " " p.15.

Norms of the Rocks of table IV.

TABLE V.

		I	II	III
Quartz		31.74	26.28	36.42
Orthoclase		26.13	27.24	36.14
Albite		23.06	24.10	19.39
Anorthite		8.34	11.95	3.61
Corundum		1.43	1.95	1.22
Zircon		0.37	—	—
Diopside	Wo	—	—	—
	Fs	—	—	—
	En	—	—	—
Hypersthene	Fs	2.80	3.04	0.30
	En	3.43	2.00	1.32
Magnetite		1.16	1.39	0.23
Ilmenite		1.06	1.06	0.23
Pyrite		0.12	0.11	—
Apatite		0.34	0.34	—

Position in C.I.P.W. classification:-

I.	I. 4, 1, 3	Liparose
II.	I. 4, 2, 3	Tocanose
III.	I. 3, 3, 2	——

From a petrographical viewpoint, this igneous rock from Rosetta Head, would be an adamellite. But it seems much more desirable to call it a contaminated granite, as it certainly has had country rock mixed with it.

The Even Grained Granite from Pt. Elliot (a strongly potassic granite) seems to represent much more closely the composition of the original granite magma.

Both Rosetta Head and Granite Island, being as they are, small cupolas of a large batholith, show granite that consolidated very near the country rock, and so no doubt received a good deal of foreign (xenolithic) material.

C THE HYBRID TYPES.

The most interesting and most abundant of these types is what Browne[1] called an "albite mica syenite".

This occurs as a contact phase all around the granite-hornfels contact. It is a whitish coloured porphyritic rock composed of white coloured tabuler albite crystals and a greyish green flaky chloritic material.

The proportion of both albite and chlorite vary from place to place. Sometimes the rock is porphyritic, while other times these large individuals are absent. The albite is normally dominant over the chlorite, but the reverse may be the case as on portion of the South West tip of the Bluff where there is a large mass of very chloritic "albite syenite". Here large individuals of albite (up to 4cm. x 4cm) are set in a greenish chloritic base, the chlorite being much more abundant than the albite.

Under the microscope the normal "albite mica syenite" is a coarse grained, porphyritic rock composed predominantly of albite (showing incipient alteration). Between the large albite crystals there is a

(1) W.R. Browne – op. cit.

mass of interwoven flakes of chloritic material, which has been derived from biotite some of which is still present, and obvious gradations from biotite to chlorite are shown. Muscovite is also present and sometimes is in parallel intergrowth with the chloritic material. Quartz crystals, grains of rutile (abundant in the chloritic material) and zircons are the accessary minerals.

Albite - mainly present as phenocrysts up to 2cm. x 2cm. in size, but also present as small crystals in the groundmass.

Some of it is checquer albite and this has been described by Browne. Perfect twinning on both the Albite and Pericline Laws is shown, as well as twinning of an irregular type. The R.I. is $<$ balsam. Sections parallel (010) give extinction of 19° to the basal cleavage - corresponds to composition $Ab_{97}An_{3}$.

Mr. E.G. Robinson, B.Sc. has kindly done the following determinations on the Universal Stage.

2V	81°(±2°)	- corresponds to composition $Ab_{94}An_{6}$.
Extinction angle in symmetrical zone	$-14\frac{1}{2}°$	corresponds to composition $Ab_{94}An_{6}$.

The mineral is biaxial positive with a large optic axial angle. Relief is low and D.R. is low. The albite for the most part is clear, but in places it is full of grey dusty inclusions. It contains inclusions which are mainly of chloritic nature. Other minute inclusions are of muscovite, rutile, zircon, and apatite.

An analysis was done of the albite on hand-picked material (grains that passed through 1mm. seive) that was obtained on crushing a specimen of the "albite syenite". The main impurity was chloritic material that is distributed as fine flakes throughout the mineral.

By allocating all the magnesia in the analysis to chlorite, the requisite amount of each constituent present as chloritic material was subtracted (using analysis of chlorite given in Table VII). All the titania is alloted to rutile (present in the chlorite flakes).

The remaining constituents then represent the composition of the albite. This was recalculated to 100.00 (on a water-free basis).

TABLE VI

	(a)	(b)	(c)				
SiO_2	65.43	1.24	64.19	1070	2140	2.93	4.01 (with TiO₂, Al₂O₃)
TiO_2	0.04	—	—				
Al_2O_3	21.16	0.94	20.22	198	594	1.08	
FeO	0.43	0.47	—				
MgO	0.86	0.86	—				
CaO	0.56	0.04	0.52	9	183 (with CaO, Na₂O, K₂O)	.02(5)	0.99 (with CaO, Na₂O, K₂O)
Na_2O	10.64	0.02	10.62	171		.94(3)	
K_2O	0.26	—	0.26	3		.02	
H_2O	0.72	—					
Total	100.10						

Analysis of albite of "albite mica syenite", Rosetta Head by D.R.Bowes.

Column (a) original analysis figures
(b) amounts of constituents present in chloritic impurity.
(c) resultant composition of albite.

