THE GEOLOGY, GEOCHEMISTRY AND GEOCHRONOLOGY OF THE NORTHERN MOST HALF OF SAINT FRANCIS ISLAND, NUYTS ARCHIPELAGO: SOUTH AUSTRALIA.

by

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ABSTRACT

The study area is located on Saint Francis Island, of the Nuyts Archipelago. Middle Proterozoic alkali granite, leucogranite, rhyolite and various granitic, rhyolitic, and doleritic dykes are the major rock units present. These are overlain by Quaternary Bridgewater formation.

U-Pb zircon dating of the rhyolite of the western end of Saint Francis Island reveals an age of 1631±3 Ma, which is interpreted as a primary age.

Chemical analyses of the western rhyolites and the eastern alkali granites indicate that both were probably formed by a partial melting process. The rhyolites and granites possibly originated from the same source. The I- and S-type classification is not satisfactory for the granites. These granite may be A-type granites, that is derived from a granulite source. The rhyolites and granites were possibly formed by partial melting of a granulite, which has had a long residence time in the crust.

1. INTRODUCTION

1.1 Location of Study Area

Saint Francis Island is one of more than 20 islands that make up the Nuyts Archipelago, which lies off the coast of South Australia, in the Great Australian Bight. The island is approximately 50 kilometres south-west of Ceduna (Fig. 1).

The area under consideration in this study is located on the northern most half of Saint Francis Island.

1.2 Aims of Study

The aims of the study are as follows:

(a) To undertake a general investigation of the geology of the northern most half of Saint Francis Island.

(b) To obtain a geological map of this area.

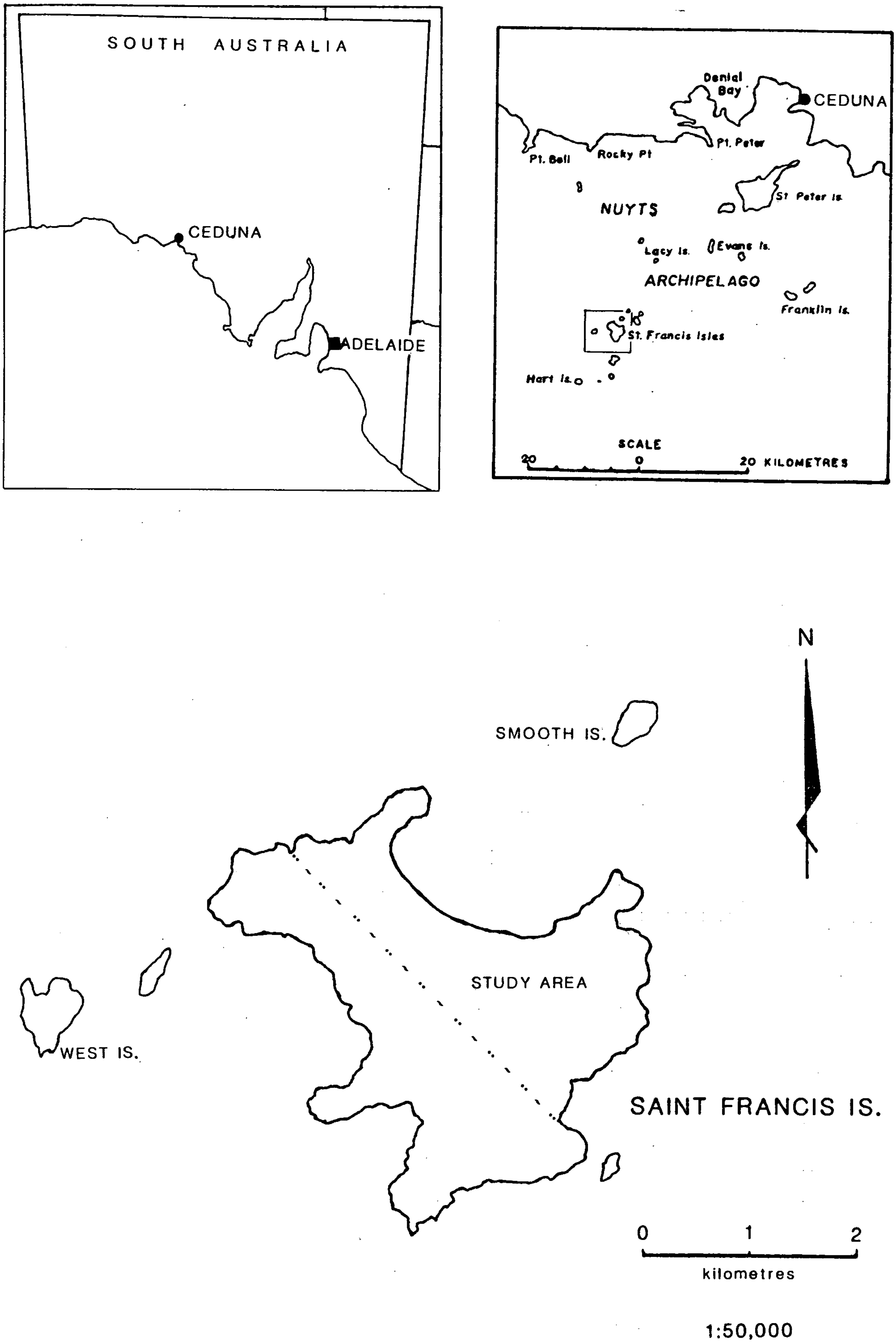
(c) To obtain a U-Pb date for the acid volcanics on the western end of the island, and compare this with other acid volcanics from the Gawler Craton.

1.3 Logistics

This study was based on samples collected by Dr. J.A. Cooper and the author during a field trip to Saint Francis Island in January 1982. Dr. Cooper, B. Morrison, two S.A.D.M.E. Regional Geologists, J. Parker and R. Flint, and the author joined a party of 20 people from the Malacalogical Society and the South Australian Museum on the field trip to the island.

Two samples of approximately 30 kilograms were collected from Saint Francis Island for the purpose of U-Pb dating of zircons. One of the samples was chosen for geochronological work, the other is stored in the Geology Department of the University of Adelaide.

FIG 1. LOCATION MAP



1.4 Previous Geological Investigations

Little geological work has been carried out on Saint Francis Island prior to 1982. In 1968 Walker and Botham prepared a geological plan based on aerial photo-interpretation only. More detailed plans were produced by Kinsman in 1973, but these were also based only on photo-interpretation.

In January 1973 R.B. Major (S.A.D.M.E.) visited Saint Francis Island, while investigating the islands in that area, and made a few, brief comments on the geology which can be found in Major (1973). (incl. in refs.)

In 1974 the S.A.D.M.E. conducted (by helicopter) a geological survey of all the offshore islands of South Australia. A number of islands within the Nuyts Archipelago, including Saint Francis, were investigated. Numerous samples were collected and petrological, geochemical, geochronological work was carried out on these. The geochronological investigations are discussed in section 4.1.1.

From the notes collected on this "fly past" survey, the geology of Saint Francis Island is briefly described in Flint and Crook (1981)a.

No further geological work was then undertaken until 1982.

2. GEOLOGICAL SETTING

2.1 Regional Geology

Saint Francis Island lies on the southern most, offshore portion of the Gawler Craton. The Gawler Craton is an extensive shield area that forms the crystalline basement under much of the Eyre Peninsula and beyond (Blissett, 1975). To the south it is bound by a series of faults defining the continental margin formerly connected to Antarctica; to the east it is bound by the Delamerian Adelaide Fold Belt (the Torrens Hinge zones marks the actual boundary); and to the north and northwest it is bound by the Musgrave Orogenic Domain (Parker et al., 1981). The rocks of the Gawler Craton range from Archean to Early Proterozoic gneisses, granites and metasediments, to Middle Proterozoic sediments, volcanics and granites (Parker et al., 1981). The late Archean to early Proterozoic basement

2.1 Regional Geology (cont.)

of the Gawler Craton consists of the Sleaford Complex in the southern, Coulta Subdomain, separated from the Mulgathing Complex in the northern, Christie Subdomain by the extensive sheet of Gawler Range Volcanics (Thomson, 1980). The Lincoln Complex refers to the Early to Middle Proterozoic rocks of the overlying sequence (includes the Hutchison Group) (Webb, 1978; and Thomson, 1980).

Deposition of the Corunna Conglomerate, extrusion of the Gawler Range Volcanics, post-orogenic granitic intrusion, and local deformation represent the final events leading to cratonization of the Gawler Craton (Parker et al., 1981).

The tectono-magmatic history of the Gawler Craton can be divided into two periods separated by an apparently quiet interval of 500 million years (Webb et al., 1978). The oldest period, the Sleafordian Orogeny, is thought to date back as far as 2800 Ma and to have ceased 2300 Ma ago (Daly et al., 1978 and 1979; and Webb, 1979). The second active period, the Kimban Orogeny (Thompson, 1969), contained several metamorphic and magmatic phases and involved some reworking of the ancient basement along with the metamorphism of sediments deposited during the quiescent interval (Webb, 1978).

The date of the rhyolite, of western Saint Francis Island, at 1631 Ma, places it towards the end of the Kimban Orogeny in the second active period. The other rocks on the island, from dates obtained by Webb et al. (1978), would be post Kimban orogenic and possibly equivalent to the Gawler Range Volcanics, also within the second active period.

2.2 Local Geology of Saint Francis Island

The major rock units present on Saint Francis Island are Middle Proterozoic leucogranites, alkali granites, acid volcanics and various vein and dyke type intrusions (all un-named units). These are unconformably overlain by Quaternary Bridge-water formation with its calcarenites and calcretes (Flint and Crook, 1981).

All of the above rock-types (excluding the Quaternary Bridge-water formation) are affected by a number of common joint sets. The jointing follows three main directions, these bring 20°, 60° and 140°. A rose diagram illustrating the joint pattern is shown in Fig. 4. These joints cut across rocks of different lithologies which indicates that they are probably a product of a regional deformation.

Saint Francis Island has outcrops of Proterozoic rocks at either end and between, at the narrowest part of the island, there are only beaches. This gives the island a distinctive shape, wider at the ends where there is Proterozoic outcrop, and narrow in the centre, where there is no outcrop. A possible explanation for this is that a shear zone runs through the middle of the island, from the north-east to the south-west. A shear zone in this region would have facilitated a greater degree of weathering which would have helped to produce the island's distinctive shape. Although there is no visible evidence of such a shear zone, only inferred, Parker and Flint (1982) found a shear zone running through the centre of Egg Island which, if continued, would cut across Saint Francis Island with the right orientation.

The geology of the island is basically separated into two groups by the long beaches and the central part of the island. These areas have no Proterozoic outcrop. The western end of the island is principally composed of acid volcanics and the eastern end of alkali granites (Fig. 2).

The chemistry of the acid volcanics from the western end of Saint Francis Island indicates that they are of rhyolitic composition (Le Maitre, 1976; Streckeisen, 1967; Appendix II, Table 6). They are predominantly grey in colour although some appear as red-grey, usually in zones which show greater fracturing of the rocks. Phenocrysts of quartz, and often tabular alkali feldspar, lie in a cryptocrystalline groundmass. These rocks are strongly affected by the regional jointing system, mentioned above, which tends to give them a very "blocky" appearance.

In the western corner of the map area (Fig. 2) there is an intrusive body of leucogranite within the rhyolite. The leucogranite is a medium grained, pink coloured granite, consisting mainly of quartz and alkali feldspar. The leucogranitic intrusion is up to 30m across in places.

