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PALAEOPROTEROZOIC NUYTS VOLCANICS OF THE WESTERN GAWLER CRATON

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CONTENTS

Figures

Tables

Plates

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ABSTRACT

U-Pb zircon geochronology of acid volcanics (Nuyts Volcanics - new name) exposed in the Nuyts Archipelago yielded an age of 1627 ± 2 Ma, supporting a previously determined age of 1631 ± 3 Ma. The major and trace element compositions, as well as the presence of a tectonic fabric suggest that the Nuyts Volcanics and the Gawler Range Volcanics represent two very different episodes of volcanism.

Associated with the Nuyts Volcanics are leucogranites and leucoporphyries, and collectively they represent a discrete episode of magmatism, most likely associated with the waning stages of the Early Proterozoic Kimban Orogeny.

INTRODUCTION

On the Gawler Craton, a number of discrete episodes of acidic volcanism during the Palaeoproterozoic have been recognized. The oldest is the Bosanquet Formation at 1845 ± 9 Ma (Rankin *et al.*, 1988) with other episodes including the Myola Volcanics and correlatives at 1791 ± 4 Ma and the younger McGregor Volcanics and Moonta Porphyry at ~1740 Ma (Fanning *et al.*, 1988). All these volcanics are characterised by varying, but moderate degrees of deformation which are attributed to various phases of the Kimban Orogeny.

In contrast, the Gawler Range Volcanics are Mesoproterozoic in age and consist of a very thick, areally-extensive suite of undeformed extrusives. Volcanism occurred over a very short time interval at 1592 ± 2 Ma (Fanning *et al.*, 1988) as, like the above formations, determined by U-Pb analyses on zircons. Undeformed Gawler Range Volcanics and the moderately to highly-deformed Palaeoproterozoic volcanic sequences are easily distinguished in the field.

Exposures of acid volcanics in the Nuyts Archipelago (Fig. 1) are only weakly foliated. Lithologically, they are broadly similar to the Gawler Range Volcanics at Toondulya Bluff, 125 km to the east, and they have been previously correlated with these volcanics (Cooper *et al*,. 1985). Previous geochronology on a porphyritic rhyolite from St Francis Island yielded a U-Pb zircon age of 1631 ± 3 Ma, which was interpreted by Rosier (1982) and Cooper *et al.* (1985) as the age for magmatism of the Gawler Range Volcanics. However, subsequent geochronology in various units of the Gawler Range Volcanics from both the Gawler Craton and Curnamona Craton consistently indicates volcanism occurred over a very narrow time interval at 1592 ± 2 Ma (Fanning *et al.*, 1988). Thus, volcanics within the Nuyts Archipelago could represent either an early phase of the Gawler Range Volcanics or a discrete older event. On field criteria and geochemical considerations, Rankin and Flint (1989) suggested the volcanics in the Nuyts Archipelago represent a discrete, older extrusive event.

To clarify the stratigraphic uncertainties, U-Pb zircon geochronology was undertaken on a specimen of porphyritic rhyolite from St Peter Island. Results confirm that the volcanics within the Nuyts Archipelago represent a discrete episode of volcanism previously unrecognised for the Gawler Craton. The volcanic suite is defined as the Nuyts Volcanics (new name).

NUYTS VOLCANICS

Derivation of the Name: Adapted from Nuyts Archipelago a group of islands along the west coast of Eyre Peninsula, named in 1627 by Francis Thijssen, the first navigator/explorer in the area, after Pieter Nuyts (then Councillor Extraordinary of the East India Government at Batavia).

Distribution: Exposed on southern St Peter Island, St Francis Island, Hart Island, and as a dyke on West Island. Lateral distribution is unknown, but known occurrences suggest a NE-trending zone, with a probable extension onto the mainland in the Ceduna area.

Reference Sections: Coastal exposure at Hawks Nest, southern St Peter Island. Coastal exposures, western St Francis Island.

Map symbol: *Ev*

Lithology: On St Francis and Hart Islands, the acid volcanics consist of dark grey and pinkish porphyritic rhyodacite to rhyolite (SiO_2 content 66-78%). Abundant (10-20%) quartz and feldspar phenocrysts (up to 5mm wide) occur in an aphanitic, siliceous groundmass. Xenoliths of flow-banded and porphyritic rhyolite are common. Rare welded lapilli are also present (Morrison, 1982; Rosier, 1982; Flint, 1987).