Recalculating column (c) to 100.00 we get:-

SiO_2	66.99
Al_2O_3	21.11
CaO	0.54
Na_2O	11.09
K_2O	0.27
	100.00

Chlorite - is a very pale green, faintly pleochroic mineral. Its R.I. is greater than balsam, and D.R. is low (approximately .010). The figure is biaxial positive with a very small optic axial angle. The chlorite occurs as small needle-like masses between the large individuals of albite. Both muscovite and biotite are found in parallel intergrowth with the chlorite which seems to have been derived from the biotite. The biotite present in the slide does not show its normal deep brown colour and marked pleochroism. Transition from biotite to chlorite can be seen.

Abundant minute red-brown pleochroic prisms of rutile are found in and around the chlorite flakes and these prisms seem to be aligned in some way. They are found along wavy lines and are not evenly distributed throughout the chlorite.

Rutile is also present in some of the biotite crystals. It is probably formed from the titania set free on the conversion of biotite to chlorite.

The following is an analysis of this chlorite:-

TABLE VII

SiO_2	30.37	.506	.506
TiO_2	1.92		
Al_2O_3	22.82	.223	.224
Fe_2O_3	0.21	.001	
FeO	11.39	.158	.697
MgO	21.16	.529	
CaO	0.55	.010	
Na_2O	0.66	.011	.013
K_2O	0.17	.002	
H_2O+	9.52	.528	
H_2O-	0.11		
P_2O_5	tr		
	98.88		

Analysis of chlorite of "albite syenite", Rosetta Head by A.W.Kleeman M.Sc

All the titania in the analysis has been allotted to rutile. This mineral is of very unusual character and its origin is still somewhat obscure.

Muscovite is fairly abundant. In general it is present in much larger flakes than the chlorite. It is recognised by its perfect basal cleavage, high polarization colours and straight extinction. A bi-axial positive figure was given with a moderately large optic axial angle.

Biotite - small tabular subhedral crystals that are pleochroic from colourless to light brown. Straight extinction and mottled polarization colours are characteristic features. Small reddish brown pleochroic crystals of rutile are found in the biotite flakes, and this seems to indicate that the flakes are in the process of alteration.

Quartz. Small anhedral crystals are found amongst the chloritic groundmass material, but are not very abundant. These grains have R.I. > balsam, low relief, low D.R. and a uniaxial positive figure.

Rutile. Reddish brown, pleochroic prisms found in and around the chloritic material and biotite. These crystals show high relief and extreme D.R.

Apatite. Euhedral prisms of apatite are present. These show high relief, low D.R. and straight extinction.

Zircon. Present as small subhedral crystals with high relief and high D.R. Often found included in chlorite and biotite flakes, and in the latter these crystals are surrounded by dense yellow pleochroic haloes.

Analyses of the "albite syenite" are given below.

TABLE VIII.

	I	II
SiO_2	56.24	64.60
TiO_2	0.98	1.04
Al_2O_3	19.75	20.37
Fe_2O_3	0.76	0.31
FeO	1.63	0.67
MnO	0.01	—
MgO	7.00	1.15
CaO	0.75	0.41
Na_2O	8.62	9.94
K_2O	0.40	0.16
H_2O+	2.90	0.85
H_2O-	0.09	0.15
P_2O_5	0.19	0.22
ZrO_2	0.15	0.03
BaO	0.13	abs.
S	0.03	abs.
	99.63	
Less O for S	0.01	
	99.62	99.90

I. "Albite Mica Syenite" from S.W. tip of Rosetta Head. Anal.D.R.Bowes.
II. "Albite Mica Syenite" from Rosetta Head. Anal. W.R. Browne.[i]

These two analyses illustrate the variations that occur in the syenite. Rock I in the above table contains less free quartz and albite and more chlorite and muscovite than Rock II. This explains the lower SiO_2 and Na_2O percentages and higher MgO, K_2O and H_2O percentages in Rock I.

Browne's calculated analysis of the chlorite from this analysis is at variance with the analysis of the chloritic material made by A.W.Kleeman. This is probably due to the hybrid and unusual nature of the rock. Browne allocated his various oxides on the assumption that the rock was igneous. It seems certain that there would be more than 2.0% quartz in the rock. Also no biotite has been formed, which is no doubt present, and the biotite is altering to chlorite giving no doubt a series of transitional compositions.

The actual analysis seems quite within limits, but the calculated composition is a variance with the determined composition.

Browne[ii] discusses "Impregnation near the Syenite Contact". Here there are veins and tongues of both granitic and "syenitic" material running through the country rock, that has been greatly chloritized in parts.

An analysis was made of one of these "syenite" stringers.

TABLE IX

SiO_2	59.00
TiO_2	0.72
Al_2O_3	19.41
Fe_2O_3	0.34
FeO	3.59
MnO	0.04
MgO	6.44
CaO	1.00
Na_2O	6.42
K_2O	0.09
H_2O+	2.47
H_2O-	0.09
P_2O_5	0.18
ZrO_2	0.08
BaO	0.08
S	0.03
	99.98
Less O for S	0.01
Total	99.97

(i) W.R. Browne - op cit.
(ii) W.R. Browne - op cit

Analysis of "Syenite" stringer in cliff, near Wharf; Rosetta Head. Anal. D.R. Bowes.

The hand specimen shows a "vein of syenite material" (up to 3.5cm. across) cutting through highly altered country rock. The "syenite" is composed of white tabular feldspars (up to 1cm. x 1cm.) set in a mass of small white feldspar crystals 1mm. x 1mm.) and dark greyish green chloritic material.

