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GEOCHRONOLOGY OF LATE TERTIARY AND QUATERNARY MINERALIZED INTRUSIVE PHORHYRITES IN THE STAR MOUNTAINS OF PAPUA NEW GUINEA AND IRIAN JAYA

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ABSTRACT

The ages of several intrusive bodies associated with porphyry copper mineralization in the Star Mountains area have been further investigated. These intrusions are largely intermediate in composition and they cut through a Cretaceous to Upper Tertiary folded sedimentary sequence. The K-Ar results demonstrate that the majority of intrusions were emplaced between 7 m.y. and 1 m.y. ago. Discordant ages found within some intrusive bodies suggest that such bodies are in fact multiple intrusions of more than one age. New age data from the monzonites and diorites in the vicinity of the Mount Fubilan (Ok Tedi) porphyry copper deposit show a time gap of 1.5 m.y. between initial magmatic emplacement (2.6 m.y.) and subsequent copper mineralization (1.1 m.y.) associated with the Fubilan porphyries. Comparison of the ages of mineralized porphyries in the Star Mountains Intrusives (3.4 to 4.6 m.y.) and Antares Monzonite (2.4 to 3.1 m.y.) with older Miocene to early Pliocene ages determined on unmineralized parts of the same intrusions likewise indicates a distinct time interval between

initial post-emplacement cooling and the later hydrothermal alteration/mineralization processes.

The youthfulness of intrusive igneous activity in this part of Papua New Guinea and Irian Jaya raises the possibility that the Quaternary stratovolcanoes in nearby areas of the Highlands may belong to the same tectonic regime, and therefore may similarly be of some economic potential.

INTRODUCTION

Tertiary and Quaternary high-level, acid-intermediate intrusions in the New Guinea - Solomon Islands region have attracted considerable interest because many such bodies have porphyry copper mineralization associated with them. In the Star Mountains area, straddling the border between Papua New Guinea and Irian Jaya (Fig. 1), there are a number of such intrusive porphyry stocks. The origin of these magmas and associated mineralization, and the geology and tectonic setting of the area, have been recently evaluated (Bamford, 1972; Davies and Norvick, in press). Most of the stocks clearly intrude a folded Tertiary sequence known as the Papuan Fold Belt (Bain, 1973), which in this area is composed of foraminiferally dated limestones and fine-grained clastic rocks of upper Eocene to middle Miocene age. This field evidence thus imposes good stratigraphic control on the maximum age of the intrusions, but no younger age limits can be inferred.

K-ar ages previously reported from three intrusive bodies in the Star Mountains area (Page & McDougall, 1972a) indicate a closely defined Pleistocene age (1.1 to 1.2 m.y.) for hydrothermal alteration and mineralization of the quartz latite porphyries in the Mount Fubilan (Ok Tedi) porphyry copper deposit, and the two other dated intrusions north of Mount Fubilan both give Pliocene ages. The general interest in this area and extreme youthfulness of the Mount Fubilan deposit in particular have led to a more extensive geochronological study, results of which are reported in this paper. Additional dating work on other hypabyssal intrusions in the close vicinity of the Mount Fubilan copper deposit was undertaken to investigate the timing of formation of different intrusive bodies in such a porphyry complex. The other hypabyssal porphyry intrusions in the Star Mountains that have been dated (Fig. 1) are also associated with copper mineralization to some degree.

FIELD COLLECTION AND K-Ar TECHNIQUES

Many of the samples used in this study were collected from drill core obtained by Kennecott Explorations (Australia) Pty Ltd, and these specimens (Table 1) are precisely located (Fig. 1). Because surface collection of fresh rock elsewhere in this densely vegetated tropical environment was not possible, some of the remaining samples were obtained amongst the float in streams of limited catchment area, and can be confidently related to the mapped intrusive bodies.

