X:2. Sr/Rb DATING ON BASEMENT ROCKS FROM VICTORIA LAND; EVIDENCE FOR A 1000 MILLION YEAR OLD EVENT

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Geological Introduction

The geological investigation of the Wright Valley and Victoria Valley system form part of an Antarctic project by Victoria University of Wellington.

The main features of the geology of this region were outlined as follows by WEBB and MCKELVEY [1959], MCKELVEY and WEBB [1962], and ALLEN and GIBSON [1962]:

The Basement Complex exposed in these valleys consists of more than 15 000 ft (4 575 m) of folded Precambrian–Lower Cambrian marbles, hornfelses and schists (Asgard Formation) invaded by acid plutonic rocks.

These plutonic rocks comprise three intrusive phases. The oldest intrusive rocks are composed of a strongly foliated granite-gneiss (Olympus) and a porphyritic granite (Dais). They are cut by pegmatite dykes and veins which form the second intrusive phase. It consists of micro-diorite (Loke), granodiorite (Theseus) and dykes intruding the metasediments, granite-gneiss and granite. The third intrusive phase includes an undeformed homogeneous granite (Vida) and dense swarms of younger lamprophyre and porphyry dykes (Vanda) invading all earlier rocks.

The peneplaned basement surface is overlain unconformably by more than 4 000 ft (1 220 m) of mid-Palaeozoic to mid-Mesozoic sediments of the Beacon Group. Ferrar Dolerite sills and dykes intrude the Basement Complex and the Beacon Group.

Previous Age Determinations

Few age determinations, and only by the A/K method, have been carried out on the rocks of this region. They are shown on fig. 1 and can be summarized as follows:

1. GOLDICH, NIER and WASHBURN [1958]: a biotite age of 520 m.yr. on a *para*gneiss from Gneiss Point.
2. ANGINO, TURNER and ZELLER [1962]: biotite ages of 500 m.yr. from a marble at Marble Point, of 425 m.yr. from a monzonitic gneiss from the west slope of Mount Nussbaum, and 458 m.yr. from a dyke of lamprophyre from Taylor Valley.
3. EVERNDEN and RICHARDS [1962]: an age on a dolerite in Victoria Land of 162 m.yr.
4. MCDOUGALL [1963]: concordant ages on pyroxene and plagioclase from dolerites in the Victoria Valley, Skelton and Beardmore Glaciers regions, ranging from 150 to 163 m.yr. Biotites and potash feldspars from basement rocks yielded ages varying from 195 to 222 m.yr., according to the distances (up to 250 ft (75 m)) from a dolerite intrusion.

These results indicate an important metamorphic episode affecting the biotite of metasedimentary and gneissic rocks; its minimum age is of the order of 500 m.yr. This episode might be correlated with the plutonic intrusions and the lamprophyre dykes. Contact metamorphism is shown near the intrusion of a 150 m.yr. dolerite.

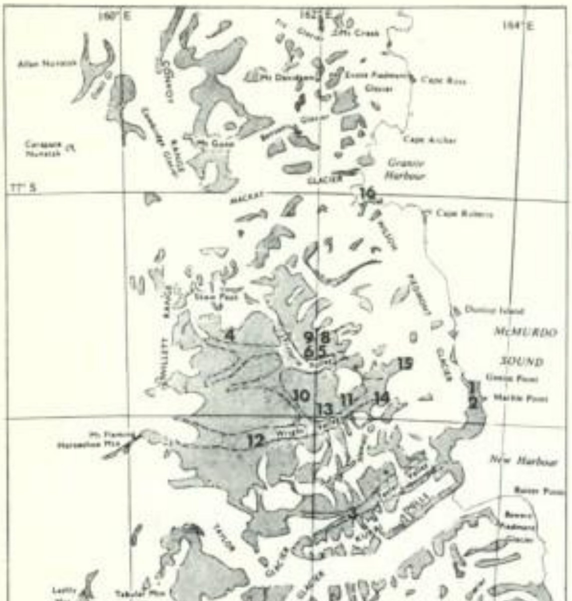

Fig. 1. Location of dated rocks from southern Victoria Land. Areas of bare rock are stippled.