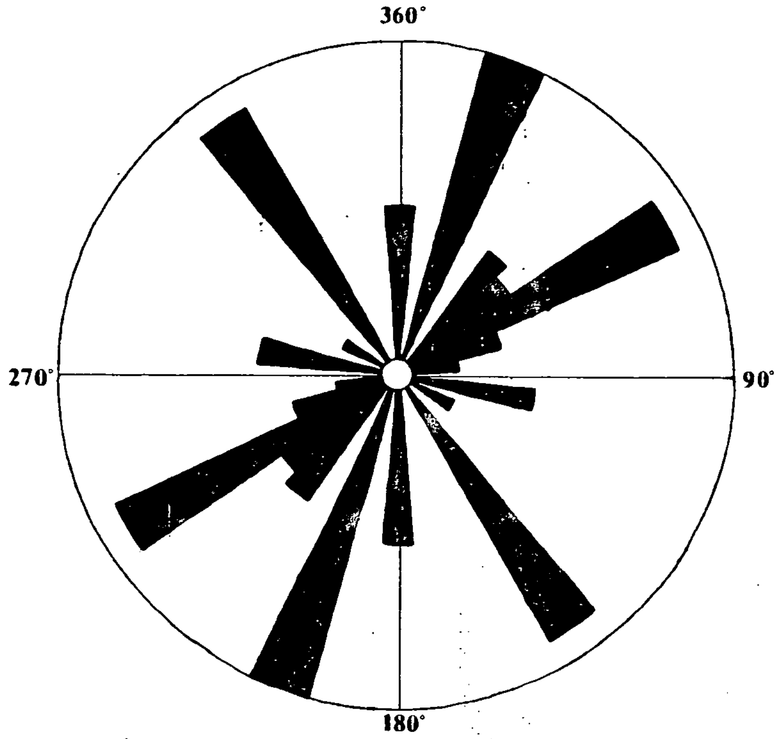


FIG 4 ROSE DIAGRAM OF JOINT PATTERNS

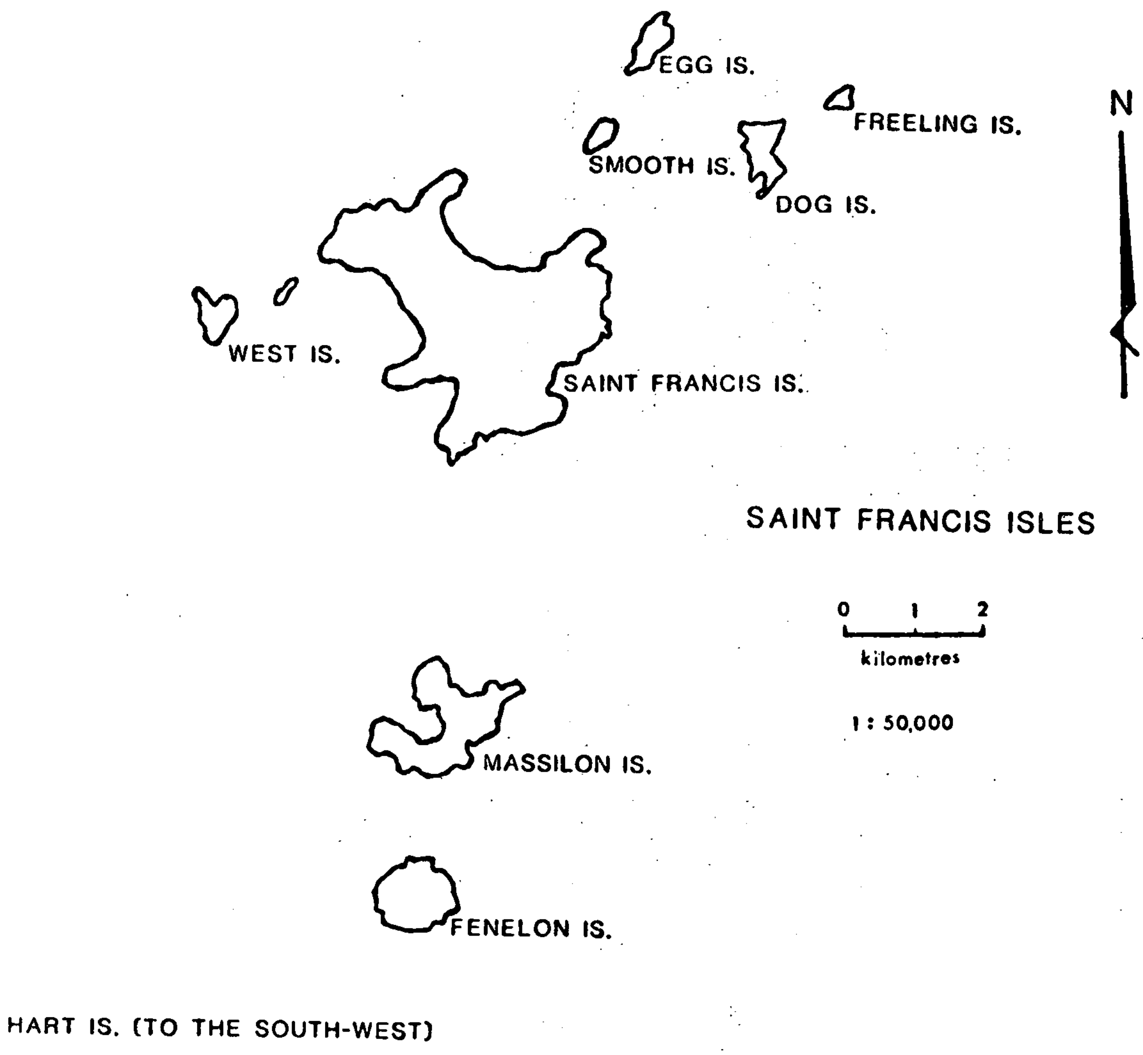


FIG 5 LOCATION OF ISLANDS IN THE SAINT FRANCIS ISLES.

At the contact with the rhyolite the leucogranite body has distinctive chilled margins (Plate 1A). A number of veins of this material run out into the rhyolite. At one point a vein of leucogranitic material is cut by a dolerite dyke, and some distance away there is brick shaped inclusion of leucogranite with a dolerite dyke (Plate 1B). This indicates that the leucogranite was emplaced before the dolerite dykes intruded the rhyolite.

There are many of these dolerite dykes intruding the rhyolite, and they tend to follow the jointsets striking at 20^{o}, and 60^{o} (Fig. 4; Plate 1C). Although most of these dykes appear to have been extruded at about the same time, there is one apparently older dolerite dyke. This dyke is in an area of more sheared rhyolite (a possible fault zone) and it has been affected to a greater degree by the weathering, but because of its general appearance, and the way it is partially folded in the rhyolite, it appears to be of an earlier generation of dykes. This would indicate that there have been at least two phases of dolerite dyke intrusion into the rhyolite.

The rhyolite closer to the northern point show a streakiness which is due to the injection of small veins and "blebs" of lighter coloured material. These veins appear to be of the same composition as the rhyolite, even though there is a colour variation. There is, at one location, a dyke (up to 0.5m wide) of this material which, when analysed, shows the same chemical composition as the rhyolite. This dyke is present on both sides of the point and is inferred to cut through the point.

The eastern end of the island is chiefly composed of alkali granites, massive grey-coloured, medium grained granites with a low mafic content (Plate 2A). The granites have also been affected by the regional jointing, but not as prominently as the rhyolite from the western end of Saint Francis Island.

Within the alkali granite there are a number of xenoliths of a coarse grained red material, of predominantly feldspar composition. These inclusions are possibly earlier pegmatites, from the original country rocks, which were incorporated in the granite.

Other xenoliths of a coarser grained material, with irregular boundaries, are also found. Chemically, though, this material is of the same composition as the surrounding granite (Section 5). There is also a colour variation within the granite from the grey to a pink-grey, which does not affect the chemical composition (Section 5).

One section of the granites has a weak foliation, represented by a poor lineation of the elongate grains, but this is not a widespread occurrence.

There are a number of dyke-type intrusives in the eastern granite, including a coarse rhyolite dyke, a finer grained rhyolite dyke, both on the north-eastern end of the island, and numerous dolerite dykes.

The coarse porphyry dyke has large, pink and green, feldspar phenocrysts (up to 2cm across) which often show a zoning effect (Plate 2B). This dyke is present at three different locations (Fig. 2) and it can be inferred that they are all part of the one intrusion. The dyke follows the 20^{o} striking joint set (Fig. 4). A similar porphyry dyke, on the south-eastern side of the island (B. Morrison 1982), could possibly be related, although it follows the jointset striking at 60^{o}. In places the dyke is up to 12m wide.

The finer grained rhyolite dyke (Plate 2C) is dark grey coloured with rectangular phenocrysts of pink feldspar. The margins of the dyke have a very fine grained groundmass, which becomes coarse towards the centre of the dyke. The dyke appears to have suffered a certain amount of shearing (sinistral deformation) as can be seen from the twisted edges. This dyke is probably one of the later events in the igneous history, but it is not possible to determine, from the field evidence, if it was intruded before or after the intrusion of the dolerite dykes.

Dolerite dykes, similar to those on the western end of the island, are also a common feature on the eastern end of the island, but less numerous. They are often more massive, and tend to strike in the same general direction (at 20^{o} and 140^{o}), again following the jointing pattern. Many of these dykes have suffered extensive weathering in some cases leaving large trenches as evidence of their existence.

Another vein-type inclusion in the alkali granite is a series of quartz-veins, of various sizes, which occur in the south-eastern corner of the map area. These veins all have a consistent strike of approximately 140°. Within some of the wider veins (up to 5cm) there are cubes of pyrite, but these are not very abundant.

3. LITHOLOGIES

Representative thin section descriptions are included in Appendix I. Classification of rock-types is according to the system of Streckeisen (1967). All rock-types belong to un-named units so the field names are used here.

3.1 Alkali Granite

This rock is a massive, medium grained, equigranular, light grey coloured granite, consisting principally of quartz and alkali feldspar, graphically intergrown (Plate 3A, 3B). Other minerals present include minor plagioclase, hornblende, aegirine-augite, biotite, opaques, traces of sphene and zircon (Plate 3C).

The granite has a low mafic content, and although this rock-type has been described, in Flint and Crook (1981)a, as containing riebeckite, this mineral was not found in samples collected by the author.

The granite varies in colour from dominantly light grey to pink-grey in places, but the chemical composition is very similar, regardless of the colour. In places there are zenoliths of coarser grained granite within the alkali granite, but these also do not vary compositionally.

3.2 Rhyolite

The rhyolites, which outcrop at the western end of Saint Francis Island, are predominantly grey to dark-grey in colour, massive, and porphyritic. The rocks contain white feldspar phenocrysts (up to 3mm) and grey quartz phenocrysts (Plate 4A). The phenocrysts contribute about 40% to the total volume of the rock, with the fine grained ground mass making up the rest.

The rock appears to be all rhyolite flow and no tuffs were seen. although there is a possibility that welded tuffs are present.

3.3 Leucogranite

A cream to pink coloured intrusive leucogranite is situated on the western end of Saint Francis Island. It is a medium grained, equigranular, massive rock, composed mainly of potassium feldspar and quartz (Plate 4B). Veins of this material intrude out into the rhyolite. The leucogranitic body has a very fine grained, almost glassy, texture at the contact with the rhyolite, a feature which indicates chilled margins (Plate 1A)

3.4 Porphyritic Rhyolite Dykes

3.4.1 Coarse Porphyry Rhyolite Dyke

This dyke-type intrusion is on the north-eastern side of the island (Fig. 2). In some places the dyke is up to 12 metres wide. The coarse texture of the rock is provided by the large feldspar phenocrysts. These are alkali feldspars and can be up to 15mm across.

The rock is generally a massive dark grey coloured unit, with the pink and green feldspar phenocrysts showing up quite clearly. The rock weathers to a whitish-grey colour with the phenocrysts becoming less obvious.

3.4.2 Fine-grained Porphyry Rhyolite Dyke

A fine-grained rhyolite dyke is located on the north-eastern part of the island (Fig. 2). It is dark-grey in colour, with a fine-grained groundmass, with small pink, rectangular phenocrysts. The dyke has a very fine-grained groundmass at the edges which becomes coarser to the middle. The dyke intrudes the alkali granite, following one of the joint-sets which strikes at about 20^{o}.

3.5 Dolerite Dykes

The dykes are dark green, fine-grained mafic material. The major minerals present are plagioclase, epidote and amphibole. At some locations the dykes have been altered to epidote by weathering. The dykes occur all around the island, and they tend to follow the joint-sets which strike at 20^{o}, 60^{o} and 140^{o}.

4. GEOCHRONOLOGY

4.1 General

4.1.1 Previous Investigation

Webb et al. (1978) have done a number of age determinations on samples collected from the Nuyts Archipelago, including Saint Francis and nearby islands. Samples analysed from Saint Francis Island include the alkali granite, leucogranite, and certain acid volcanics. The ages of these rocks were determined using Rb/Sr systematics.

The dates obtained, rock-types and sample localities, are shown in Table 1. The location of the islands where the samples were collected can be seen in Fig. 5.

4.1.2 Purpose of Dating

When this project was first initiated it was thought that no geochronological work, of any sort, had been carried out on the rocks of Saint Francis Island. When the work by Webb was realised, it was still thought that there was no age determination of the acid volcanics of the western end of Saint Francis Island. Because the western end of the island is geographically separated from the eastern end, it was thought that an age from the western part of the island may provide useful information when looking at the overall geology of the island. It was also thought that a date on these acid volcanics would be useful to determine if there is any correlation with other rocks of the Gawler Platform.

4.2 Sampling and Dating Procedure

Two samples, of approximately 30 kilograms, were taken from the western end of Saint Francis Island. One sample was of the rhyolite and the other was of the leucogranite. As at this stage it was still thought that no age determination had been carried out on the rhyolite this sample was chosen for the geochronological work.

TABLE 1: PREVIOUSLY DATED SAMPLES

AGE	ROCK TYPE	LOCATION
1547 ± 17 Ma	LEUCOGRANITE	FREELING ISLAND, DOG ISLAND, MASSILON ISLAND, FENELON ISLAND, HART ISLAND
1542 ± 22 Ma	LEUCOGRANITE	FREELING ISLAND, DOG ISLAND
1490 ± 12 Ma	ACID VOLCANICS	SAINT FRANCIS ISLAND, HART ISLAND, NEST ISLAND
1489 ± 15 Ma	LEUCOGRANITE	SAINT FRANCIS ISLAND
1478 ± 15 Ma	ALKALI GRANITE	SAINT FRANCIS ISLAND, MASSILON ISLAND, FENELON ISLAND,
1466 ± 79 Ma	YOUNG GRANITE	WEST ISLAND

A zircon concentrate was obtained from approximately 33 kilograms of relatively fresh rhyolite, which was taken from the western end of the northern beach (Station 795-29, see Fig. 3).

The zircons were separated and concentrated following the procedure laid out in Appendix IV. The zircons obtained were generally glassy, and euhedral ~~shaped~~ (Plate 5 A-E).

Regression lines were computed using a program developed by Ludwig (1980).

4.3 Results

U and Pb elemental concentrations, daughter/parent isotope ratios, and ages for all sample fractions are reported in Table 2. The concordia plots are reproduced in Figs. 6a, 6b and 6c. One of the points, on the concordia plots, is exactly concordant, four are slightly normally discordant and one is reversely discordant.

The diagram in Fig. 6a has all of the six points plotted, and they all lie very close to the concordia curve. The upper intercept yields an age of 1631 ± 2 Ma (MSWD 1.84). The Model 2 concordia-intercept solution used in regressing these points assumes that all are given equal weight and that any variation is geological in origin.

A second plot (Fig. 6B) using a Model 1 concordia-intercept solution, which assumes all scatter is due to analytical error, gives an upper intercept value of 1631 Ma (MSWD 1.84).

If the reversely discordant point is omitted (Fig. 6C) then the concordia upper intercept value remains virtually the same at 1630 ± 5 Ma (MSWD 1.45).

Forcing either the five or six points through a non-negative point, the origin, the age obtained is 1631 ± 3 Ma (MSWD 2.09).

The age determination on the rhyolite is very good, and this is only possible as all points are nearly concordant.

TABLE 2 GEOCHRONOLOGICAL DATA, ACID VOLCANIC

Sample No.	Size (B.S.S.) and magnetic fraction (Slope, Dip)*	Sample Wt	Pb ppm	U ppm	Atomic Ratios				Age Estimates		
					$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
95/29 D4	-140 + 200 10^{o}, 1^{o}-½^{o}	0.0069	74	203	0.2854	3.947	0.10029	1402.3	1619	1623	1630
95/29 D5	-140 + 200 10^{o}, <½^{o}	0.00946	69	180	0.2994	4.139	0.10026	1097.0	1688	1662	1629
95/29 E4	-200 + 230 10^{o}, 1-½^{o}	0.0093	79	214	0.2888	3.992	0.10026	1473.0	1635	1633	1629
95/29 E5	-200 + 230 10^{o}, <½^{o}	0.01036	80	221	0.2838	3.936	0.10059	1877.0	1611	1621	1635
95/29 F4	-230 + 270 10^{o}, 1^{o}-½^{o}	0.00836	76	207	0.2835	3.924	0.10039	1029.2	1609	1619	1631
95/29 F5	-230 + 270 10^{o}, <½^{o}	0.00956	82	227	0.2842	3.939	0.10051	1552.5	1612	1622	1634

* Size BSS: British Standard Sieve.

Magnetic - 10^{o} Slope, X Dip.