The country rock next to the vein is a light greyish-green colour and is very fine grained. It shows parallel bands of dark greyish green chloritic material. These bands are approximately parallel to the edge of the vein. On splitting the rock in this direction, get a face of greenish-grey chlorite.

Some of the feldspars in the "syenite" vein are very cracked and shattered, the cracks being filled in part with chloritic material.

The chlorite near the edge of the vein seems to eddy about the feldspar crystals. It seems as if a magma from which plagioclase feldspar was crystallizing was injected into a fissure and has assimilated the country rock and so produced a rock of hybrid nature.

A microscopic examination of the rock shows it to be of a very unusual nature. The rock has porphyritic texture and is completely crystalline.

There seem to be two generations of crystals -
(1) large individuals of plagioclase feldspar which have been ~~badly~~ corroded - crystallized out from the injected (granitic) magma.
(2) Medium grained individuals of albite, perthite, chlorite and quartz - these have been formed due to reaction between the magma and the country rock.

First generation.
This consists of large plagioclase phenocrysts which are full of minute inclusions that suggests corrosion and reaction. The edges of these phenocrysts are very ragged. ~~The~~ Cracks traverse the crystals and there are again filled with small flaky crystals.

Some of the phenocrysts are zoned - surrounded by a rim of later material that is practically free from inclusions.

Multiple twinning is shown in a few places, but it is mainly covered over by products of reaction. This plagioclase feldspar shows a biaxial positive figure and an R.I $>$ balsam. A Universal Stage determination would be necessary to determine the exact composition, but the above properties point to it being andesine - formed from the crystallization of the granitic magma.

The inclusions of the feldspar phenocrysts are quartz, chloritic material, apatite and rutile.

A fine grained mass of alteration products has been formed around the feldspar laths. This mass is mainly composed of a mosaic of quartz and pellucid grains of plagioclase that show multiple twinning. The maximum extinction in the symmetrical zone is approximately -12°. This gives an approximate composition of Ab_{92-94}(albite).

There are also flakes of chlorite throughout the mosaic.

Second Generation.
The minerals of this generation were formed mainly due to the reaction of the magma with the country rock. Albite, quartz, perthite and chlorite are the minerals making up this part of the rock. They are of varying shapes and sizes and of sporadic occurrence. In some

parts there is an abundance of quartz, in other parts there is an abundance of chlorite, and in yet other parts an abundance of feldspar.

Albite - present as subhedral crystals showing in many cases the characteristic Albite (multiple) Twinning. It also shows Pericline twins and other irregular types of twinning. The figure is biaxial positive with a moderately large 2V. R.I. is < balsam. Maximum extinction angle in symmetrical zone is $-14\frac{1}{2}^{\circ}$ - corresponds to composition $Ab_{94}An_6$. These small crystals are somewhat turbid due to the presence of a greyish incipient decomposition product. The albite here corresponds in composition with that in the "albite mica syenite".

Perthite - an intergrowth of albite in a potash feldspar host, giving the characteristic blebs that are aligned in one direction. The centre of some of these crystals is turbid due to incipient alteration. The edges of the crystals are very ragged which indicates that reaction has taken place. At the corroded edges of these crystals is a mosaic of recrystallized albite and quartz.

Quartz - this generally occurs as granoblastic aggregates of recrystallized quartz, often associated with chlorite which is idioblastic towards the quartz. Characteristic sutured outlines are shown. The crystals are clear and colourless except for a few inclusions of sericite, zircon and apatite.

Chlorite. This has similar optical properties to that found in the "albite mica syenite". Many of the flakes show bending. This often occurs around the phenocrysts and may be connected with the flowing of the magma. The rutile inclusions are not as abundant as in the "albite mica syenite" itself. No original biotite can be seen.

Apatite - large subhedral crystals showing characteristic high relief and low D.R. It seems as if the apatite forming part of the magma and the apatite of the sediment have come together and crystallized as large individuals. In places the apatite is present as irregular and anhedral aggregates.

Zircon. euhedral prismatic crystals of high R.I. and high D.R.

Muscovite - two or three small subhedral tabular crystals showing straight extinction and high polarization colours. There is also some sericite found as an alteration product of the plagioclase.

Rutile needles are concentrated in a ragged line along the boundary of the vein. The rutile is not as common or as evenly disseminated as in the "albite syenite" itself.

The country rock through which the vein runs is a mass of quartz, albite and chlorite (and needles of rutile). The chloritic material is oriented parallel to the ~~edge~~ boundary of the vein.

Quartz present as a fine grained recrystallized mosaic.

Albite. Pellucid recrystallized grains, some of which show Albite twinning. R.I. is < balsam.

Maximum extinction angle in symmetrical zone is -15°. Corresponds to composition $Ab_{95}An_5$.

Chlorite is abundant and is idioblastic against both the albite and the quartz. The properties are the same as has been described above. The chlorite is more abundant near the edge of the vein.

Rutile - small recrystallized reddish-brown pleochroic crystals evenly distributed throughout. These small crystals are quite abundant.

Muscovite - two or three minute flakes found in association with the chlorite.

A specimen of this highly altered country rock, right next to the contact with the stringer was analysed.