1. 520 m.yr.: A/K biotite age on a *para*gneiss (GOLDICH and others [1958]).
2. 500 m.yr.: A/K biotite age on a marble (ANGINO and others [1962]).
3. 425 m.yr.: A/K biotite age on a gneiss (ANGINO and others [1962]).
   458 m.yr.: A/K biotite age on a lamprophyre dyke (ANGINO and others [1962]).
4. 163 m.yr.: A/K pyroxene age on a dolerite (McDOUGALL [1963]).
5. 159 m.yr.: A/K plagioclase age on a dolerite (McDOUGALL [1963]).
6. 162 m.yr.: A/K plagioclase age on a dolerite (McDOUGALL [1963]).
7. 154 m.yr.: A/K plagioclase age on a dolerite (McDOUGALL [1963]).
8. 185 m.yr.: A/K biotite age on a granodiorite near a dolerite intrusion (EVERNDEN and RICHARDS [1962]; cited in McDOUGALL [1963]).
   211 m.yr.: A/K biotite age on a granodiorite near a dolerite intrusion (EVERNDEN and RICHARDS [1962]; cited in McDOUGALL [1963]).
   210 m.yr.: A/K biotite age on a granodiorite near a dolerite intrusion (EVERNDEN and RICHARDS [1962]; cited in McDOUGALL [1963]).
9. 222 m.yr.: A/K feldspar age on a granodiorite near a dolerite intrusion (EVERNDEN and RICHARDS [1962]; cited in McDOUGALL [1963]).
10. 342 m.yr.: Rb/Sr biotite age on a schist near a dolerite intrusion (this work).
11. 494 m.yr.: Rb/Sr biotite age on a schist (this work).
12. 481 m.yr.: Rb/Sr biotite age on Olympus gneiss (this work).
13. 494 m.yr.: Rb/Sr biotite age on Olympus gneiss (this work).
    435 m.yr.: Rb/Sr biotite age on a pegmatite (this work).
    495 m.yr.: Rb/Sr biotite age on a granodiorite (this wotk).
    477 m.yr.: Rb/Sr biotite age on a porphyry dyke (this work).
    942 m.yr.: Rb/Sr feldspar age on a porphyry dyke (this work).
    1 000 m.yr.: Rb/Sr total rock age on a porphyry dyke (this work).
14. 487 m.yr.: Rb/Sr biotite age on Dais granite (this work).
15. 487 m.yr.: Rb/Sr biotite age on Dais granite (this work).
16. 486 m.yr.: Rb/Sr biotite age on Irizar granite (this work).
    475 m.yr.: Rb/Sr feldspar age on Irizar granite (this work).
    535 m.yr.: Rb/Sr total rock age on an aplite (this work).

Analytical Results

To obtain more information about the geochronology of this region, Sr/Rb ages were measured on 12 specimens of the main rock units. They were sampled by McKelvey and Webb, and are described in the appendix.

Isotopic dilution techniques, as described by ALDRICH and others [1956], were applied for rubidium and strontium determinations on biotite, feldspar and total rock. The reproducibility of Sr/Rb ages is approximately 3 per cent on the biotites, and from 10 to 15 per cent on the measured total rocks and feldspars. The analytical results are given in table 1.

Out of the 10 biotite ages, 9 were around 480 m.yr. (434–495 m.yr.). The biotite of sample 1, a schist taken in the vicinity (a few hundred feet) of a dolerite dyke yields an age of 340 m.yr. This age is obviously lowered by contact metamorphism, but to a lesser degree than EVERNDEN and RICHARDS [1962] have found closer

TABLE 1

Sr/Rb analytical results and ages on rocks from Victoria Land

No.	Rock type	Formation	Latitude / Longitude	Mineral *	Rb (ppm)	^{87}Sr rad. (ppm)	^{87}Sr rad. / ^{87}Sr total %	Age † (m.yr.)
1	Schist	Asgard	77°27′ S.	B	481	0.85	23.2	345±12
			161°56′ E.		472	0.93	27.8	338±12
2	Schist	Asgard	77°28′ S. 162°16′ E.	B	527	1.04	61.3	494±15
6	Gneiss	Olympus granite-gneiss	77°32′ S. 161°30′ E.	B	677	1.29	59.3	481±15
8	Gneiss	Olympus granite-gneiss	77°32′ S. 161°30′ E.	B	649	1.26	61.2	494±15
17	Porphyritic granite	Dais granite	77°29′ S.	B	452	0.85	14.9	479±30
			162°33′ E.		577	1.13	29.5	495±15
18	Porphyritic granite	Dais granite	77°24′ S. 162°45′ E.	B	422	0.81	30.6	487±15
21	Pegmatite	In Olympus granite-gneiss	77°30′ S. 162°08′ E.	B	241	0.41	18.5	435±25
22	Granodiorite	Theseus granodiorite	77°30′ S. 162°04′ E.	B	640	1.25	43.1	495±15
25	Granite	Irizar granite	77°00′ S.	B	644	1.23	34.4	486±15
			162°32′ E.	F	262	0.46	7.2	445 } 475±80
						0.52	8.2	508 }
29	Porphyry dyke		77°30′ S.	B+H	798	1.51	55.9	477±15
			162°04′ E.	F	158	0.60	11.6	956 }
					282	1.05	13.5	940 } 942±80
						1.04	13.4	931 }
				T.R.	171	0.70	13	1 030 }
					172	0.65	12	960 } 1 000±80
						0.67	12.4	1 003 }
30	Aplite		77°00′ S. 162°30′ E.	T.R.	173	0.34	4.4	535±120