FIG 6a: Model 2

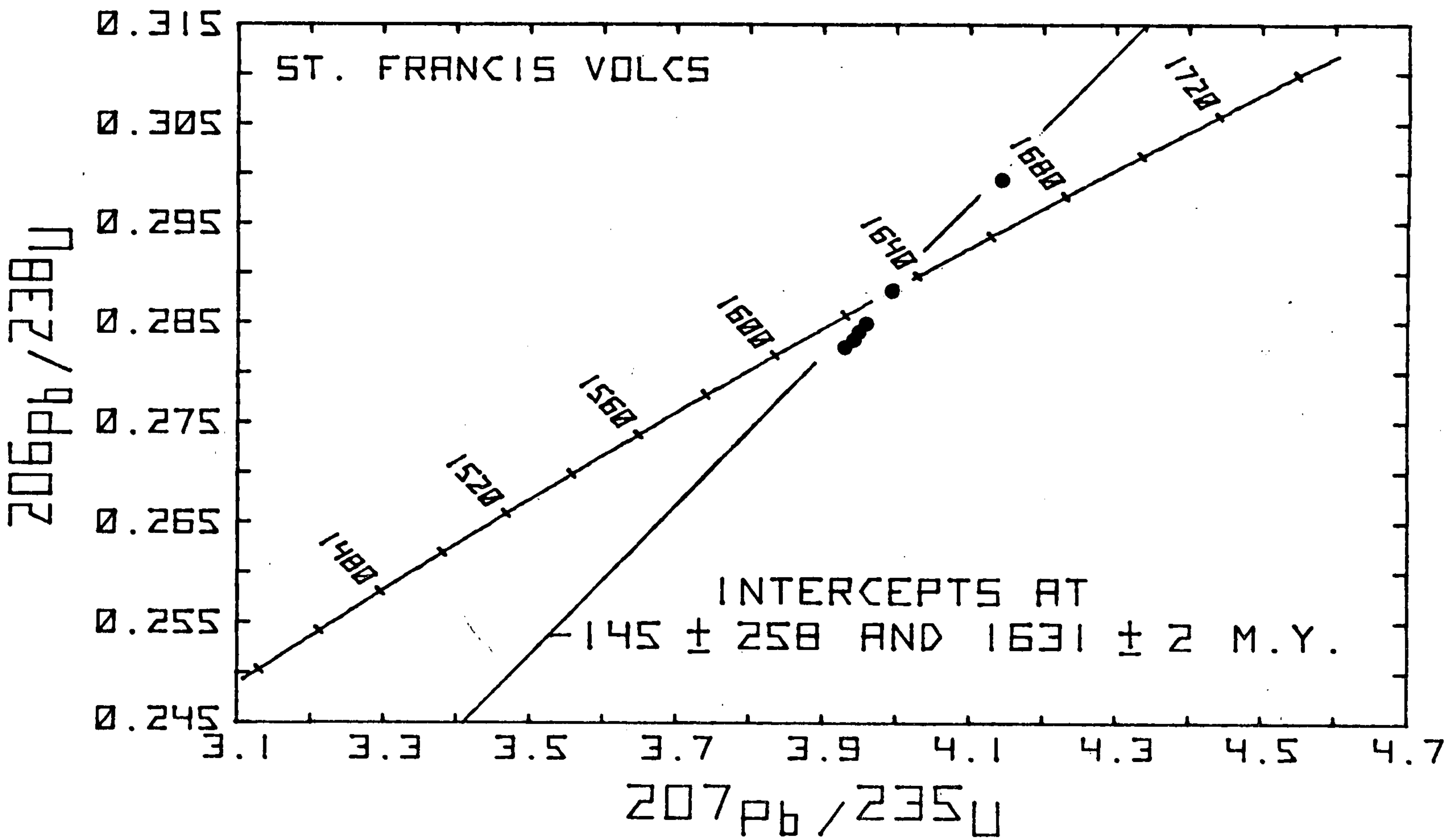


FIG 6b: Model 1

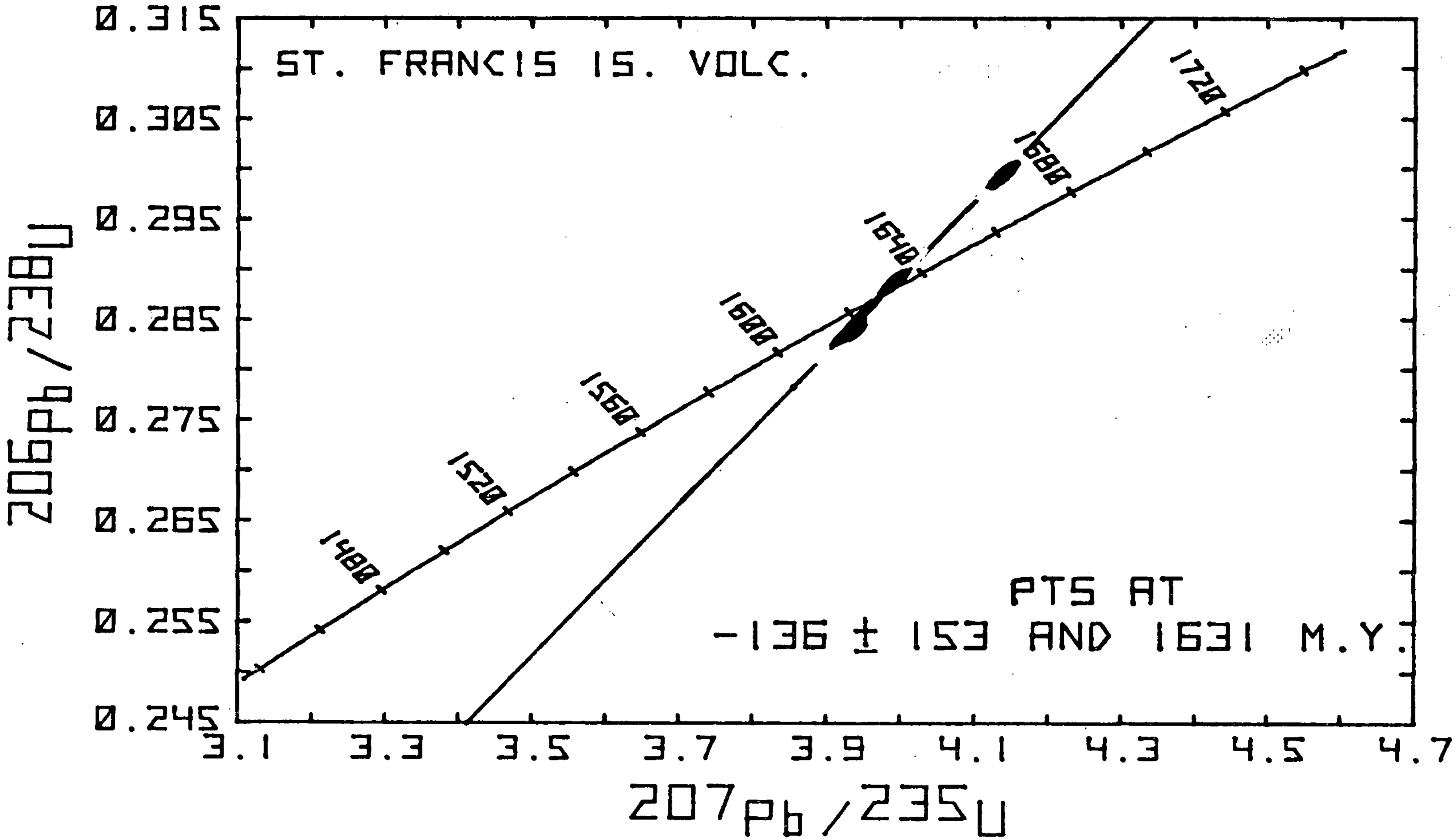
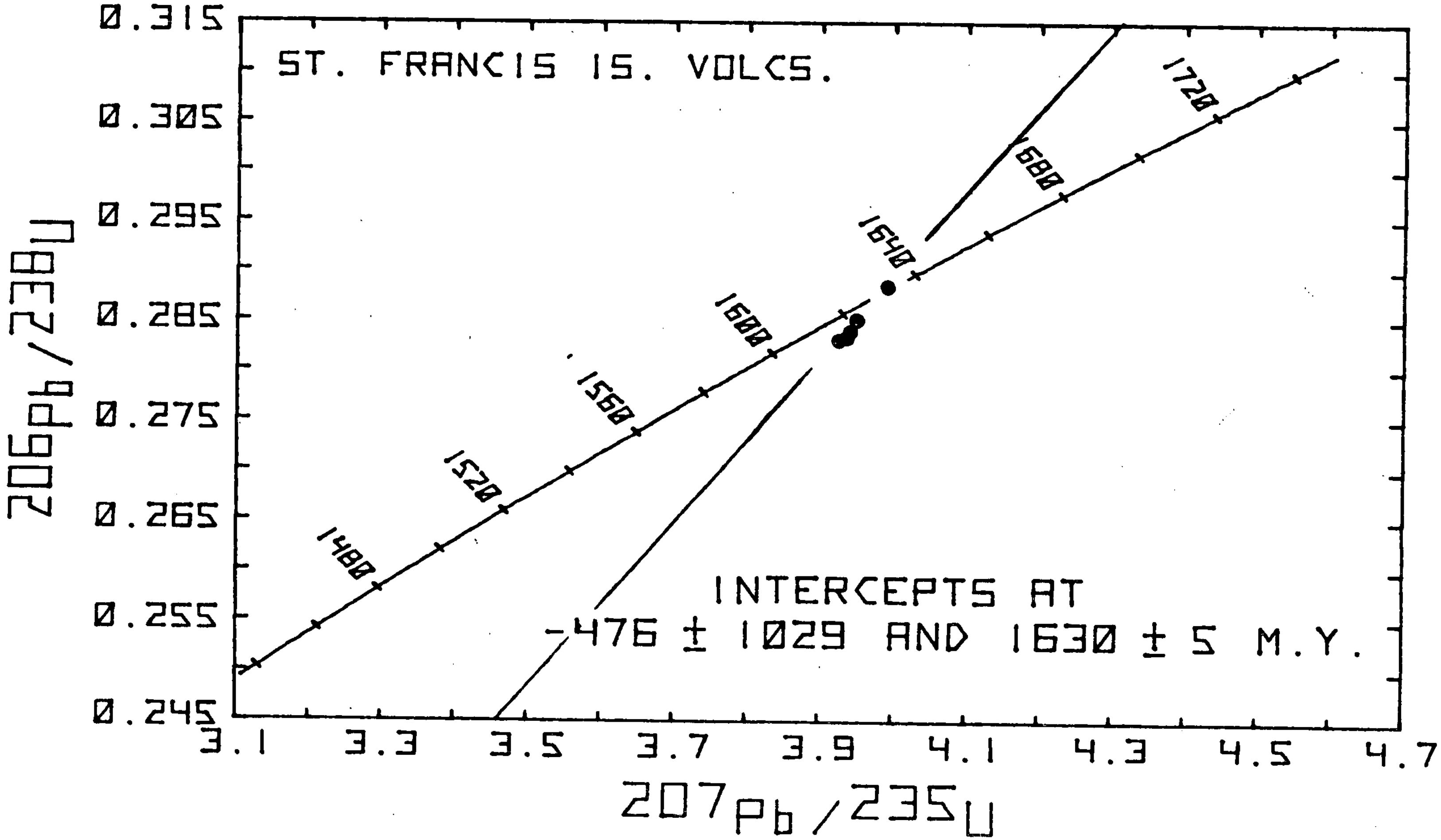


FIG 6c



ST. FRANCIS IS. VOLCS.
INTERCEPTS AT
-476 ± 1029 AND 1630 ± 5 M.Y.
1480
1520
1560
1600
1640
1680
1720
0.315
0.305
0.295
0.285
0.275
0.265
0.255
0.245
3.1
3.3
3.5
3.7
3.9
4.1
4.3
4.5
4.7
206Pb/238U
207Pb/235U

4.4 Discussion of Results

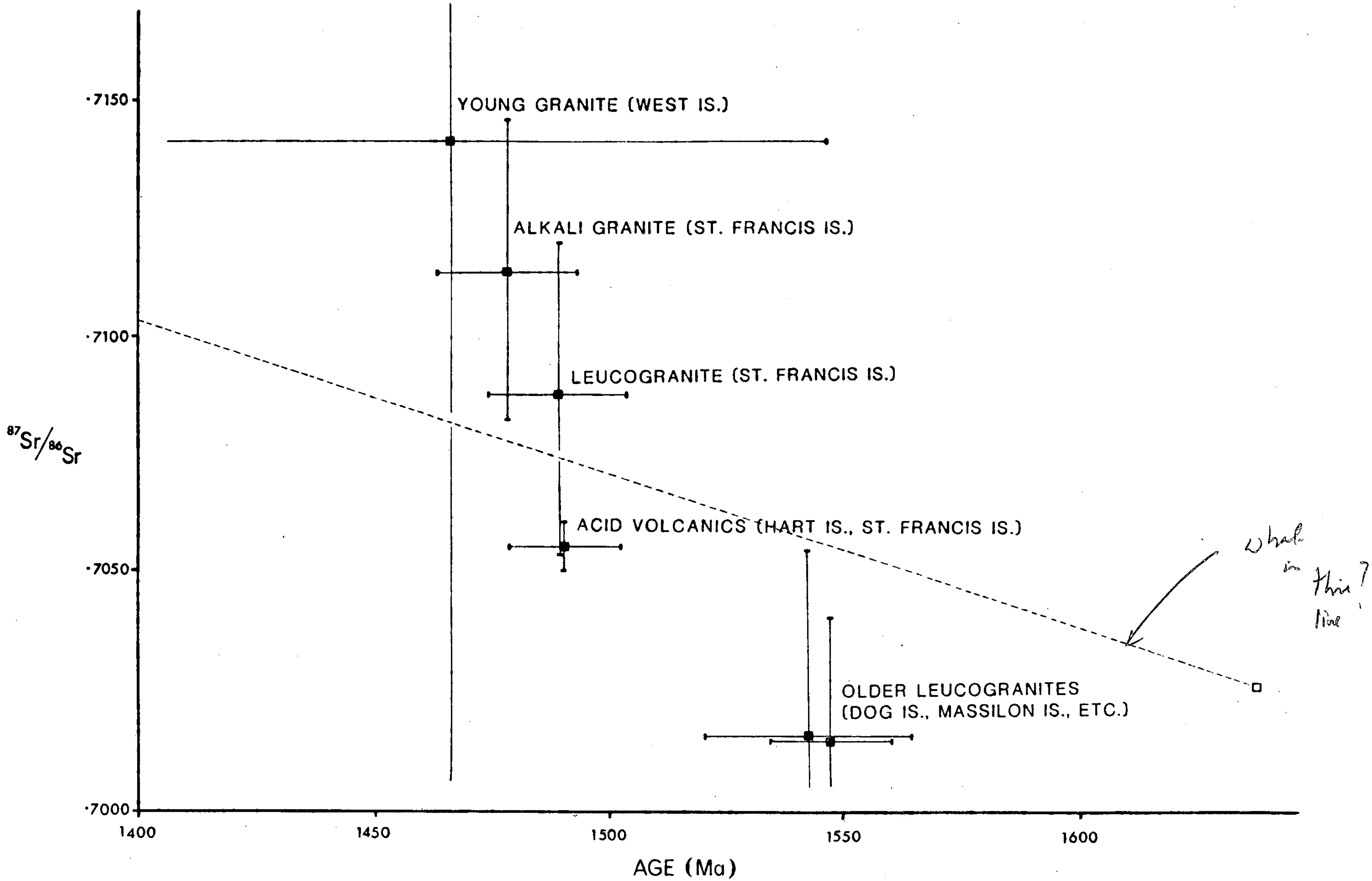
Because of the near concordancy of the points the age determination is very good, and this is so whichever model is used. This gives a very reliable age of the crystallisation of the rhyolite.