TABLE X

SiO_2	46.39
TiO_2	1.28
Al_2O_3	21.94
Fe_2O_3	0.65
FeO	5.95
MnO	0.09
MgO	11.61
CaO	1.28
Na_2O	4.53
K_2O	0.52
H_2O+	5.39
H_2O-	0.05
P_2O_5	0.23
ZrO_2	0.04
BaO	0.05
S	0.02
F	0.01
	100.03
Less O for S & F	0.01
Total	100.02

Chloritic schist, in contact with "Syenite" stringer, Rosetta Head. Anal. D.R. Bowes.

D. ROCKS FORMED FROM THE HORNFELS BY SEGREGATION AND GRANITIZATION.

(a) Near The Wharf.

Near the wharf on the north-eastern side of the headland is a very complicated and twisted mass of rocks. Here very chloritic material is abundant; it is present as masses, knots and veins. In intimate association with these chloritic types are rocks that are practically white in colour and consist essentially of a fine granoblastic mass of quartz and albite (also some chlorite present)

It seems as if the hornfels has been changed into two types by segregation (especially of magnesia). This segregation was probably performed by the process of granitization.

Analyses of both of these types were made.

TABLE XI

	I	II
SiO_2	58.91	43.81
TiO_2	0.85	1.33
Al_2O_3	21.42	24.68
Fe_2O_3	0.82	1.20
FeO	1.90	5.14
MnO	0.03	0.08
MgO	4.50	12.74
CaO	0.78	0.53
Na_2O	8.72	1.80
K_2O	0.16	2.62
H_2O+	1.47	5.74
H_2O-	0.06	0.17
P_2O_5	0.21	0.32
Total	99.[illegible]	100.16

II. Highly chloritic "vein" material, near the wharf, Rosetta Head.
Anal. D. R. Bowes.

I. Associated light coloured rock, near the wharf, Rosetta Head.
Anal. D. R. Bowes.

Rock I of Table XI is composed essentially of quartz and albite (in abundance) and chloritic flakes.

Rock II of Table XI is composed essentially of interwoven flakes of chlorite and muscovite and smaller granoblastic masses of quartz and albite. The micaceous parts are woven about the clots of the more salic material.

There is a very sharp contact between the more chloritic and the less chloritic types. Actually there is an intermediate zone, again with very sharp boundaries. The chlorite has been described, and has the appearance of running in veins, but this is only because of the sharp demarkation between the two main types.

The chemical composition of these two types is very interesting and will be discussed later.

(b) In Petrel Cove.

An andalusite mica schist and a cordierite mica schist from Petrel Cove were described by Browne.[1] In both of these types the same chloritic material, as discussed before, occurs.

(1) W. R. Browne – op. cit.

A specimen of the cordierite schist was analysed.

TABLE XII

SiO_2	58.75
TiO_2	0.70
Al_2O_3	20.48
Fe_2O_3	0.63
FeO	3.97
MnO	0.03
MgO	5.93
CaO	1.78
Na_2O	3.33
K_2O	1.97
H_2O+	1.43
H_2O-	0.15
P_2O_5	0.60
ZrO_2	0.21
BaO	0.13
S	0.15
	100.24
Less O for S	0.06
Total	100.18

Knotted cordierite schist, West side of Petrel Cove. Anal. D.R.Bowes.

The high magnesia percentage, marked proponderance of soda over potash, and the very high phosphate percentage suggest that the origin of this rock was very unusual.

The P_2O_5 was determined by two different methods, but the same result was obtained for each determination.

Both of these rocks described by Browne are knotted schists with knots of andalusite and cordierite respectively. Weathering has made these knots stand out, so that the outcrops of these rocks can be readily traced.

The knots in the cordierite schist are individuals and aggregates of medium to large ~~xenoblasts of~~ xenoblasts of cordierite, comprising anything up to a half a dozen intergrown or interlocking grains.

Whole areas of cordierite in the slide show optical continuity and the cordierite is crammed with inclusions.

The mineral is recognized by the yellow pleochroic haloes around the zircons that occur in it as inclusions and also by its biaxial negative figure.

These knotted schists are present in irregular bands whose strike is at an angle to both the bedding and the regional cleavage.

E. THE DOLERITE DYKES AND QUARTZ VEINS.

Cutting through both the granite and the surrounding country rock are a number of dolerite dykes, and numerous quartz and pegmatitic veins.

(1) The Dolerite Dykes.

There are four dolerite dykes in the limited area that was mapped. A slide was made of the dyke that occurs on the coast line on the south eastern side of Rosetta Head. This is a dark greenish black coloured, heavy, dense, fine grained dyke rock composed of a mesostasis of fine interlocking crystals of white feldspar and a dark mafic mineral.

Under the micrsocope it is a holocrystalline, fine grained rock showing sub-ophitic texture. Subhedral laths of plagioclase are partially enclosed by crystals of green uralitic hornblende. The hornblende is present as pseudomorphs after augite.

Plagioclase feldspar. One large zoned phenocryst is present. The centre zone of the crystal is showing alteration in the cracks and also is covered in places by small prismatic crystals of hornblende. The outermost zone is practically free from hornblende.

Universal stage measurements would be necessary to determine the composition of this phenocryst.

The small plagioclase laths show Albite (multiple), Carlsbad-Albite and Pericline Twinning. The laths often show wavy extinction. They are quite fresh and show no alteration. Maximum extinction in the symmetrical zone is $+31\frac{1}{2}^{o}$; this indicates a composition of $Ab_{43}An_{57}$.— Labradorite.