Associated with the volcanics are three suites of rhyodacite/rhyolite dykes. The first suite consists of highly porphyritic rhyodacite, with up to 50% feldspar phenocrysts and xenocrysts. These dykes, which occur only on the eastern end of St Francis Island, are up to 12m wide. The second suite consists of dark grey-black rhyodacite dykes up to 3m wide, with abundant euhedral feldspar phenocrysts (up to 5mm wide) aligned within an aphanitic groundmass. The third suite consists of grey-pink, hyolitic, flow-banded rhyodacite, with common feldspar and quartz phenocrysts concentrated towards the centre of the dykes. These dykes, which are up to 3m wide, have chilled margins up to 0.4m wide (Flint, 1986; 1987).

On St Peter Island, the unit consists of pink to grey, fine-grained porphyritic rhyolite to rhyodacite, with up to 30% quartz and feldspar phenocrysts (up to 2mm wide) (Plate 1). No primary layering is evident in outcrop, although eutaxitic textures, with fiammé and agglomeratic layers can be seen in wave-washed beach cobbles, indicating extrusive emplacement. The rhyodacite is weakly to moderately foliated; the foliation is defined by the alignment of very fine-grained mica. The foliation is subvertical and trends approximately north-south.

<u>Field Relationships</u>: On St Francis Island the volcanics are intruded by the second and third suites of rhyodacite dykes, a leucocratic porphyritic granite, and fine-grained dolerite dykes. The granite was interpreted by Flint (1986) as part of the Mesoproterozoic Hiltaba Suite, but this correlation is no longer supported. The three suites of rhyodacite/rhyolite dykes intrude a distinctive alkali-rich, medium-grained to porphyritic granite. Relationships of this granite to other units are not exposed, but it is inferred to represent an intrusive phase of the same volcano-plutonic event (Rankin and Flint, 1989). Contacts between the granite and the main mass of volcanics are not exposed. The third rhyolite dyke suite also intrudes mylonitic gneisses of the Lincoln Complex on West Island, where the dyke suite is truncated by leucocratic and porphyritic granite.

On St Peter Island the volcanics are intruded by an undeformed diorite of unknown age. The base and top of the volcanic sequence are not exposed, and no contacts with the Lincoln Complex granitoids (St Peter Suite; see Flint *et al.*, in prep.) are exposed. The volcanics are unconformably overlain by Pleistocene aeolian calcarenites of the Bridgewater Formation.

GEOCHRONOLOGY

Previous Work

Initial geochronology of volcanics from the Nuyts Archipelago was undertaken by Webb *et al.* (1982, 1986). Fourteen samples of rhyodacite and rhyolite were analysed using the Rb-Sr technique. Regression of seven samples from Hart Island produced an isochron of 1469 ± 101 Ma, and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7062 ± 0.0032. The large error in the age was due to the very restricted range in Rb/Sr ratio. Regression of all fourteen specimens (also including volcanics from St Francis and St Peter Islands) produced a Model 1 isochron of 1490 ± 12 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7056 ± 0.0005.

The Rb-Sr ages are considerably younger than the age of crystallisation reported by Rosier (1982) and Cooper *et al.* (1985) from U-Pb zircon isotope analysis on rhyolite from western St Francis Island. Six fractions were analysed, one of which was concordant, yielding a crystallisation age of 1631 ± 3 Ma.

A rhyolite specimen (5633 RS 147) was collected from St Peter Island by Rankin and Flint (1989) for further U-Pb zircon isotopic analysis to confirm the earlier-reported age and extent of volcanism within the Nuyts Archipelago.

Procedures

Selected abraded single zircon grains were analysed. The samples were crushed to -60 BSS mesh by repetitive short bursts in a Sieb mill, deslimed and a heavy mineral concentrate prepared by static separations in tetrabromoethane and methylene iodide. "Hand magnetics" were removed and paramagnetics to 1.5 Amps using a Frantz isodynamic separator. The zircon concentrate was not sized, but 10-20 grains with an approximate length in the range 100 to 200 µm were hand selected from the bulk concentrate and abraded following the technique of Krogh (1982). The most pristine of the abraded grains were mounted in refractive index oils and the grains checked for the presence of inherited cores.