* B = biotite; F = feldspar; H = hornblende; T.R. = total rock.

† λ Rb = 1.39×10^{-10} yr.$^{-1}$; common strontium 87/86 = 0.709.

to a dolerite intrusion (see McDOUGALL [1963]). This is consistent with their results.

The feldspar age of Irizar granite is 475±80 m.yr.; its biotite age is 486 m.yr.; both are close to the total rock age of an associated aplite (30) of 520±120 m.yr.

The total rock and feldspar ages of a porphyry dyke (29) in the Olympus granite-gneiss are found to be respectively 1 000±80 and 940±80 m.yr., whereas the biotite age is only 480±15 m.yr.

As the total rock and feldspar contain about 12 per cent radiogenic ^{87}Sr, the value taken for the 87/86 ratio of common strontium is important. The value used here is 0.709±0.004 which corresponds to the composition of strontium of another sample of the Vanda porphyry dyke (27) and of the Olympus granite-gneiss. Strontium was measured on total rocks and feldspars with low Rb/Sr ratios and corrected in some cases for a small radiogenic contribution. No strontium-rich mineral could be separated for common strontium measurements in sample 29.

To yield an age of 500 m.yr., the total rock and feldspar should have incorporated a common strontium with a 87/86 ratio of 0.76. In the case of an homogeneous intrusive rock like this porphyry dyke, such an anomalous strontium would be unusual (HURLEY and others [1963]).

Neither of two other porphyry dykes yielded enough radiogenic strontium to be dated.

Conclusions

From these results, the following conclusions can be drawn:

1. The data obtained on the biotite of all the different rocks confirm the existence of an approximately 500 m.yr. extended metamorphic episode affecting the gneissic complex. This episode was already indicated from the biotite A/K ages.
2. The total rock and feldspar ages on Irizar granite and aplite are taken as evidence that the last intrusive phase of plutonic activity in this region took place at that same time or a little earlier (less than 640 m.yr.).
3. The results on the porphyry dyke are especially interesting, as they are the first geochronological indication in Victoria Land of a Precambrian event. This rock was described as being part of the Vanda lamprophyre and porphyry formation, the younger intrusive phase of the Basement Complex. If this is true, its age is in contradiction to the 500 m.yr. age of Irizar granite and aplite. It could be, however, that this dyke is part of an older dyke system (second intrusive phase according to McKelvey and Webb [1962]).

Complementary age measurements and field investigations are needed before reaching any definite geological conclusions.

Anyhow, the radiometric measurements show that, with the assumption that the porphyry dyke remained a closed system for rubidium and strontium, and incorporated normal strontium at the time of its emplacement, the age of this event would be around 1 000 m.yr.

This would suggest that the 500 m.yr. ages on the biotites are not related to the general metamorphism of the gneisses but have to be ascribed to a later event.

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Appendix

Description of the samples

Sample 1. *Schist from the Asgard Formation.* From the crest of the main ridge, Olympus Range, 2 miles (3.2 km) east of Bull Pass, south-east of Mount Cerberus. Composed almost entirely of biotite flakes measuring up to 3 mm in length. This sample was taken from a 3 ft (0.9 m) band of schist occurring in a much thicker succession of marble. Intrusive dolerite dyke occurs within several hundreds of feet of this sample.

Sample 2. *Schist from the Asgard Formation.* From the northern wall of eastern Wright Valley, 1 mile (1.6 km) south-east of Mount Theseus. Composed of quartz and feldspar. In thin section, it comprises alternating fine- and coarse-grained quartz–plagioclase laminae. Fine layers are densely packed with biotite flakes. The sample occurs in association with marbles, hornfelses and more basic schists.