It has an R.I. > balsam and shows a biaxial positive figure with a large optic axial angle.

Hornblende (uralite) - pseudomorphs after augite. These prismatic crystals are pleochroic from yellowish green (x) to olive green (y) to green (z). Relief is rather high with R.I.> balsam. D.R. is moderately high. The figure is biaxial negative with a moderately high optic axial angle.

The hornblende contains small grains of secondary magnetite.

Iron Ores. black grains of ilmenite scattered throughout the slide. Magnetite is found in small grains in the amphibole flakes. Some reddish haematite is around some of the grains.

Apatite. Exceedingly fine needles with high relief and low D.R. and straight extinction. The apatite is scattered throughout.

Rutile - a few reddish brown pleochroic grains.

Biotite - a few small flakes showing pleochroism from reddish-brown to almost colourless, and with straight extinction.

Another dolerite was also examined under the microscope. The dyke occurs by the granite hornfels contact and practically on the path leading up the western side of the Bluff.

This is very similar in both texture and composition to the one described above. The plagioclase is slightly more abundant and shows better defined twinning. The composition was found to be $Ab_{42}An_{58}$. The hornblende is present in smaller crystals and some of the ilmenite has gone to leucoxene.

There are two other dykes. They are parallel and about 20 yards apart and run in the direction N.30°E, cutting through the hornfels about 600 yards north of the headland.

Browne[i] has described one of these, and it is very similar to the one described above, except for the fact that the sub-ophitic texture is not always shown.

The following is an analysis of this dolerite dyke.

TABLE XIII

SiO_2	49.32
TiO_2	1.96
Al_2O_3	21.03
Fe_2O_3	1.79
FeO	8.31
MgO	2.31
CaO	10.91
Na_2O	2.97
K_2O	0.47
H_2O+	0.63
H_2O-	0.10
CO_2	abs.
P_2O_5	0.12
S.	p.n.d.
Total.	99.92

Uralitic dolerite dyke north of Rosetta Head. Anal. H. Yates.[ii]

(2) Quartz and Pegmatitic Veins.

Between Petrel Cove and Half Way Beach (about ½ mile west) there are numerous quartz veins, the widest being approximately 4 feet. For the most part these veins are barren, but some of them have yielded andalusite and rutile crystals. The constituents of these minerals were no doubt obtained from the country rock through which the veins forced their way.

There are also quartz veins north of the headland shown on the rock platform next to the road leading to the wharf. Four quartz veins also outcrop on the landward slope of the headland.

All of these veins seem to run in the direction of the regional cleavage.

There are also numerous pegmatitic veins criss-crossing through the country rock both in Petrel Cove and on the wave-cut platform on the other side of the headland. These pegmatitic veins are chiefly composed of quartz, orthoclase and muscovite.

(i) W.R. Browne - op cit

(ii) Given by Browne

IV PETROLOGY AND DISCUSSION.

The hornfels, into which the granitic liquid was injected, were typical sediments. Table I gives four analyses of specimens from different localities which show the variations from more mafic to more salic types.

There is a conformable series of sediments, beginning at the Grey Spur where a basal conglomerate rests on Earlier Precambrian (Barossian) schists and gneisses, which stretch down to the sea at Encounter Bay, Victor Harbour, etc. The beds of this series dip → S and strike approximately N.E. A hornfels is the last bed of this series before it disappears into the sea, and it was into this bed that the granite was intruded.

The age of this series is not definitely known, but it is thought to be Late Precambrian (equivalent to the Adelaide Series on the Adelaide side of the ranges).

The cliff face exposed near the wharf at Rosetta Head shows some very chloritic (magnesia rich) rocks (see Table XI, Analysis II), and also some very albitic (soda rich) rocks (see Table XI, Analysis I). These rock types are in contact with the normal hornfels type and seem to be original hornfels ~~sediments~~ that have been changed in some way.

The following is a comparison of some of the constituents of these types with those of the hornfels (Table I, Analysis I).

TABLE XIV

	SiO_2	Al_2O_3	MgO	Na_2O	K_2O
Hornfels	58.82	18.34	4.00	3.39	3.28
Chloritic rock	43.81	24.68	12.74	1.80	2.62
Albitic rock	58.91	21.42	4.50	8.72	0.16

This indicates that in some manner magnesia must have been segregated in the chloritic rock and soda in the albitic rock. Yet in both of these unusual types Al_2O_3 seems to have been added and K_2O subtracted.

The cordierite schist from Petrel Cove is also seen to be an unusual type (see Table XII).

TABLE XV.

	SiO_2	Al_2O_3	MgO	Na_2O	K_2O
Cordierite schist	58.75	20.48	5.93	3.33	1.97

This indicates that MgO and Al_2O_3 have been added, whilst K_2O has been subtracted.

The following analyses given by Clarke[1] of typical shales and slates indicate that these rocks at Rosetta Head are not typical sedimentary (or metamorphic) types.

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(1) F.W. Clarke "The Data of Geochemistry" (1924) pp 552 & 554.