The zircons were washed with distilled acetone, weighed by difference into PFA dissolution vials and acid washed using 7 N HNO_3. The grains were rinsed several times with 7 N HNO_3, concentrated HNO_3 and finally a cold rinse with HF. The zircons were spiked with a mixed ^{205}Pb-^{235}U tracer and dissolved with HF/HNO_3 in a Krogh (1978) style vessel at c.200°C for two days.

Following dissolution, approximately 200 µl of 6 N HCL and 1 drop of H_3PO_4 were added and evaporated to dryness. The total unextracted sample was loaded with silica gel and H_3PO_4 on a single Re filament and the Pb and U analysed from the one load. The samples were measured using a Finnigan MAT261 mass spectrometer in the static multicollection mode; the $^{206}Pb/^{204}Pb$ ratios determined using a secondary electron multiplier in combination with the Faraday cups. The Pb isotope data have been corrected for 0.12% a.m.u. mass discrimination. Uncertainties and error-correlations were calculated at the 95% confidence limits following Ludwig (1980).

A total procedural blank measured in conjunction with these zircons contained 29 pg of Pb and 0.2 pg of U. The data have been corrected for the laboratory blank and also for an assumed initial Pb isotope composition using the Stacey-Kramers model (Stacey and Kramers, 1975) composition at the approximate age of the sample, i.e. 1630 Ma.

Results

The U-Pb isotopic data are given in Table 1 and have been plotted on Fig. 2.

Five of the six grains analysed effectively plot as a single point close to, and for three grains, within error of the concordia (see Fig. 2). The analysis for grain 4 has a significantly lower measured $^{206}Pb/^{204}Pb$ ratio and hence a higher uncertainty in the calculated radiogenic ratios (see Fig. 2). This analysis is also more discordant and for this reason, coupled with the high common Pb correction, it has been excluded from age calculations. In essence the other five data points are coincident and concordant to barely discordant. Any apparent loss in radiogenic Pb is assumed to have taken place at the present day.

On the basis of these assumptions a weighted mean of the $^{207}Pb/^{206}Pb$ model ages at 1627 ± 2 Ma gives the best estimate for the crystallisation age of these zircons. The zircons are euhedral and generally simple grains with zonation that is interpreted as resulting from a single igneous crystallisation event. The age of 1627 ± 2 Ma is therefore considered to represent the crystallisation age of the rhyolite.

STRATIGRAPHIC CORRELATIONS AND INTERPRETATIONS

The U-Pb zircon ages of 1631 ± 3 Ma (Cooper *et al.*, 1985) and 1627 ± 2 are considerably older than the U-Pb zircon age of 1592 ± 2 Ma obtained by Fanning *et al.* (1988) for the Gawler Range Volcanics. Interpretation of the Nuyts Volcanics as an older discrete extrusive event is supported by dissimilarities in both major and trace element geochemistry (Rankin and Flint, 1989). The Nuyts Volcanics are appreciably younger than other known Palaeoproterozoic acid volcanics of the Gawler Craton, namely the Myola Volcanics (1791 ± 4 Ma; Fanning *et al.*, 1988), the McGregor Volcanics and Moonta Porphyry (1740 Ma; Fanning *et al.*, 1988). Correlatives of the Nuyts Volcanics are not known elsewhere either on the Gawler Craton or in other Proterozoic terrains in South Australia. The Nuyts Volcanics therefore represent a discrete episode of volcanism at ~1625-1634 Ma.

Granitic plutonism was broadly synchronous with volcanism and is represented by leucocratic granites and porphyries. A distinctive, grey granite, exposed on St Francis, Fenelon, Masillon, Smooth and Egg Islands contains very low mafic mineral content (<2%) consisting of aegerine-augite, hornblende and magnetite. White leucocratic porphyries exposed on West Island, western St Francis Island and at Point Peter and Cape Beaufort also contain extremely low mafic mineral contents and, in part, have a mylonitic matrix. Both these leucogranites to leucoporphyries are highly differentiated and are geochemically distinct from the Hiltaba Suite granites associated with the Gawler Range Volcanics. Their porphyritic nature, presence of a weak tectonic fabric and proximity to volcanics suggest that these leucogranitoids represent low-volume, igneous emplacement associated with the episode of volcanism forming the Nuyts Volcanics.

Such an association, combined with the presence of mafic plugs such as those intruding the volcanics on St Peter Island, show affinities to the Caledonian-style post-orogenic tectonic setting of Pitcher (1982). This model involves tensional relaxation of a previously-compressed crust, with major faulting and rapid uplift allowing exposure of the mid-crustal level Lincoln Complex granitoids prior to extrusion of the Nuyts Volcanics. The volcanics and associated granite would be sourced from "localised remelting of hot but now depleted lower crustal rocks in response to mantle diapirs rising into the stabilising but deeply-faulted crust" (from Pitcher, 1982).