Sample 6. *Gneiss from the Olympus granite-gneiss*. From the southern shoreline of Lake Vanda, central Wright Valley. Gneiss having an average grain-size of 1–2 mm and composed principally of quartz, orthoclase, oligoclase and biotite, and accessory zircon and apatite. Biotite (deep brown) flakes are strongly aligned. The sample was obtained from gneiss exposures which have been densely intruded by much younger lamprophyre dykes.

Sample 8. *Gneiss from the Olympus granite-gneiss*. From the same locality as sample 6. Composed of quartz, orthoclase (sericitized), oligoclase and biotite. Average grain-size of sample is 2–3 mm. Biotite occurring as brown flakes (1 mm), in some cases folded around feldspars.

Sample 17. *Porphyritic Dais granite*. From the northern spur of Mount Loke, southern wall of eastern Wright Valley. Has a coarse porphyritic texture, with phenocrysts of bright pink orthoclase up to 30 mm diameter set in a matrix of quartz, hornblende and biotite. This sample was taken from an area in which dioritic dyke intrusion is particularly dense. Contacts between the host rock, i.e. this sample, and the dykes are sharp.

Sample 18. *Porphyritic Dais granite*. From the northern wall of Wright Valley, near Mount Doorly. Has a coarse porphyritic texture, with pink orthoclase phenocrysts (up to 25 mm) set in a matrix of quartz, oligoclase, hornblende and biotite. Allanite, zircon, iron oxide and apatite occur as accessory minerals. Orthoclase has a perthitic texture and often encloses the plagioclase. Biotite and hornblende form up to 13 per cent of the rock. The geographic limits of the Dais granite are not easily defined, as no intrusive contacts have been observed. This rock type passes gradationally into gneisses (Olympus granite-gneiss).

Sample 21. *Pegmatite in porphyroblastic gneiss*. From the northern wall of Wright Valley, 2 miles (3.2 km) south-west of Mount Theseus. It occurs within an irregular-shaped body which cuts across the gneisses. It is composed of quartz, orthoclase and biotite. The latter occurs in books of up to 2 cm across.

Sample 22. *Theseus granodiorite*. From the northern wall of Wright Valley, 3 miles (4.8 km) east of Bull Pass. It has a hypidiomorphic-granular texture and contains zoned plagioclase, orthoclase, quartz, biotite and occasional patches of quartz-feldspar micropegmatite. Accessory minerals include chlorite, zircon, apatite and allanite.

Samples 24 *and* 25. *Irizar granite*. From Granite Harbour. It is a coarse-grained homogeneous rock displaying a hypidiomorphic-granular texture and containing quartz, orthoclase, oligoclase and small amounts of biotite and green hornblende. It is similar in composition to Vida granite.

Sample 27. *Porphyry dyke from Vanda lamprophyre and porphyry formation*. From the northern wall of Wright Valley, 3 miles (4.8 km) east of the southern entrance of Bull Pass. Composed of pink perthitic orthoclase (2 cm), sericitized oligoclase and clusters of hornblende, biotite and quartz. These grains are set in a matrix of micrographically intergrown quartz and feldspar. Frequently, the orthoclase surrounds well sericitized oligoclase. Biotite and greenish black hornblende form less than 5 per cent of the rock. Zircon and apatite are common accessory minerals.

Sample 29. *Porphyry dyke*. From the same place as sample 27. Composed of phenocrysts of pale pink orthoclase (up to 20 mm), plagioclase, quartz, hornblende (4 mm) and biotite set in a light green matrix. It resembles sample 27 in the hand specimen.

Sample 30. *Aplite*. From Granite Harbour. It is a moderately fine-grained rock, pink to brick-red in colour and composed of quartz, orthoclase (sericitized), albite, minor amounts of biotite and iron oxides.

Discussion

G. Warren: In the light of the remarks by Dr. Nicolaysen (who has presented the paper on behalf of the authors) on the contradictory evidence of dates of 480 and $\sim$ 1 000 m.yr. for the same rock, it is worth repeating that in some favourable areas a direct check on this is possible; namely, where a granitic body intrudes an *Archaeocyathus* limestone. On Professor Dorothy Hill's confident dating of these fossils as early to Middle Cambrian, ages exceeding 600 m.yr. for such an intrusion can immediately be discounted.