TABLE XVI

	I	II
SiO_2	60.15	60.96
TiO_2	0.76	0.86
Al_2O_3	16.45	16.15
Fe_2O_3	4.04	5.16
FeO	2.90	2.54
MnO	tr.	0.07
CaO	1.41	0.71
BaO	0.04	0.04
MgO	2.32	3.06
Na_2O	1.01	1.50
K_2O	3.60	5.01
Li_2O	tr.	—
H_2O-	0.89	0.17
H_2O+	3.83	3.08
P_2O_5	0.15	0.23
CO_2	1.46	0.68
SO_2	0.58	—
C	0.88	—
$N.H_3$	—	0.01
Total.	100.46	100.23

I. Composite analysis of fifty-one Palaeozoic shales, U.S.A. by H.N. Stokes.
II. Purple Slate, Castleton, Vermont, U.S.A. by W.F. Hillebrand.

Thus these rocks from Rosetta Head are much richer than normal sediments in Al_2O_3 and MgO., and some are richer in Na_2O. Whilst segregation of constituents from the surrounding rocks would explain to some measure the high values of these constituents, it could hardly account for all the variations met with and could not be responsible for the enrichment of the rocks in the large amounts of magnesia and soda met with. Also it could not account for the fact that there is an addition of alumina and magnesia and a subtraction of potash in all the rocks.

It is therefore suggested that these rocks owe their origin to the progess of granitization. Dunn[i] suggests that the term "diabrochite" might be applied to such rocks. He says "... The diabrochites differ from migmatites in that the added material is not obviously granitic". Doris Reynolds[ii] has used this term in her paper on the Newry Igneous Complex. So the term diabrochite will be used to designate these unusual types that occur at Rosetta Head which owe their origin to the process of granitization, and yet are not of granitic composition.

Accordingly we have a chlorite-diabrochite (Table XI, Analysis II) and an albite diabrochite (Table XI, Analysis I) occurring in the cliff near the wharf at Rosetta Head.

(i) J.A. Dunn "Granite and Magmatism, and Metamorphism". Economic Geology Vol XXXVII, No 3 May 1942: pp 231-238

(ii) D.L. Reynolds "The South-Western End of the Newry Igneous Complex. A Contribution towards the Petrology of Granodiorite" Journal of the Geological Society, London Vol XCIX 1943 pp 205-246.

~~near the wharf at Rosetta Head~~.

The cordierite and andalusite rocks found in Petrel Cove probably have a similar origin, so they will be tentatively called cordierite-chlorite-diabrochite and andalusite-chlorite-diabrochite respectively. It has not been proved that these rocks owe their formation to the processes of granitization, but there is little doubt that further research will prove this to be so.

These cordierite and andalusite rocks no doubt represent a Mg-Al front of granitization. By the introduction of Mg and Al (also perhaps Fe), the biotite of the original hornfels was converted to a very magnesia and alumina rich chlorite. The products of this process can also be seen in the cliff section near the wharf where this magnesia rich chlorite has also been formed.

Granitization advanced wave after wave.

Dunn[1] says - "There can here be no picture of a granitic magma forcing or stoping its way upwards, but only of moving liquids soaking the schists along cleavage planes and between intergrain faces, leaving the original trend lines at first undisturbed, granitizing the schists, removing some constituents, generally Fe, Mg, Ca and Na and depositing others, such as potash, feldspar and quartz. As liquids increase in quantity the mass itself first becomes mushy or pasty then increasingly fluid, although still retaining the old mineral trend lines, but those parts in which there is complete fluidity may culminate in a magma capable of moving bodily upwards and which may eventually crystallize as normal massive, non-gneissic granite. In this way a magma may leave the schists from which it was formed far behind, and may ultimately become emplaced as a massive granite in unmetamorphosed rocks. During the process of emplacement further hydridization may occur...".

This description of the process of granitization and then mobilization (rheomorphism) fits in very well with observations at the Bluff.

The Mg-Al front was followed by a Na front. The actual front can be seen in the cliff section near the wharf, and is the contact between the albite rich rocks (diabrochite) and the so-called "chlorite veins" (chlorite-diabrochite). The introduction of Na and the removal of most of the Mg has left a rock composed essentially of albite and quartz. There is also some chlorite present, but it becomes less conspicuous further from the actual front.

It is into rocks so formed that the granitic liquid has been intruded. The granite liquid itself was, no doubt, originally a product of granitization (K-Si-Al front) that has been mobilized deep in the earth's crust and intruded into the upper levels of the crust. This mobilized material has completely engulfed all the rocks produced by the earlier fronts of granitization except at Rosetta Head (and also possibly at Cape Willoughby, Kangaroo Is. where an albitite has been described by Tilley[2]) where just a few of these unusual types remain.

The result of adding inclusions which belong to a discontinuous reaction series and are later in that series than the phase with which the liquid is saturated, is for them to pass into solution by precipitating their heat equivalent of the phase with which the liquid is saturated.

Albite, being later in the reaction series than andesine (with which the liquid was saturated), was taken into solution by the precipitation of its heat equivalent of andesine.

Chlorite (and the associated muscovite) being later in the reaction series than biotite (with which the liquid was saturated) was taken into solution by the precipitation of its heat equivalent of biotite.

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(1) J.A. Dunn. op cit p.232.
(2) C.E. Tilley op cit.

Thus the liquid received a notable addition of both magnesia and soda whilst both andesine and biotite were precipitated. This no doubt left an unusual type of liquid which may have given rise to the large microcline microperthite pheoncrysts present in the granite.