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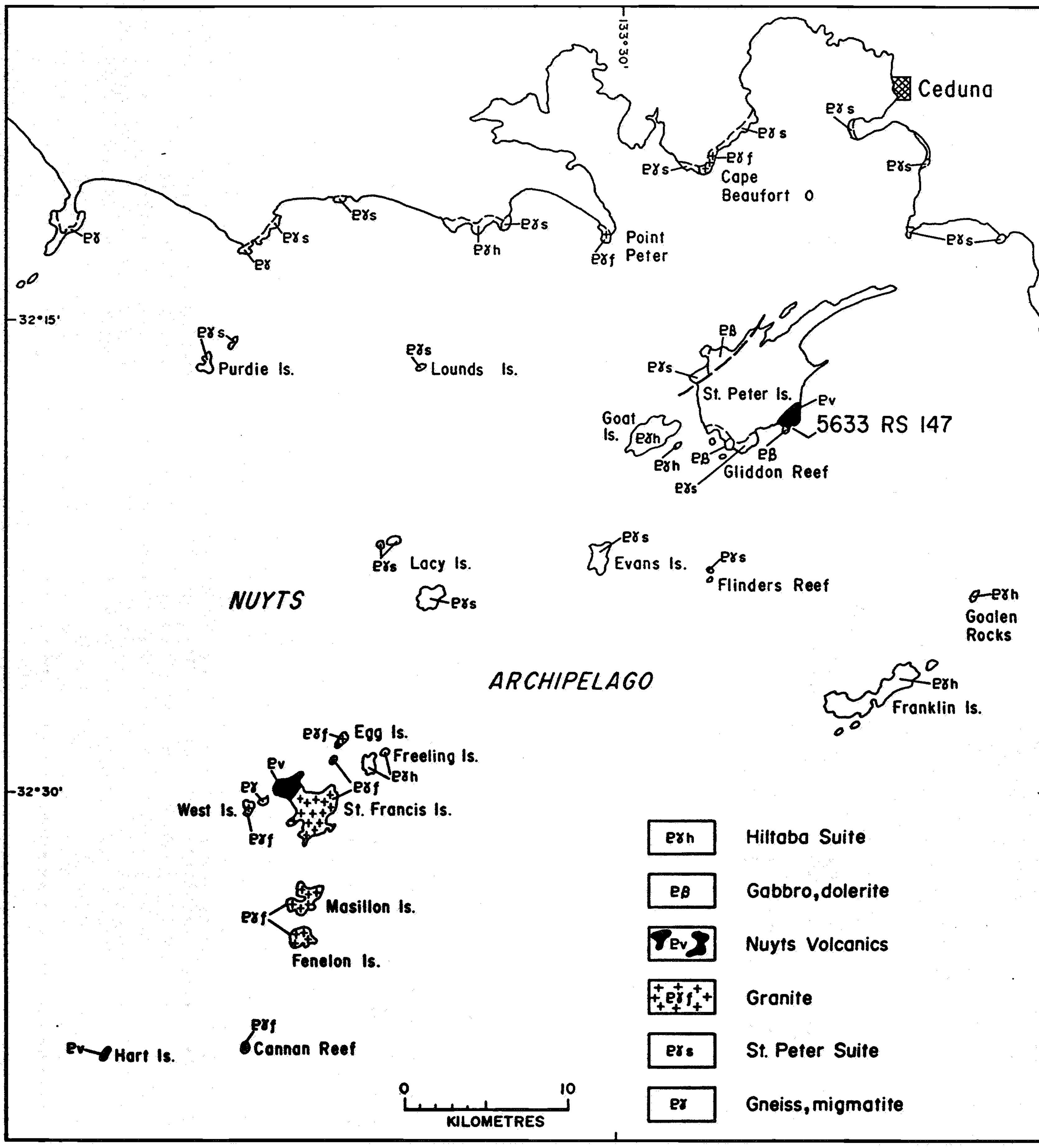
Table 1. Summary of U-Pb data for zircons analysed from St Peter Island, 5633 RS147