The age which Webb et al. (1978) eventually arrived at for the acid volcanics of the Saint Francis Isles was 1490 ± 12 Ma. This age was determined using Rb/Sr systematics which have a reputation for giving ages that are too young, often considerably younger than the actual ages of igneous crystallisation, Page (1978). Page states that this is common where the Rb/Sr isochron technique is applied to slightly altered Precambrian igneous rocks, especially acid volcanics. If this is the case with the rocks from the Saint Francis Isles then it would appear that the age determined for the rhyolite on Saint Francis Island, by Webb et al., is in error and that the older age of 1631 ± 3 Ma is, in fact, a more reliable age.

The discrepancy between the U-Pb and the Rb/Sr isochron ages of the Saint Francis Western acid volcanic could mean that the other Rb/Sr isochron ages on the island are also too young. It is impossible to determine if this is, or is not, the case without carrying out U-Pb work on the other rocks. Because of the lack of data it is assumed here that the ages arrived at by Webb et al. (1978), for the alkali granite and leucogranite, are correct.

The results of Webb et al. (1978) indicate that there were at least two events in the igneous history of the Saint Francis Isles, one around 1550 Ma and the other around 1490 Ma. The rhyolite of western Saint Francis Island is older than either of these groups. To determine if it is, in some way, related to rocks from either of these groups, the $^{87}Sr/^{86}Sr$ ratios were plotted against the ages obtained, Fig. 7. The dashed line on the graph is the one on which the $^{87}Sr/^{86}Sr$ ratio, of a rock which had the rhyolite (of Western Saint Francis Island) as its source, with $^{87}Rb/^{86}Sr = 2.6$, would lie. Assuming that at 1630 Ma the $^{87}Sr/^{86}Sr$ initial ratio would have been approximately 0.7029 (Bulk Earth, Allegre et al. (1979)) and that the rhyolite formed with at least that Sr initial ratio, then this gives the

FIG 7 $^{87}Sr/^{86}Sr$ AGE DIAGRAM FOR PREVIOUSLY DATED SAMPLES FROM THE SAINT FRANCIS ISLES.



position of the line. As it can be seen, there could be a possible relationship between the granites of the 1490 Ma group and the western Saint Francis Island rhyolite. It can be said then, from this evidence alone, that the rhyolite is a possible source rock for the granites, or that the rhyolite and the granites are derived from the same source rock.

4.5 Stratigraphic Implications

The rhyolites, from the western end of Saint Francis Island, dated at 1631 Ma, are the oldest, yet determined rocks on the island. The next event, on the western part of the island, was the intrusion of the leucogranite between 1500 Ma and 1470 Ma (Webb et al., 1978). Following this, at some stage, was the intrusion of the dolerite dykes.

On the eastern end of the island the first event was the formation of the granite, between 1500 Ma and 1460 Ma (Webb et al., 1978). This would appear to indicate that the two granites, at either end of the island, are contemporaneous. The various dykes, which intrude the granite at the eastern end of the island, were intruded at some stage after this but, because no ages have been determined on them, it is difficult to say how they lie in the sequence in relation to each other. From the field evidence alone, it appears that the coarse porphyry is the older of the three, then the dolerite dykes (which were probably intruded at the same time at both ends of the island) and the fine-grained rhyolite dyke the youngest.

Whether the rhyolites, of the western end of Saint Francis Island, lie in the overall stratigraphy of the Gawler Platform is uncertain. They have a much older age than the Gawler Range Volcanics, which are thought to have been extruded at about 1525 Ma (Webb, 1979).

There are at least two acid volcanic units, from the Gawler Craton, which may be of the same stratigraphic position as the Western Saint Francis rhyolite.

The first is the sequence of weakly metamorphosed rhyolites and rhyodacites known as the Myola Volcanics (Parker et al., 1981). From the deformational history of this sequence, it is thought that it formed between about 1700 Ma and 1600 Ma (Parker et al., 1981). Although this appears to be in an older age range than the Saint Francis Island rhyolites, it may have some units which are stratigraphically equivalent.

The other group which may be an equivalent unit is the McGregor Volcanics (Parker, 1980a), this term replaces Moonabie Volcanics and Moonabie Porphyry. The McGregor Volcanics are a bimodal suite of acid, ash-flow tuff and basaltic lava flows. It is thought that acid and basic volcanics have different origins (Giles et al., 1979), with the basic volcanics being derived from a mantle source and the acid volcanics formed by partial melting of a dry, basic granulite lower crustal source (Giles et al., 1979). The McGregor Volcanics have been dated by Rb/Sr systematics which give an age of about 1645 Ma to 1615 Ma (Webb et al., in prep.). The acid volcanics of the McGregor Volcanics are, therefore, a distinctly possible stratigraphic equivalent for the western Saint Francis rhyolite.

5. GEOCHEMISTRY

5.1 Introduction

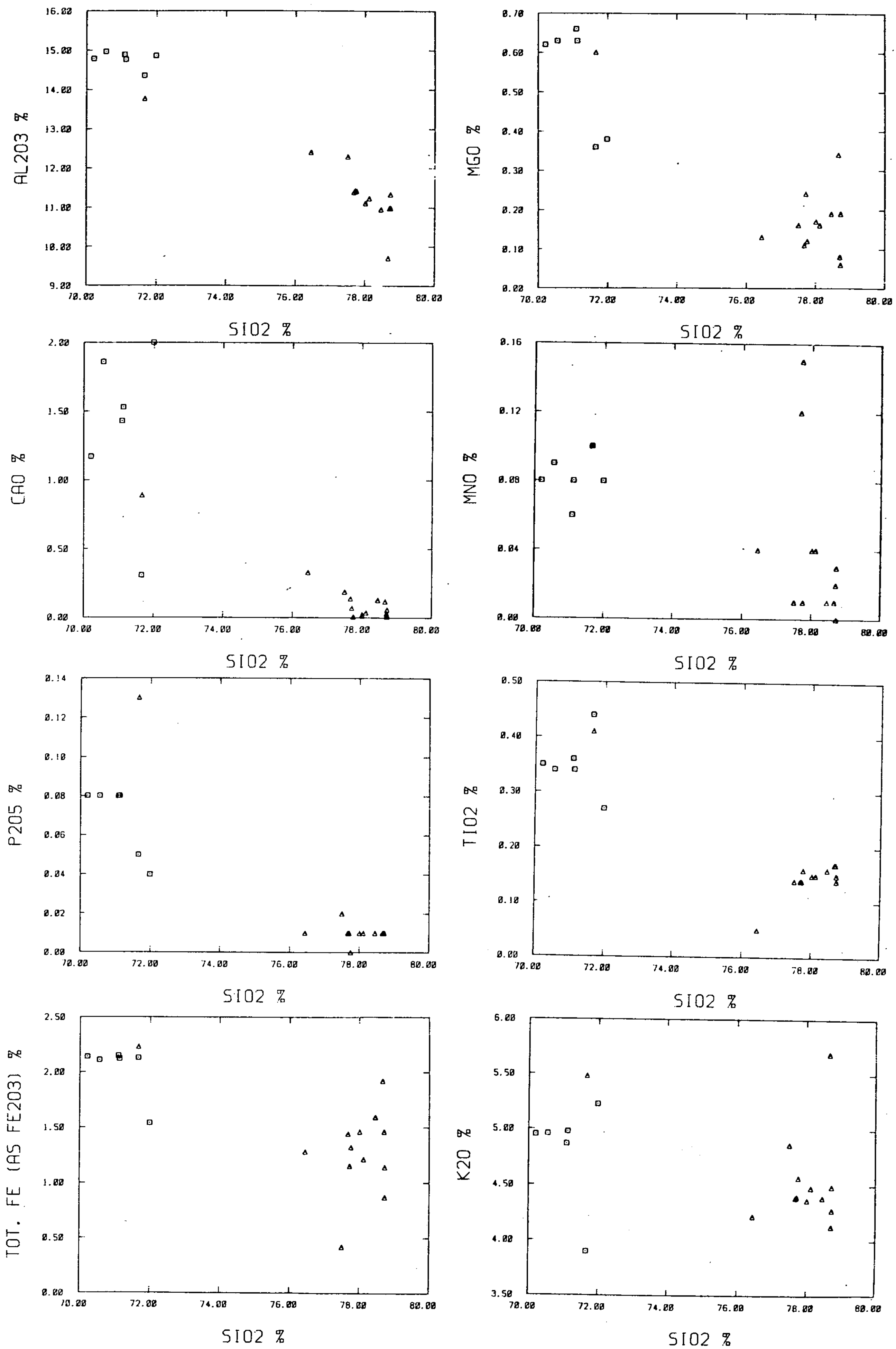
Twenty-two whole rock samples were analysed for major oxide and trace element components. Complete chemical analyses are reported in Table 4, Appendix II.

5.2 Whole Rock Chemistry

5.2.1 Major Element Trends

A convenient way to represent major element variations is to plot major oxide versus silica Harker Variation diagrams (White et al., 1977; Chappell, 1978; Barker, 1979). These plots, for the rhyolite and granites, are shown in Fig. 8.

White et al. (1977) said that a particular source rock will form a minimum melt on partial melting. Progressive separation of melt and restite will give a range of compositions along a "mixing" line.



AL2O3 %
MGO %
CAO %
MNO %
P2O5 %
TIO2 %
TOT. FE (AS FE2O3) %
K2O %
SIO2 %

FIG 8

▲ Granites
▫ Acid Volcanics

Such a "mixing" line appears to be defined for the data points of the granites and rhyolite, with the granites in a position close to the minimum melt composition. This would indicate that the granites and the rhyolites had a common source, or that the rhyolite was the source of the granites.

The mixing line is particularly well defined for the plots involving Al_2O_3 and TiO_2.

5.2.2 Trace Element and Element Ratio Trends

Selected trace element Harker variation diagrams are plotted in Fig. 9. A number of these diagrams are consistent with the major element Harker variation diagrams, in that the granites and rhyolite appear to lie on a common mixing line, with the granites again close to a position of minimum melt composition. The Ba and Sr variation diagrams are a good example of this. Some of the diagrams do not display this feature, showing only a greater variation of trace element relative to silica.

Selected element-element ratios are plotted in Fig. 10. Absolute abundances of trace elements in the rhyolite are invariably higher than in the granites, with the exception of Nb and Y. This is also expressed well in a chondrite normalised incompatible element plot (Fig. 11).

The diagrams involving Ca/Sr and Ce/Nd show the rhyolite and granites follow the same trend, whereas the plots involving TiO_2/Zr, K_2O/Rb and Nb/Zr have the rhyolite and granites in separate groups with individual trends.

The Rb-Ba-Sr ternary plot of El Bouseily et al. (1975) (Fig. 12) suggests that the granites are strongly differentiated granites.

5.3 Application of "I- and S-Type" Classification

Chappell and White (1974) devised a classification scheme based on chemical, mineralogical, and field evidence that distinguished between granitoids derived by partial melting of igneous (I-types) and those derived by partial melting of sedimentary rocks (S-types). This scheme was derived for granitoids of major batholiths in the Tasman Orogenic Zone of Eastern Australia.