The addition of magnesia and soda (mainly) to the liquid would explain the increase in the magnesia percentage of the Porphyritic Granite (of both Rosetta Head and Granite Island) with repsect to that of the Even-Grained Granite (Port Elliot). It would also account for the lower $\frac{K_2O}{Na_2O}$ ratio in the Porphyritic Granite (see Table IV).

TABLE XVII

	MgO	Na_2O	K_2O
Even-grained (Pt. Elliot)	0.13	2.31	6.06
Porphyritic (Rosetta Head)	1.11	2.74	4.35
Porphyritic (Granite Is.)	0.80	2.85	4.60

The mobilized granitic liquid in most palces intruded its way up in the zone that had not been granitized (i.e. into the ~~sedimentary~~ hornfels). So the granite contains inclusions of sedimentary origin (hornfels). These were not dissolved in the granitic liquid but reacted with it, and were soaked with granitic juices. The so-called "diorite" and "adamellite porphyry" (as described by A.W.Kleeman[i]) were produced by these processes.

So the only inclusions that can be seen in the granite were originally hornfels, the unusual diabrochites having been dissolved.

When the intrusive granitic liquid was finally unable to intrude its way any further, it reacted with the diabrochite types in situ giving rise to the so-called "albite-mica syenite". This rock would be better termed a hybridized albite-chlorite diabrochite.

In the field this hybridized diabrochite occurs in an intermediate position between the granite and the hornfels except in a few instances where, as on the large included block of sediment just south of the wharf, the granite is inferred to be present below; or, as on the S.W. tip of the Bluff, where the covering hornfels has practically all been removed; or where, as at the cliff section by the wharf, the granitic liquid has not permeated the whole of the diabrochite.

It seems as if the granite has easily permeated the soft, open textured diabrochite, but that the permeation stopped at the diabrochite - hornfels boundary (i.e. the border of the granitized sediments) due to the fact that the close textured recrystallized hornfels did not allow easy permeation.

Browne[ii] described the occurrence of the "albite-mica syenite" as being due to the process of "fractionation with sinking of crystals". He pictured the albite crystals (crystallizing from the magma) rising and forming the "albite-mica syenite". One specimen of a vein of this "albite-mica syenite" from the Bluff shows a large albite crystal in a wider part of a narrow vein. It would have been impossible for the crystal to have floated into place; it must have grown in place.

Also the field distribution of the types, and the sharp nature of the contacts makes the crystal differentiation theory untenable.

The various types of hybridized diabrochite that have been produced owe their composition to that of the original diabrochite produced by granitization.

The type analysed by Browne[ii] (Table VIII, Analysis II) is higher in SiO_2, Al_2O_3 and Na_2O, but lower in Fe_2O_3, FeO, MgO, CaO, K_2O and H_2O than that analysed by the author (Table VIII, Analysis I).

(i) A.W. Kleeman op cit.
(ii) W.R. Browne op cit.

Apart from the Al_2O_3 and CaO (which seem anomalous) the same kind of variations (but in different proportions) is shown by the albite diabrochite and chlorite diabrochite.

TABLE XVIII

	SiO_2	Na_2O	Al_2O_3	CaO	Fe_2O_3
(a) Hybridized diabrochite (Browne)	64.60	9.94	20.37	0.41	0.31
(b) Hybridized diabrochite (Bowes)	56.21	8.62	19.75	0.75	0.76
(c) Albite Diabrochite	58.91	8.72	21.42	0.78	0.82
(d) Chlorite Diabrochite	43.81	1.80	24.68	0.53	1.20

(cont.)	FeO	K_2O	MgO	H_2O
(a) Hybridized diabrochite	0.67	0.16	1.15	1.00
(b) Hybridized diabrochite	1.63	0.40	7.00	2.99
(c) Albite diabrochite	1.90	0.16	4.50	1.53
(d) Chlorite diabrochite	5.14	2.62	12.74	5.91

Thus the more albitic hybridized diabrochites, similar to the one analysed by Browne, are derived from the albite diabrochites, and the more chloritic hybridized diabrochites from the chloritic diabrochites by reaction with granitic liquids.

There are, no doubt, all stages between the albite rich hybridized diabrochites and the very chlorite-rich hybridized diabrochites, such as the very chloritic type containing large albite individuals found on the S.W. tip of the Bluff.

Reciprocal reaction between the granitic liquid and the diabrochite no doubt played a part in the formation of these hybrids. Nockolds[1] states "that if the xenolith is rich in magnesia then potash tends to enter rather than soda, whereas if the zenolith is rich in lime, soda tends to enter rather than potash".

The case at the Bluff is complicated by the fact that the original diabrochite was very rich in both magnesia and soda. So here the tendency would be for the soda to be replaced by potash. This does not seem to have operated to any great extent.

The main function of the granitic liquid seems to have been to provide a fluid medium in which the soda of the rock could come together and form large crystals of albite.

It has been noted that on the S.W. tip of the Bluff, the more chloritic hybridized diabrochites occur higher above sea-level than the albitic types. This is due to the fact that the Mg-Al front was the first of the fronts in granitization and penetrated higher up into the crust than the Na front that followed. In the cliff section by the wharf the chloritic types are seen to occur higher up then the albitic types.

There are innumerable variations that depend on various factors. The Mg-Al front and the succeeding Na front, made its way along the easiest path. This is illustrated by the presence of large blocks of hornfels (in situ) that have not been altered, that occur both just south of the wharf and on the ridge leading to the S.W. tip on the other side of the headland. The most cracked and easily permeated rocks were naturally the first to be affected by the on-coming wave of granitization.