Sample 5633 RS 147	Weight (mg)	Conc U	(ppm) Pb	$^{206}Pb/^{204}Pb$ measured	Atomic Ratios (radiogenic)			Calculated Model Ages (Ma)		
					$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
Grain 1	0.002	319	100	701.8	0.26990	3.7364	0.10040	1540	1579	1632
Grain 2	0.003	233	81.2	682.5	0.28770	3.9767	0.10025	1630	1629	1629
Grain 3	0.006	246	85.6	1049	0.28682	3.9690	0.10036	1626	1628	1631
Grain 4	0.002	188	69.7	169.7	0.26780	3.7523	0.10162	1530	1583	1654
Grain 5	0.003	87.3	31.9	365.8	0.28735	3.9562	0.09985	1628	1625	1621
Grain 6	0.003	228	73.9	621.7	0.27546	3.7940	0.09989	1569	1592	1622



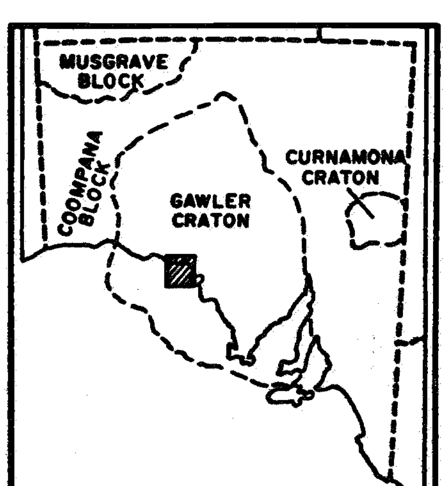


Figure......1

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EARLY PROTEROZOIC NUYTS VOLCANICS
OF THE WESTERN GAWLER CRATON

NUYTS ARCHIPELAGO GENERAL GEOLOGICAL PLAN

COMPILED L. Rankin	CDO DATE 10·10·90
DRAWN B. Donovan	SCALE As Shown
DATE Aug. 1990	PLAN NUMBER
CHECKED	S 21667

Job No. 5091

Job No. 5091

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EARLY PROTEROZOIC NUYTS VOLCANICS
OF THE WESTERN GAWLER CRATON

U-Pb CONCORDIA PLOT

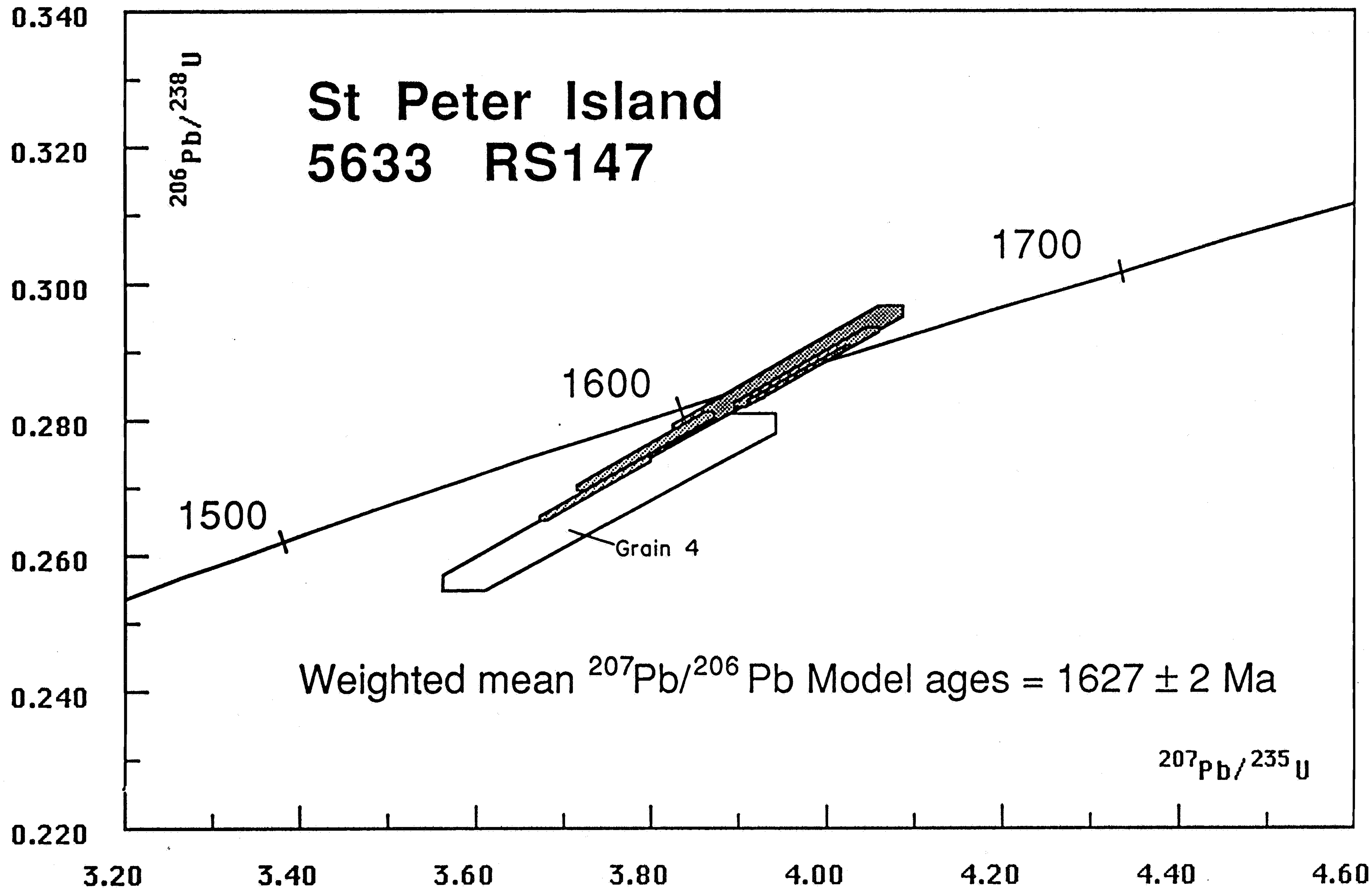
COMPILED L.Rankin
DRAWN B.Donovan
DATE Aug. 1990
CHECKED