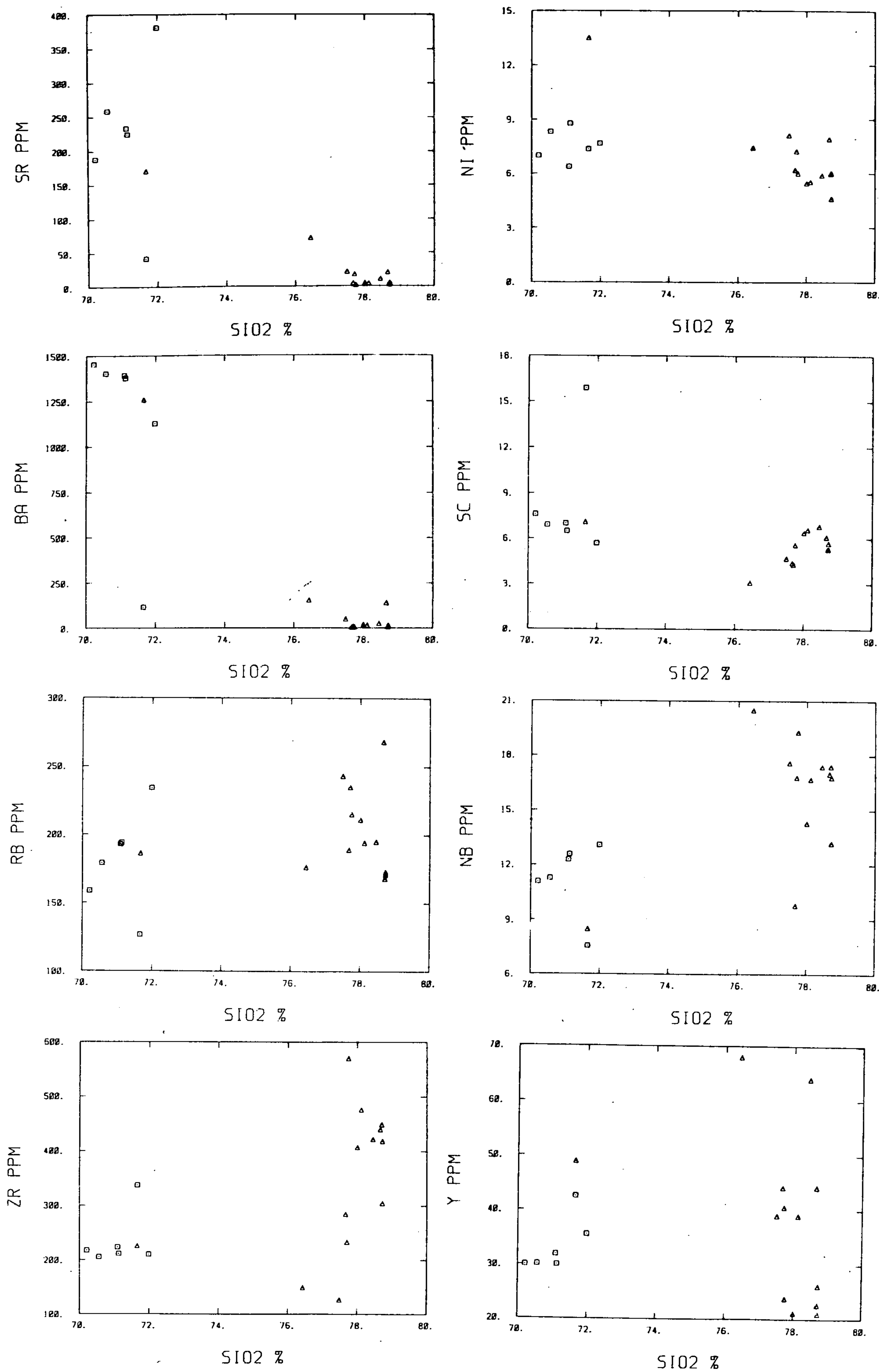


FIG 9

△ Granites

□ Acid Volcanics

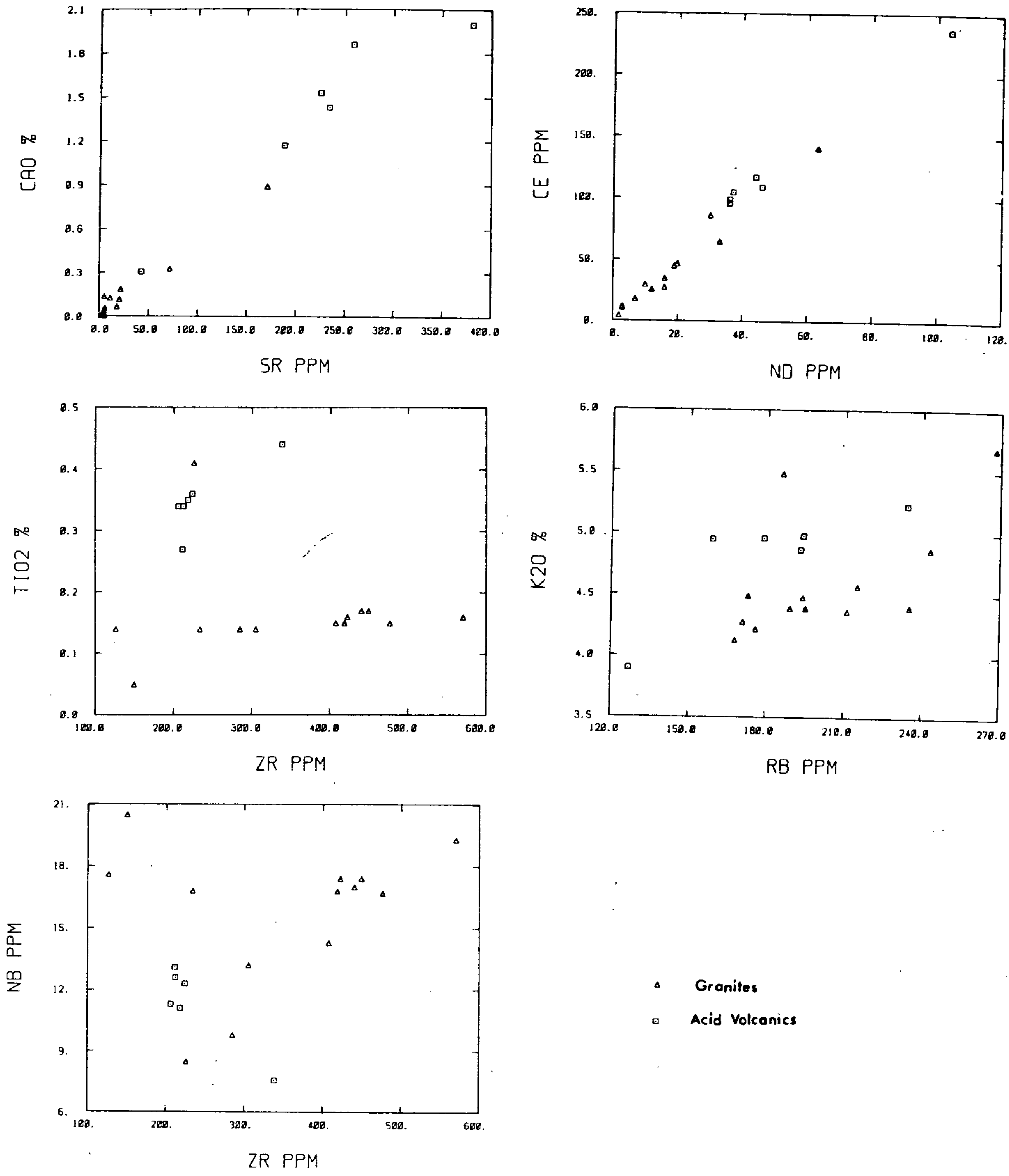

CAO %
SR PPM
CE PPM
ND PPM
TIO2 %
ZR PPM
K2O %
RB PPM
NB PPM
ZR PPM
Granites
Acid Volcanics

FIG 10

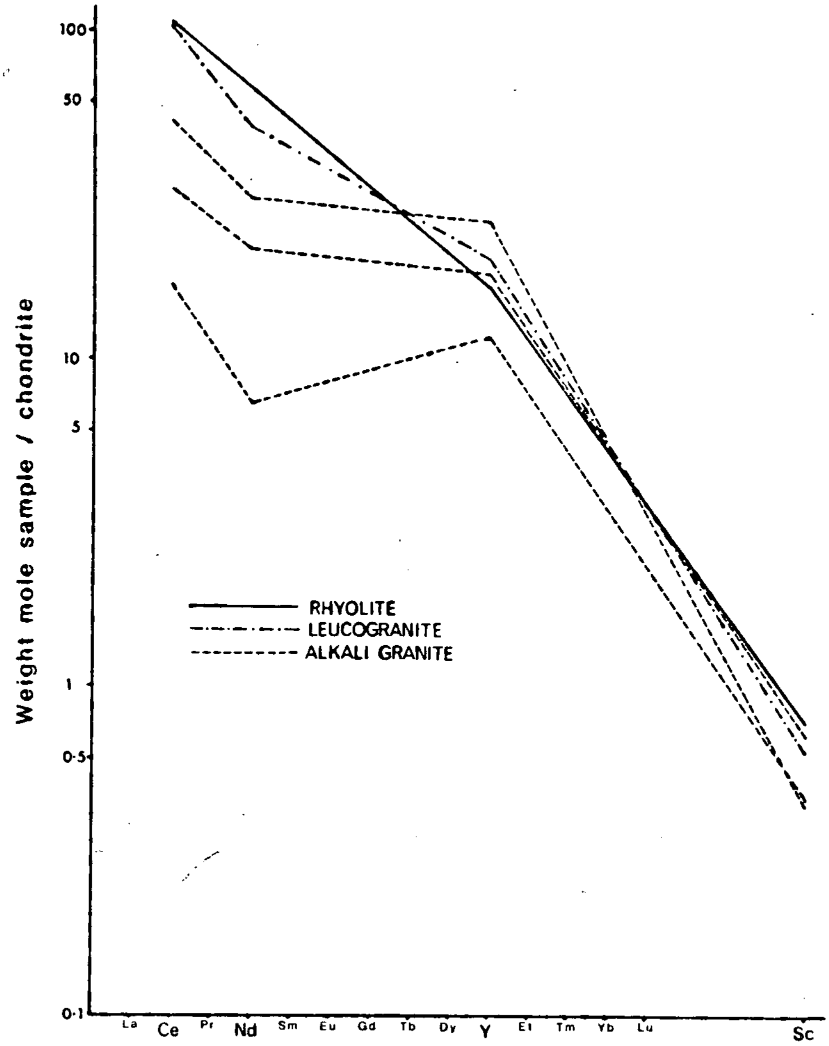

Weight mole sample / chondrite
100
50
10
5
1
0·5
0·1
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Y
Er
Tm
Yb
Lu
Sc
RHYOLITE
LEUCOGRANITE
ALKALI GRANITE

FIG 11

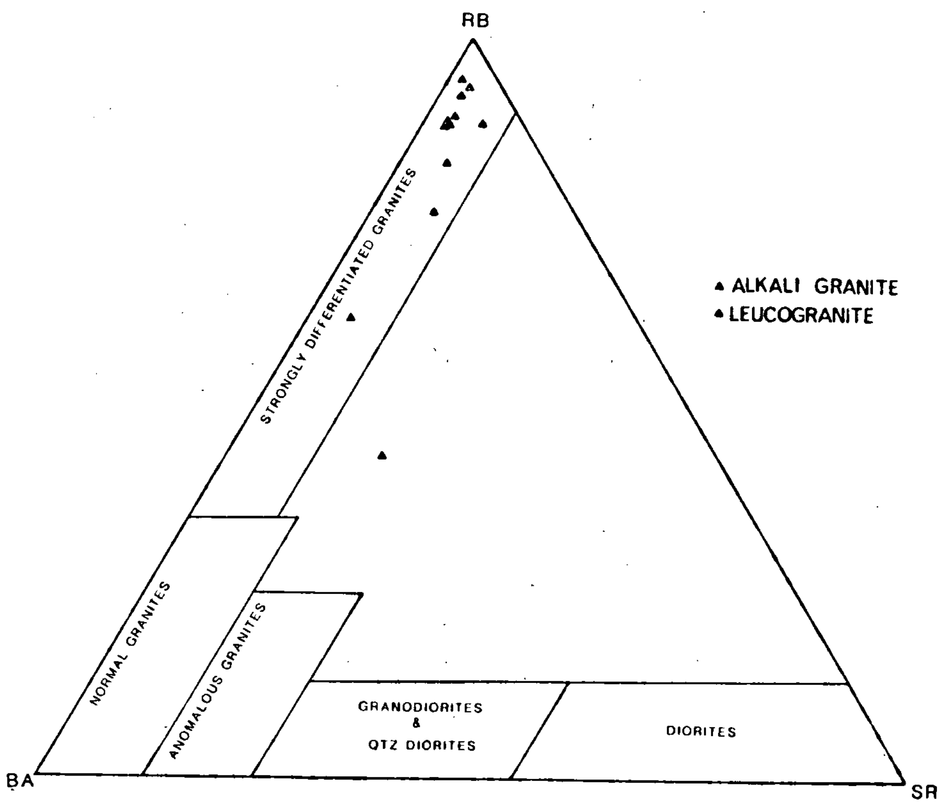

RB
BA
SR
STRONGLY DIFFERENTIATED GRANITES
NORMAL GRANITES
ANOMALOUS GRANITES
GRANODIORITES & QTZ DIORITES
DIORITES
ALKALI GRANITE
LEUCOGRANITE

FIG 12

TABLE 3 I AND S-TYPE GRANITOID CHARACTERISTICS

	Chappell & White 1974)			
	I-Type	S-Type	Pink Leucogranite	Alkali Granite
Na_2O	felsic >3.2% mafic >2.2%	<3.2 for 5% K_2O <2.2 for 2% K_2O	3.78 I	4.24 I
mol $\frac{Al_2O_3}{Na_2O+K_2O+CaO}$	<1.1	>1.1	1.04 I	0.94 I
C.I.P.W. NORM	Diopside or <1% corundum	>1% corundum	0.5% corundum I	diopside I
$^{87}Sr/^{86}Sr$	0.704 - 0.706	>0.708	~~0.7088~~ Webb data .7015 I	0.7114 S

The characteristics of I- and S-type granitoids, as defined by Chappell and White (1974), are listed in Table 3.

Neither the leucogranite or alkali granite fit convincingly into the scheme. Although they appear to have most of the characteristics of the I-type granitoids, the initial Sr ratios are not within the I-type range. This may be because the initial ratios are from bad fitting isochrons.

It may be that the I- and S-type classification can only be strictly applied to Phanerozoic granitoids, and possibly only to those in areas with similar tectonic histories to that of the Tasman orogenic zone.

5.4 Petrogenetic Models

5.4.1 Partial Melting

Harker variation diagrams (Figs. 8 and 9) suggest that the granites of Saint Francis Island may be of a minimum melt composition. The data points of the granites often plot very close to the SiO_2 axis, and in several cases, occupy the position of minimum melt.

The granite, being of near minimum melt composition, should plot near the low temperature regions of relevant phase diagrams. On the Ab-An-Or ternary diagram (Fig. 13) the granites plot in the low temperature trough. On the Qtz-Ab-Or ternary diagram (Fig. 14) they plot near the ternary eutectic defined for water vapour pressures of 4 kb.

The granites are enriched in light rare earth elements relative to the heavy rare earth elements (Fig. 11), as would be expected with a partial melting process that had minimal liquid to mobilise the heavy rare earth elements.

The alkali granite has graphically intergrown quartz and alkali feldspar, which indicates a eutectic melt.

The granite also has a low ferromagnesium element content, elements which are likely to be relatively depleted in the partial melt (Byerly et al., 1976).