The tongueing in and out of the granite (of the hybridized diabrochite) both on the eastern side and on the S.W. tip of the headland is explained by local variations in respect to easiness of access and Permeation.

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(1) S.R. Nockolds "Some Theoretical Aspects of Contamination in Acid Magmas" The Journal of Geology, Vol. XLI, No 6 Aug - Sept 1933.

~~permeation~~.

Nockolds[1] states that the contact between the crystallized granitic liquid and the sedimentary rock is sharp - this is so at the Bluff.

The chloritic "vein" that runs along the middle of one of these tongues of hybridized diabrochite no doubt represents the Mg-Al front and the hybridized diabrochite the Na front. The chloritic vein had not been altered, so the permeating granitic liquids must have stopped at the contact.

There are also numerous minor variations and local incidents.

The "order of intrusion" is of some interest.
It is found to be

(i) granite
(ii) dolerite
(iii) pegmatitic and quartz veins.

This is given by a study of the dolerite dyke on the eastern side of the headland. Here (as described above) the dolerite shows flow structure parallel to its contact with the granite. Also quartz and pegmatitic veins cut through the dolerite.

Hybridized diabrochite is here associated with the granite and the dolerite dyke also shows flow banding where it is in contact with this rock. This indicates that the hybrid types were not due to post-magmatic or pneumatolytic effects.

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(1). S.R. Nockolds - op.cit.

V. THE AGE AND EXTENT OF THE INTRUSION.

The geosyncline into which both the later Precambrian and Cambrian sediments were deposited was destroyed by a period of orogeny in the late Cambrian. This was followed by intense granitization of the sediments that were forced down deep into the earth's crust. The granitic material so formed was in the main, mobilized and intruded into the upper parts of the crust.

The granite of the Victor Harbour Batholith outcrops at Port Elliot(i), Rosetta Head and islands off the coast. It is also thought ~~xxxxxxx~~ to outcrop on The Pages and Tilley(ii) considers that the Cape Willoughby Granite (Kangaroo Is.) is part of the same batholith. Similar igneous intrusions have been traced along the Coorong.(iii)

It seems certain that the Murray Bridge Granite and its associates, and some of the Mt. Painter Granites are of approximately the same age.

The age of the Mt. Painter Granite has been placed at 400 (±50) million years.(iv) This indicates that this intrusion (and probably the others mentioned) are of early Palaeozoic age.

The small granite islands that occur in Encounter Bay as well as Rosetta Head and Port Elliot are but small cupolas of a large granite batholith that probably stretches far out under the sea, and also to some limited extent inland.

This granite may have been intruded into the roots of the mountain range that formed the gathering ground for the Permian ice.

(i). W.R. Browne - op cit.
(ii) C.E. Tilley - op cit.
(iii) D. Mawson and L.W. Parkin "Some Granitic Rocks of South Eastern South Australia" Trans. Roy. Soc. S.Aus. Vol 67 (2) 1943
(iv) A.W. Kleeman "An Age Determination on Samarskite from Mt. Painter, South Australia" Trans. Roy. Soc. S.Aus Vol 70 (2) 1946.

VI SUMMARY.

The following is a summary of the geological history of the area.

1. Deposition of the new hornfels type ~~of sediment~~ in steadily shallowing geosynclinal basin in the late Precambrian(?)

2. Folding and crumpling of beds during the Late Cambrian period of orogeny.

3. Granitization of the sediments pushed down into the earth's crust with the formation of diabrochite types higher up.

4. Mobilization of the granitic material so formed and its intrusion into the upper levels of the crust - early Palaeozoic times.

5. Reaction of the intruded granitic liquid with the diabrochite to give hybridized diabrochite.

6. Introduction of dolerite dykes.

7. Introduction of pegamtitic and quartz veins.

8. Long period of erosion exposing the granite at the Bluff.

9. Glaciation of the area in permian times with the production of glacial topography and the deposition of glacial till.

10. Subsequent erosion to that shown at the present day.

Only the broader features of the problem have been discussed, and even as regards these no finality has been reached. More chemical analyses, microscope work and field work, perhaps even including a study of the other outcrops of this granite mass, need to be done before any finality on the matters under discussion can be reached.

Dunn[1] says that "... a zone richer in chlorite and biotite will form in the outer part of the zone saturated with solutions; under certain circumstances soda, as albite, may also become somewhat concentrated along with chlorite and biotite".

Thus it appears that similar occurrences of rocks have been described in other parts of the world.

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(1). J.A. Dunn - op. cit.

VII CHEMICAL PROCEDURE.

Washington's "The Chemical Analysis of Rocks" was followed except for the determination of lime and magnesia in Analyses I and II in Table XI, where the separation given by Hillebrand and Lundell (Applied Inorganic Analysis" p.487) using alcohol was used, and for the determination of flourine in Table X where the gravimetric method was used as given by Van Tongeren (Gravimetric Analysis, p. 120)

In Table	IV	Analysis I,	SiO_2 is considered to be high
" "	VII		H_2O " " " " low
" "	VIII	Analysis I	H_2O " " " " low
" "	XI	Analyses I & II	S, ZrO_2 and BaO have not been determined.

VIII ACKNOWLEDGEMENTS.

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