C D O
DATE 10.10.90

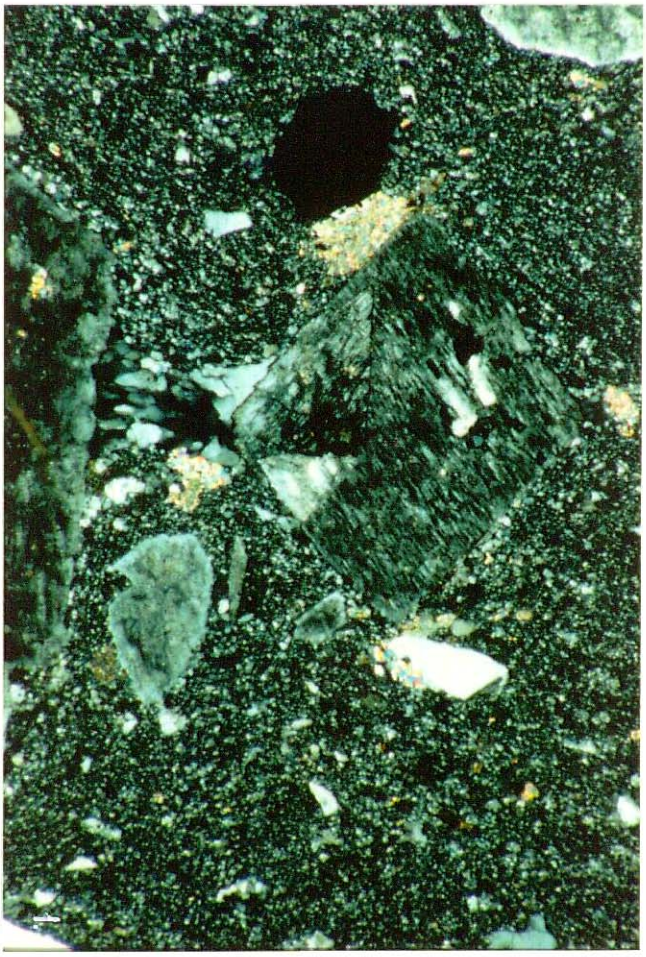
SCALE As Shown

PLAN NUMBER
S 21668

Figure.....2



Data plotted as 95% confidence limits error ellipses.



Euhedral feldspar and smaller quartz phenocrysts in a fine-grained siliceous matrix, with recrystallisation of quartz in pressure shadows between adjacent feldspar phenocrysts. Specimen 5633 RS 146, field of view 2.0 x 1.5 mm.
Photo no. 39072