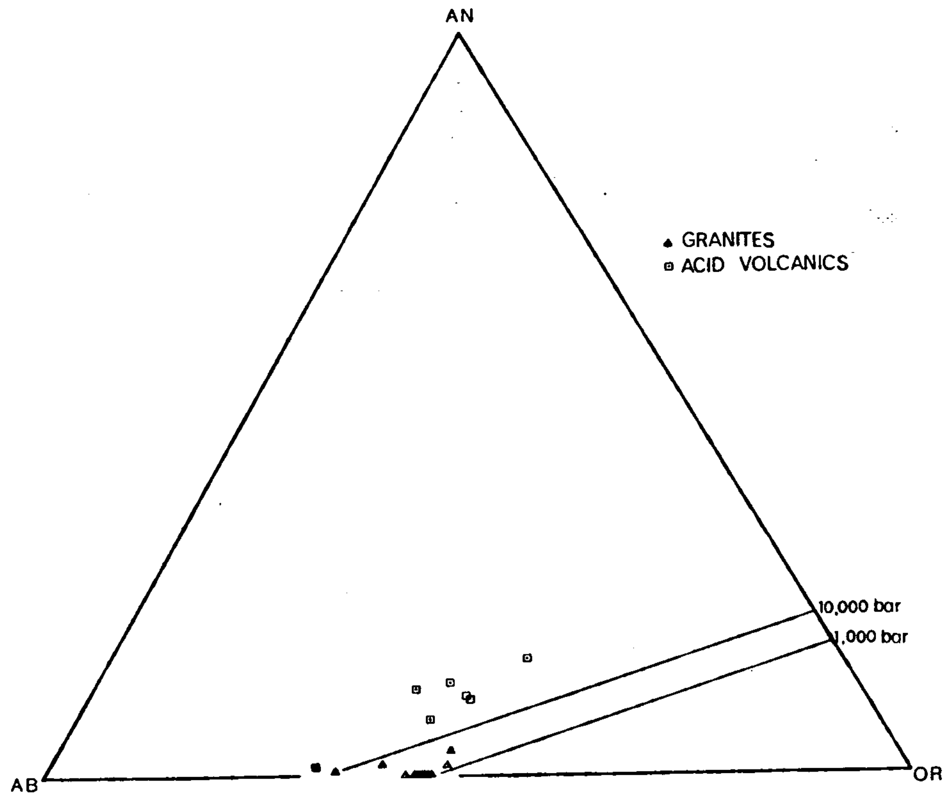

AN
GRANITES
ACID VOLCANICS
10,000 bar
1,000 bar
AB
OR

FIG 13

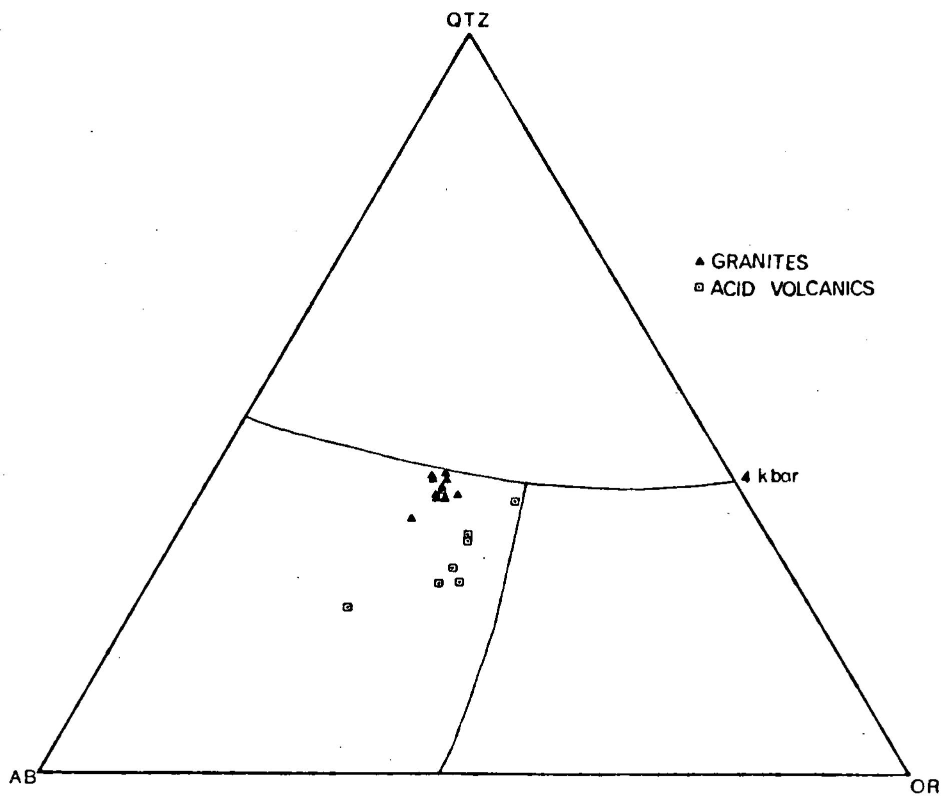

QTZ
GRANITES
ACID VOLCANICS
4 k bar
AB
OR

FIG 14

A high potassium content and a depletion of Ca, two features exhibited by the granites, are parameters expected of early partial melts (Snetsinger, 1967; Winkler and Von Platten, 1961).

The element vs. element plots (Fig, 11) shows that for the granite the plot involving Ce-Nd indicates these elements were both controlled by restite phases (such as zircon (Zr, U); apatite (Sr, Ba); ilmenite (Ti, Sc) on partial melting. This trend is reflected in the Nb/Zr plot for the granite.

The granite may in fact be an "A"-type granite, which is a granite derived by partial melting of a granulite source, that has had a long residence time in the crust. This would account for the depleted Sr and Rb values and also the higher (than expected for that age) initial Sr ratios.

The rhyolite could also have been formed by a partial melting process. From Section 4. the possible relationship between the rhyolite and granites could mean that they were produced by partial melting of the same source, but possibly at different stages.

The rhyolites show the same rare earth pattern as the granites and they also plot close to the low temperature regions on the ternary Ab-An-Or and Qtz-Ab-Or diagrams.

The rhyolite is enriched in Ba and Rb relative to Sr. The high Ba, as well as high potassium and residual elements, might be expected from the initial phase of partial melting of sialic material (Weaver et al., 1972).

It must be noted that high K_2O, relative to Na_2O, can be caused by a type of alteration, not uncommon in acid-ash flow tuffs, examples of which can be seen as highly sericitised and turbid plagioclase phenocrysts which can be found in the rhyolite. This would mean that little significance can be attached to the values of K_2O, Na_2O and other mobile elements such as Rb, Sr and Ba (Giles and Teale, 1979).

The element versus element plots for the rhyolite show in both the Nb/Zr and TiO_2/Zr plots that the Nb and Ti are acting incompatibly relative to the Zr. In the Ce/Nd plot both elements are being controlled by restite phases.

From studies of rhyolites with similar chemical characteristics, Giles (1979) has determined that 20-30% partial melting of a lower crustal source, dry, basic granulite, in which plagioclase, clinopyroxene, orthopyroxene and magnetite are residual, would produce the observed characteristics. Giles (1979) also stated that it is possible some of the rhyolites and granites may represent direct, higher level crustal melts.

Thus it seems probable that the granite and rhyolite could both have formed as a result of partial melting of a granulite source.

5.4.2 Fractional Crystallisation

Fractional crystallisation is a common differentiation process of igneous rocks, and provides an alternative to partial melting as a method of formation.

Some of the evidence indicates that the granite on Saint Francis Island could also have been formed by fractional crystallisation.

The low Ba content could be explained by the fact that Ba is typically diminished during the final stages of fractionation (Siedner, 1964). Alkali granites form as a late product of a crystal fractionation series. Low abundances of V, Sr and Cr would argue in favour of crystal fractionation, in view of the common depletion of these elements during this process (Ewart et al., 1968).

The Rb-Ba-Sr ternary diagram classifies the granite as a strongly differentiated granite, which supposedly represent a very late stage differentiate.

On the Qtz-Ab-Or ternary diagram the granite plot close to the ternary eutectic, the point to which residual liquids of differentiation processes proceed.

By similar reasoning the formation of the rhyolites could also be explained by crystal fractionation. The higher Ba content would indicate that it is not a "late-stage" differentiate.

If fractional crystallisation is the method of formation there should be large volumes of more mafic differentiates somewhere (Barth, 1962) which are not present on the island, although they may occur at depth.

In summary the majority of the evidence points to formation of the rhyolite and granites by partial melting, most probably of a granulite source.

Plate 1

A: **Leucogranite Intrusive:**

Showing vein of leucogranitic material running into rhyolite, and chilled margin of leucogranite.

B: **Leucogranite inclusion in dolerite dyke;**

C: **Dolerite dyke;**

Dyke of doleritic material, striking at 140°.

Plate 2

A: **Alkali Granite:**

Typical outcrop; on eastern side of island.

B: **Coarse porphyry rhyolite dyke:**

Note the large feldspar phenocrysts. Zoning is visible in some.

C: **Fine porphyry rhyolite dyke:**

The shearing is obvious at the edges of the dyke,

Plate 5

A: **Zircons**: Transmitted light:

Euhedral grains, no frosting.

B: **Zircons**: Transmitted light.

C; **Zircon Fraction D4**;

Euhedral crystals. No frostong of crystals,

D: **Zircon Fraction D4**:

E: **Zircon Fraction E4**:

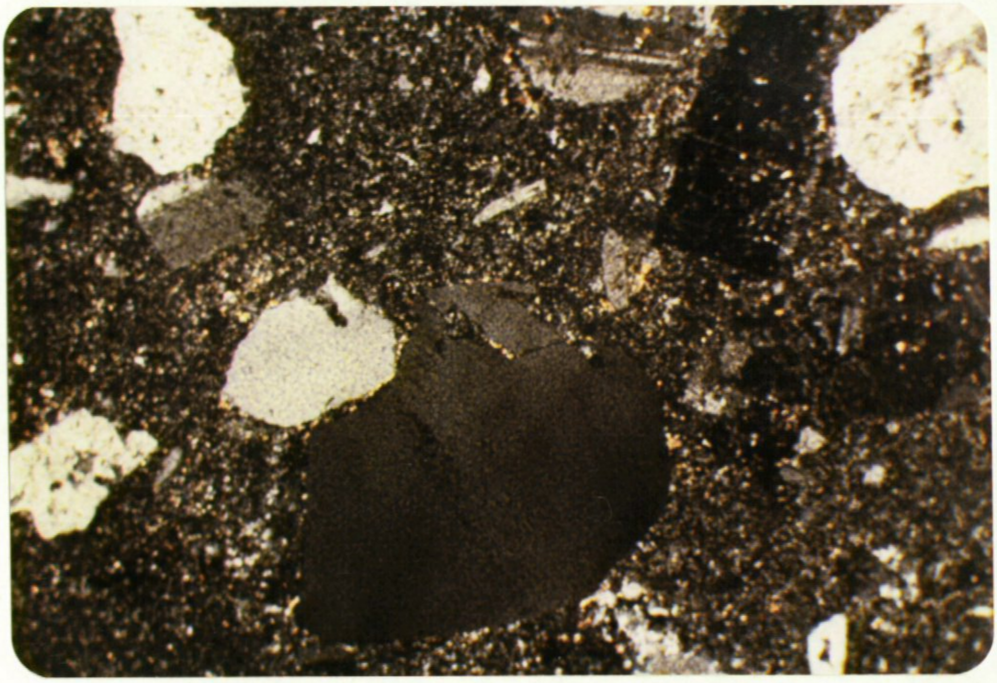
Plate 4

A: **Rhyolite:**

Thin section 795-4. Large feldspar phenocrysts in fine-grain groundmass. Sericitisation of plagioclase visible.

B: **Leucogranite:**

Thin section 795-1. Large crystals obvious, Quartz shows sutured edges.



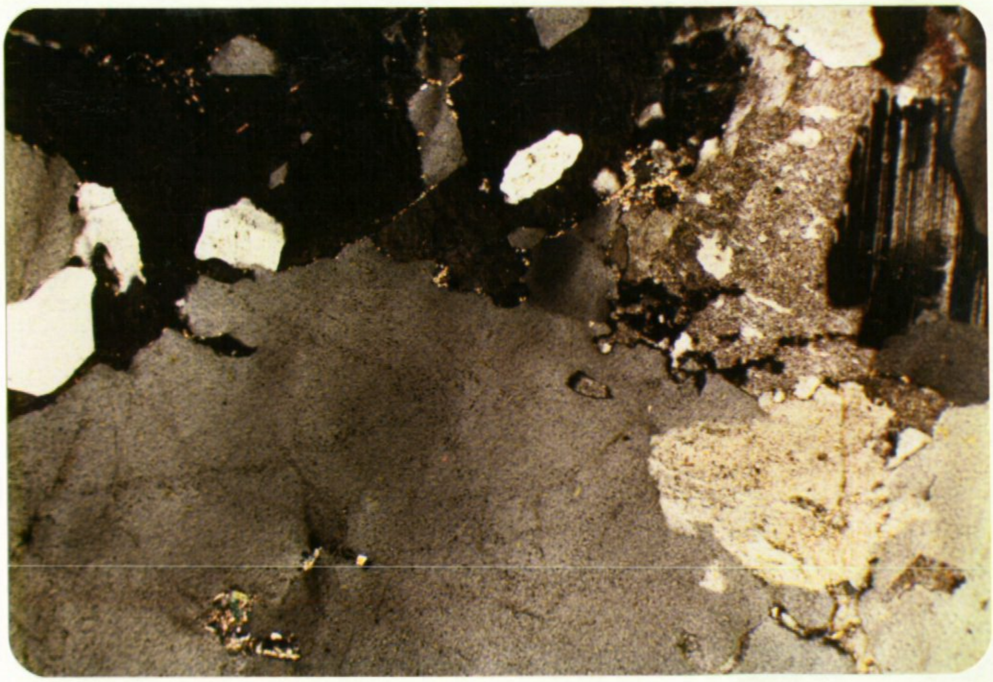


Plate 5

A: **Zircons**: Transmitted light:

Euhedral grains, no frosting.

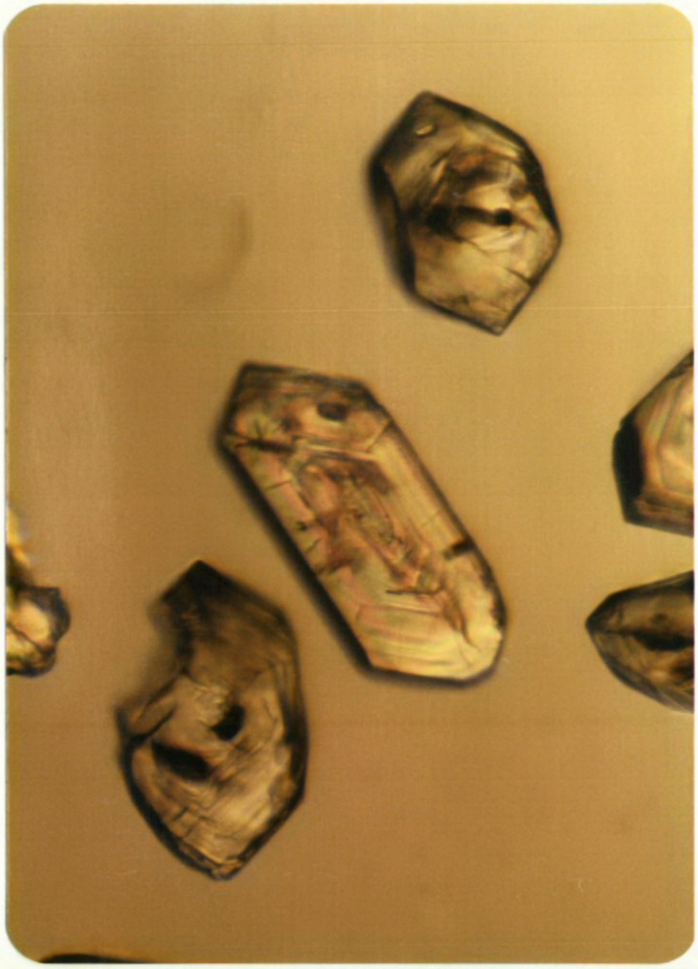
B: **Zircons**: Transmitted light.

C; **Zircon Fraction D4**;

Euhedral crystals. No frostong of crystals,

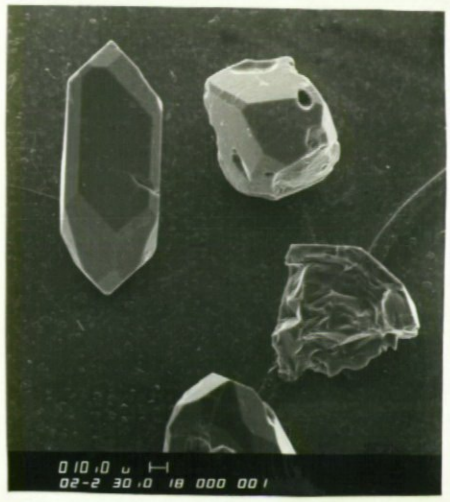
D: **Zircon Fraction D4**:

E: **Zircon Fraction E4**:

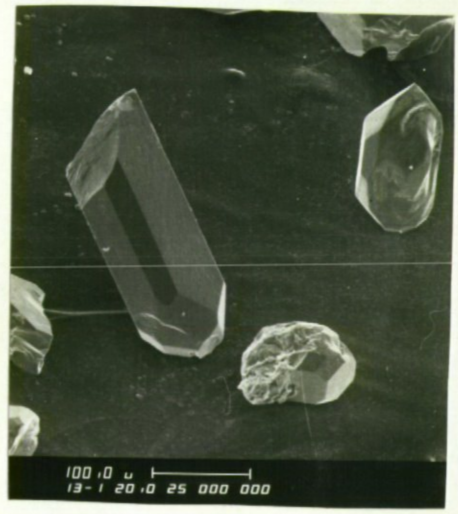


A

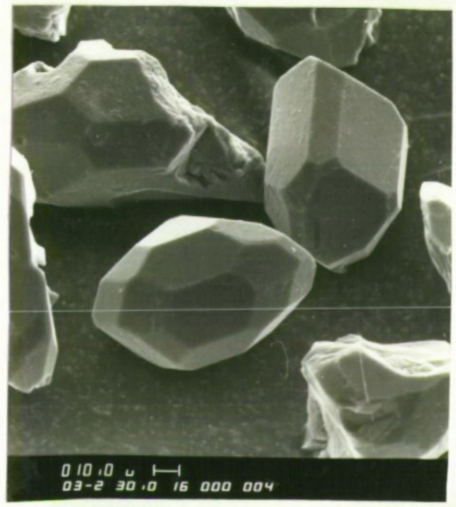
B


010.0 u
02-2 30.0 18 000 001

C


100.0 u
13-1 20.0 25 000 000

D


010.0 u
03-2 30.0 16 000 004

E

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APPENDIX I

THIN SECTION DESCRIPTIONS

(a) To avoid repetition, only representative thin sections have been described here. Descriptions are in numerical order within each rock type.

(b) Location of the samples may be obtained from the location map (Fig. 3) at the end of this section.

(c) Thin section numbers are the same as those for the corresponding geochemical samples.

795-1 Leucogranite

H-S: Cream to pink coloured, medium grained granite, composed mostly of quartz and alkali feldspar. Intrudes the rhyolite at the western end of Saint Francis Island.

T-S: The rock is made up of medium to coarse grained quartz and alkali feldspar, and medium grained plagioclase. Minor biotite, hornblende and opaques are also present.

Quartz is abundant as irregularly shaped crystals, which show strongly undulose extinction.

The alkali feldspar is perthitic orthoclase, showing patchy exsolution. Some of the alkali feldspars show Ealsbad twins.

Plagioclase occurs as irregular grains, showing albite twinning. Much of the plagioclase is sericitised to some degree.

Quartz	47%	Opaques	2%
Alkali feldspar	33%	Biotite	1%
Plagioclase	11%	Hornblende	1%
Sericite	5%		

795-11 Alkali Granite

H-S: Grey coloured, medium grained, massive granite, with the major components being quartz and alkali feldspar. This unit is present in large quantities on the eastern end of the island.

T-S: Quartz and alkali feldspar are the main minerals in the rock. Plagioclase is also present, in small quantities, and there is minor pyroxene, present as aegirine-augine, opaques and sphene. The quartz grains range in size from 0.3mm to 4mm. They show strong undulose extinction and have sutured edges in places. The quartz and alkali feldspar are often graphically intergrown. The alkali feldspar is perthitic and lightly clouded. The grains are often quite large, up to 4mm. The plagioclase crystals are smaller and show multiple twinning.

Aegirine-augite crystals are a dark yellowish-green colour, weakly pleochroic and have near parallel extinction. The opaque and sphene often occur near the pyroxene, probably replacing it.

Alkali Feldspar	49%	Aegirine-augite	3%
Quartz	39%	Opaques	2%
Plagioclase	7%	Sphene	trace

795-21 Alkali Granite

H-S: Same as above.

T-S: The major minerals appear in the same relationships as above, the only difference in this slide being a cluster of zircon crystals. The zircons are present as euhedral crystals which are grouped together in one small section of the slide. If the granite were formed by partial melting then these zircons are possibly crystals incorporated from the source rock.

Alkali Feldspar	47%	Opaques	5%
Quartz	34%	Zircon	5%
Plagioclase	6%	Sphene	trace
Pyroxene	3%		

795-4 Rhyolite

H-S: Grey coloured, fine-grained rock with phenocrysts of feldspar and quartz. The rhyolite occurs in quantity at the western end of Saint Francis Island.

T-S: The slide is made up of potassium feldspar, quartz and plagioclase phenocrysts, lying in a fine-grained groundmass. The phenocrysts are anhedral and vary greatly in size (from 0.2mm to 3mm). The alkali feldspar phenocrysts are often perthitic. The quartz phenocrysts are rounded, embayed crystals, all showing undulose extinction. Phenocrysts of plagioclase sometimes show the multiple twinning. These phenocrysts are also often sericitised to a great degree. The groundmass shows the effects of sericitisation as well.

Epidote is present as an alteration feature of the plagioclase phenocrysts.

Groundmass	60%	Phenocrysts:	
		Alkali Feldspar	15%
		Plagioclase	7%
		Quartz	11%
		Mafics	2%
		Opaques	5%

795-7 Rhyolite

H-S: Same as above.

T-S: Major minerals present in same relationship to those above. Th e degree of sericitisation is greater, with more of the plagioclase laths being affected. There is also extensive sericitic veining in the groundmass which connects with the sericite in the feldspar phenocrysts. Proportions similar to above.

795-20 Coarse Porphyry Rhyolite Dyke

H-S: The large feldspar phenocrysts within this rock give it a mottled appearance. This dyke is located on the eastern side of the island, intruding the granite.

T-S: The large alkali feldspar phenocrysts dominate the slide. Smaller, rounded, embayed quartz phenocryst and small plagioclase laths are also present. The alkali feldspar phenocryst range in size between 10mm and 1mm. They often show inclusions of groundmass material.

There is some epidotisation of plagioclase.

The groundmass is fine-grained and made up mainly of quartz and alkali.

Groundmass	50%	Phenocrysts:	
		Alkali feldspar	35%
		Quartz	5%
		Plagioclase	3%
		Mafics	3%
		Opaques	4%

795-25 Fine-grained Porphyry Rhyolite Dyke

H-S: Dark grey colour rock with small, pink, rectangular feldspars. The dyke is on the north-eastern side of the island.

T-S: The phenocrysts of alkali feldspar lie in a very fine-grained groundmass, which appears to have a flow texture. The elongate grains and small stringers of opaques within the groundmass define a lineation parallel to the strike of the dyke. The groundmass appears to flow around the euhedral shaped feldspar phenocrysts. These phenocrysts are perthitic. They range in size from 4mm to 0.8mm.

Groundmass	80%	Phenocrysts:	
		Alkali Feldspar	18%
		Opaques	2%

795-2 Dolerite Dyke

H-S: Dark green, fine-grained dolerite dyke, intruded into the rhyolite, on the western side of the island.

T-S: Fine grained amphibole and plagioclase groundmass, with phenocrysts of plagioclase, which have in places almost totally been altered to epidote. Small quantities of biotite, chlorite, and opaques are present.

The phenocrystic plagioclase laths have a decussate texture. Many are relict crystals which have been partially replaced by epidote.

Biotite is present along fractures within the rock. Opaques are fine- to medium-grained.

Hornblende	38%	Biotite	3%
Plagioclase	33%	Chlorite	1%
Epidote	20%	Opaques	5%

795-23 Dolerite Dyke

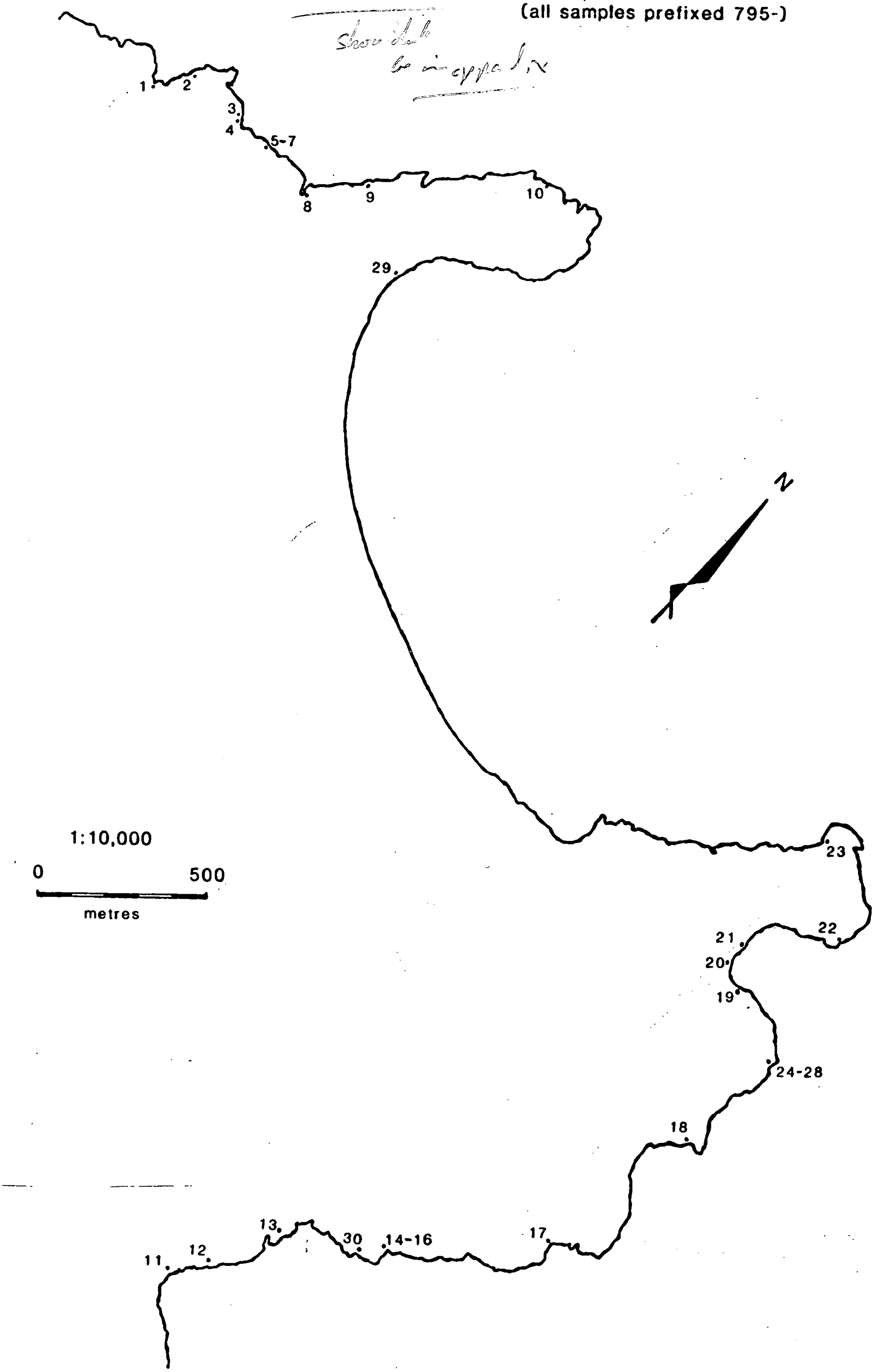
H-S: Fine-grained, dark green coloured dyke. This dyke is located on the north-eastern side of the island, intruding the alkali granite.

T-S: The rock consists of amphibole, epidote, feldspar, and opaques. The slide is fairly even grained, about 2-3m, with the minerals in random orientations.

Between the ferromagnesium minerals there is a feldspar and quartz matrix. The feldspar is fine-grained and interstitial.

Feldspar	44%	Quartz	5%
Epidote	23%	Opaques	7%
Amphibole	21%		

FIG 3 SAMPLE LOCATION MAP
(all samples prefixed 795-)



APPENDIX II

GEOCHEMICAL DATA

(a) Major oxide and trace element analyses for 21 rock samples are reported in Table

Na_2O was determined by flame photometry.

The remaining major oxides, together with Sr, Ba, Rb, Y, Zr, Nb, Sc, Cr, Ce and Nd were determined on the programmable Siemen S.R.S. machine. H_2O^+ corresponds to the loss of weight of the sample after ignition at 950°C. Ni and V were determined on the Philips XRF machine.

(b) Silicate analyses of a rhyolite average (Le Maitre, 1976) and two South Australian Middle Proterozoic acid volcanics are reported in Table

TABLE 4 MAJOR OXIDE AND TRACE ELEMENT ANALYSES

	Leuco-granite 795-1	Alkali granite 795-11	795-12	795-13	795-14	795-15
SiO_2	77.49	78.70	78.11	78.72	78.66	78.45
Al_2O_3	12.29	10.98	11.23	11.33	9.71	10.95
Fe_2O_3	0.21	0.73	0.61	0.44	0.96	0.8
FeO	0.19	0.66	0.54	0.39	0.86	0.72
MnO	0.01	0.02	0.04	-	0.01	0.01
MgO	0.16	0.08	0.16	0.06	0.34	0.19
CaO	0.19	0.03	0.04	0.02	0.2	0.13
Na_2O	3.78	4.09	4.24	3.85	2.07	3.80
K_2O	4.87	4.13	4.48	4.49	5.69	4.39
TiO_2	0.14	0.17	0.15	0.15	0.17	0.16
P_2O_5	0.02	0.01	0.01	0.008	0.01	0.01
H_2O+	0.34	0.19	0.25	0.23	1.22	0.25
TOTAL	99.69	99.79	99.86	99.68	99.82	99.85
Sr	22.3	4.1	5.4	5.9	21.2	11.8
Rb	243	168	194	173	268	195
Ba	51	10	18	16	142	27
Y	39.1	22.7	39	26.2	44.2	64
Zr	127	449	476	418	440	422
Nb	17.6	17.4	16.7	16.8	17.0	17.4
Sc	4.7	5.3	6.6	5.3	6.1	6.8
Cr	<4	<4	<4	<4	<4	<4
Ni	8.1	6	5.5	6	7.9	5.9
V	3.1	6.3	5.1	7.1	7.7	4.9
Ce	86	12	26	5	28	65
Nd	30	3	12	2	16	33

TABLE 4 (cont.)

	Alkali granite 795-17	795-18	795-19	795-21	795-22	795-30
SiO_2	76.43	77.70	78.72	77.74	78.00	77.66
Al_2O_3	12.4	11.43	10.98	11.41	11.11	11.39
Fe_2O_3	0.64	0.58	0.57	0.66	0.73	0.72
FeO	0.58	0.52	0.51	0.59	0.66	0.65
MnO	0.04	0.15	0.03	0.01	0.04	0.12
MgO	0.13	0.24	0.19	0.12	0.17	0.11
CaO	0.33	0.07	0.06	0.01	0.02	0.14
Na_2O	4.55	4.37	4.16	4.37	4.50	4.12
K_2O	4.22	4.40	4.28	4.57	4.37	4.39
TiO_2	0.05	0.14	0.14	0.16	0.15	0.14
P_2O_5	0.01	0.01	0.01	-	0.01	0.01
H_2O+	0.35	0.33	0.16	0.11	0.21	0.15
TOTAL	99.73	99.93	99.81	99.75	99.97	99.60
Sr	72	18.3	6.2	2.6	5.3	5.6
Rb	176	235	171	215	211	189
Ba	156	12	15	9	22	7
Y	68	40.6	21.1	23.9	21.2	44.2
Zr	150	234	305	570	407	285
Nb	20.5	16.8	13.2	19.3	14.3	9.8
Sc	3.1	4.3	5.7	5.6	6.4	4.4
Cr	<4	<4	<4	<4	<4	<4
Ni	7.4	7.2	4.6	6.0	5.8	6.2
V	8.6	3.3	7.7	4.6	8.5	5.0
Ce	35	45	18	11	30	47
Nd	16	19	7	3	10	20

TABLE 4 (cont.)

	Western acid volcanics					Eastern acid volc.
	795-5	795-6	795-8	795-10	795-29	795-25
SiO_2	70.22	71.13	71.10	71.99	70.56	71.66
Al_2O_3	14.79	14.77	14.89	14.86	14.97	14.36
Fe_2O_3	1.07	1.06	1.08	0.77	1.06	1.07
FeO	0.96	0.95	0.97	0.69	0.95	0.96
MnO	0.08	0.08	0.06	0.08	0.09	0.10
MgO	0.62	0.63	0.66	0.38	0.63	0.36
CaO	1.17	1.53	1.43	2.00	1.86	0.31
Na_2O	4.29	3.58	3.49	2.69	3.91	5.92
K_2O	4.95	4.98	4.87	5.23	4.96	3.90
TiO_2	0.35	0.34	0.36	0.27	0.34	0.44
P_2O_5	0.08	0.08	0.08	0.04	0.08	0.05
H_2O+	0.69	0.74	1.05	0.89	0.49	0.19
TOTAL	99.27	99.87	100.03	99.89	99.89	99.31
Sr	188	225	234	381	259	42.8
Rb	159	194	193	234	179	127
Ba	1454	1379	1394	1129	1404	119
Y	30.1	30.1	32.0	35.7	30.2	42.6
Zr	218	212	224	211	206	338
Nb	11.1	12.6	12.3	13.1	11.3	7.6
Sc	7.6	6.5	7.0	5.7	6.9	15.9
Cr	<4	<4	<4	<4	<4	<4
Ni	7.0	8.8	6.4	7.7	8.3	7.4
V	19.8	25.0	27.8	11.7	33.7	13.9
Ce	96	105	117	99	109	236
Nd	36	37	44	36	46	104

TABLE 4 (cont.)

	Coarse porphyry 795-20	Mafic dykes 795-2	795-23
SiO_2	71.66	57.18	48.16
Al_2O_3	13.77	17.16	17.82
Fe_2O_3	1.12	3.56	5.92
FeO	1.00	3.20	5.33
MnO	0.1	0.17	0.20
MgO	0.6	2.87	5.38
CaO	0.89	4.64	8.41
Na_2O	4.22	4.31	3.99
K_2O	5.48	3.22	0.78
TiO_2	0.41	0.73	1.12
P_2O_5	0.13	0.49	0.55
H_2O+	0.23	1.38	1.49
TOTAL	99.61	98.91	99.15
Sr	171	723	1092
Rb	186	217	27.3
Ba	1259	1231	417
Y	48.9	21.4	23.5
Zr	226	148	79
Nb	8.5	5.6	4.1
Sc	7.1	12.0	26.5
Cr	<4	<4	<4
Ni	13.5	4.8	31.2
V	23.5	100	266
Ce	141	66	73
Nd	63	30	37

TABLE **5** RHYOLITE COMPOSITIONS FOR COMPARISON

	Rhyolite*	(2)	(3)
SiO_2	72.82	69.54	72.48
Al_2O_3	13.27	14.04	13,0
Fe_2O_3	1.48	4.20	2.43
FeO	1.11	-	-
MnO	0.06	0.08	0,05
MgO	0.39	0.61	0.73
CaO	1.14	1.17	0.28
Na_2O	3.55	2.73	2.64
K_2O	4.30	6,27	6.18
TiO_2	0.28	0.33	0.35
P_2O_5	0.07	0,04	0,03
H_2O+	1.10	0.67	1.04
TOTAL	99.88	99.68	99,24
Sr		50	39
Rb		385	203
Ba		714	940
Y		160	44
Zr		606	413
Nb		59	22
Sc		5	8
Cr		<8	<8
Ni		-	-
V		<6	<6
Ce		338	125
Nd		-	-

* Average of 116 rhyolite analyses from Le Maitre (1976)

(2) Typical rhyolite, southern Mount Painter Block.

(3) Typical rhyolite, Gawler Range Volcanics, Lake Everard area.

APPENDIX III

GEOCHEMICAL TECHNIQUES

(a) Crushing of Sample

(1) Weathered surfaces were removed using a pick and a diamond saw.

(2) Samples weighing approximately one kilogram were crushed in a large jaw crusher.

(3) The crushed sample was ground to approximately 200 particle size using a Siebtechnik tungsten carbide mill.

(b) Whole Rock Analysis

(1) Approximately three grams of crushed sample was ignited at 960°C overnight, to determine the percentage loss of volatiles.

(2) 280 milligrams of ignited powder was weighed out with 20 milligrams of sodium nitrate, and 1.5 grams of lithium tetraborate flux. The mixture was fused in a platinum crucible, by Mr. P. McDuie, to form a fused disk.

(3) This was subsequently analysed on the Siemens S.R.S. by Mr. J. Stanley.

(c) Trace Element Analyses

(1) Approximately five grams of unignited samples were made into pressed pellets.

(2) Ni and V were determined by the author on the Philips X.R.F. using the pressed pellets, under the conditions shown in Table IIIA.

(3) The other trace elements were determined by Mr. J. Stanley on the programmable Siemens S.R.S.

APPENDIX III (cont.)

(d) Na_2O Determination

(1) Samples of ignited powder weighing approximately 30 milligrams were digested in a solution of 50% H_2SO_4/50% HF = 1/10, in teflon beakers.

(2) The digested solutions were then made up to 100ml volumes in an A-grade volumetric flask.

(3) The Na_2O concentration was determined using a Corning-Eel Flame Photometer. Four sodium standards were used with each measurement.

TABLE 6   TRACE ELEMENT ANALYSIS CONDITIONS, PHILIPS X.R.F.

Element	X-Ray Tube Operating Conditions	Count Rate (sec)	Analytical Line	Back ground	Inter- ference	Anal. Crystal	Collinator	Detector	Mass Hbs.Coef.	Counting Stand.	Inter- national stand.
Ni	W 60kV,40mA	1x100	NiKα 71.56^{o}	70.56^{o}	-		Coarse	S	NiKα	PCC-1	MNT BR
V	W 60kV,40mA	2x40	V Kα 93.49^{o} TiKβ 94.29	91.49^{o}	-		Coarse	S	V Kα	MDP+V (Spike #1)	AGV-1 BR

APPENDIX IV

GEOCHRONOLOGICAL TECHNIQUES

1. A 33 kg sample was broken up with a sledge hammer, then crushed in a jew crusher and pulverised in a disc grinder until it could be passed through a -30 mesh.
2. This was then put through a Wilfley table, and the heavies collected.
3. The strongly magnetic fraction was separated by hand magnet,
4. The remaining sample was separated using the heavy liquid TBE (tetrabromoethane) and the heavies were collected.
5. A second hand magnet separation removed more magnetics.
6. The heavies were then put through the Franz electromagnetic separator on several different settings.
7. The least magnetic fraction was separated further by the use of the heavy liquid methylene iodide.
8. The heavies were washed in acid and underwent ultrasonic treatment.
9. The final zircon concentrate was purified by hand picking and then divided into a number of size and magnetic fractions by sieving and electromagnetic separation using the Franz.
10. Six of these fractions were chosen so as to give as wide a range in size and magnetic susceptibility as possible.
11. Five to ten milligrams of each fraction was then washed in a mixture of nitric and hydrochloric acid and then dissolved in a mixture of HF and HNO_3 at 210^o to 220^oC under pressure for one week.
12. The solution was then divided into two fractions and a mixed U/Pb Spike added to one of these.
13. The spiked and unspiked fractions were then run through ion exchange columns and the Pb unspiked, Pb spiked and U-spiked fractions collected.
14. Each of these were subsequently loaded onto a single rhenium filament beads and analysed on the mass spectrometer.

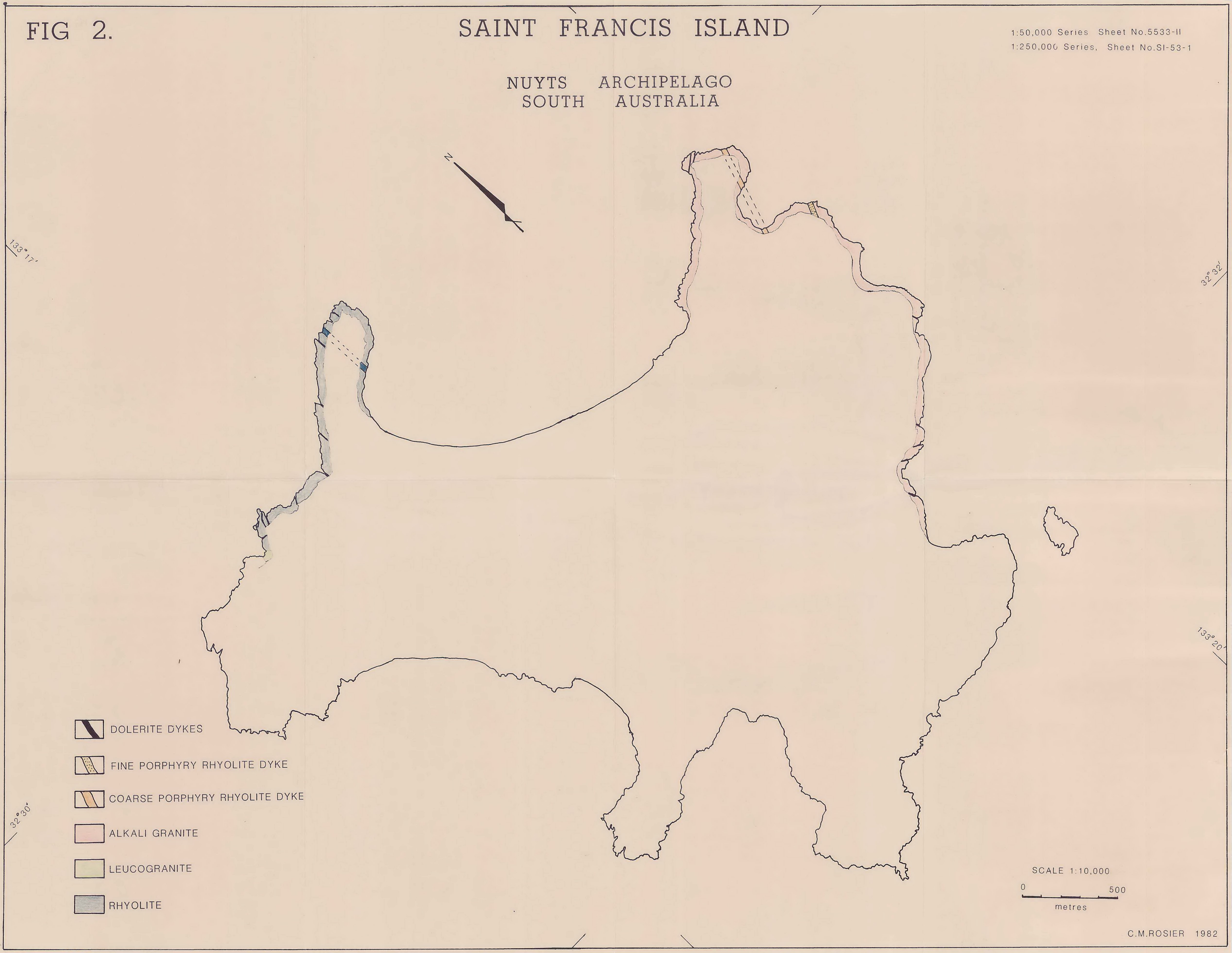


FIG 2.
SAINT FRANCIS ISLAND
NUYTS ARCHIPELAGO
SOUTH AUSTRALIA
1:50,000 Series Sheet No.5533-II
1:250,000 Series, Sheet No.SI-53-1
N
133° 17'
32° 32'
133° 20'
32° 30'
DOLERITE DYKES
FINE PORPHYRY RHYOLITE DYKE
COARSE PORPHYRY RHYOLITE DYKE
ALKALI GRANITE
LEUCOGRANITE
RHYOLITE
SCALE 1:10,000
0
500
metres
C.M.ROSIER 1982