Dating work in this study employed the K-Ar technique on both whole rocks and separated minerals (biotite, hornblende and plagioclase). Potassium values were measured in duplicate by flame photometry (Cooper, 1963) and the isotope dilution method of argon analysis followed the procedures described by McDougall (1966). Two of the K-Ar ages in Table 1 reported on the Antares Monzonite and the four ages from the Tabe and Bolivip Stocks were measured by A.W. Webb (AMDL Report 4092/72). Physical constants used in the K-Ar age calculations are: $\lambda_{\beta} = 4.72 \times 10^{-10}\ yr^{-1}$, $\lambda_{e} = 0.585 \times 10^{-10}\ yr^{-1}$, $K^{40}/K = 1.19 \times 10^{-2}$ atom percent. The precision quoted for each age represents two standard deviations and is calculated from the accumulated uncertainties in physical measurements for each analysis (McDougall et al., 1969). Unless otherwise stated, the Cenozoic physical time scale adopted in this paper is that of Berggren (1969).

GEOLOCICAL SETTING AND K-Ar AGE RESULTS

The major structural feature of this area is a west-northwest trending fold belt about 60 km wide, in which Tertiary and Mesozoic sedimentary rocks have been broadly folded and faulted. This succession is intruded by a great many relatively undeformed hypabyssal stocks of acid-intermediate composition, and their ages of emplacement are the subject of this study. The

K-Ar results are discussed in five separate sections, and all the ages are summarized in a histogram (Fig. 2).

(i) Mount Fubilan Area

The monzonitic intrusive rocks in the vicinity of Mount Fubilan intrude Upper Cretaceous and Tertiary sediments, the youngest of which are middle Miocene (lower Tf Stage). Porphyry copper mineralization is primarily related to a central orthoclase-rich intrusion, known as the Fubilan intrusion (Bamford, 1972), and also referred to as the Hong Kong intrusive, which yielded consistent K-Ar whole-rock and biotite ages of between 1.1 and 1.2 m.y. (Page and McDougall, 1972a). This Pleistocene age has been interpreted as the time of hydrothermal alteration and mineralization.

A barren intrusion of monzonite and quartz diorite, referred to informally as the Sydney type, occurs along the southern margin of the mineralized Fubilan intrusion. Bamford (1972) implies that the Sydney monzonite is older than the Fubilan intrusion.

Six samples of the Sydney intrusion south of Mount Fubilan and one sample 1.6 km to the northeast have been dated, and the results are given in Table 1. The whole-rock ages range from 2.2 to 3.0 m.y. and have a mean value of 2.52 ± 0.28 m.y. (standard deviation). The hornblende measurement on sample 72-215 is somewhat older at 3.1 m.y., but because of high air contamination in the argon run, this single age is considered tentative. All of the biotite results are distinctly younger than whole-rock and hornblende ages, but the biotite ages nevertheless group closely together with a mean of 1.37 ± 0.18 m.y.

The mean whole-rock age of 2.5 ± 0.3 m.y. is considered to be a minimum because the samples contain about 3 to 5 percent biotite, the apparent ages of which are clearly much younger than the age of emplacement. The young biotite ages in the Sydney monzonite samples are either equal to, or slightly older than, the earlier determined age (1.1 to 1.2 m.y.) of mineralization related to the nearby Fubilan intrusion. The most likely interpretation is that the biotites in the Sydney monzonite lost virtually all their accumulated radiogenic argon at 1.1 m.y., as a result of heating at the time of mineralization and alteration of the Fubilan intrusion. Except for sample 72-202, which is a recrystallized monzonite, and in which the biotite is certainly secondary, all the other Sydney monzonites are generally unaltered. Primary minerals making up these rocks are clinopyroxene, amphibole, biotite, sphene, zoned plagioclase (An_{25}-An_{50}), orthoclase and quartz. The rocks have a typical monzonitic texture and the ferromagnesian minerals are generally euhedral. No petrographic clue exists for the thermal event which evidently caused argon to outgas from the biotite. Considering that the biotites (which make up about 3 percent of the Sydney monzonites) lost most of their radiogenic argon accumulated until the time of the Fubilan intrusion, one can calculate that the measured whole-rock ages are 4 to 5 percent too young. This results in a corrected mean whole-rock age of 2.6 $\pm$ 0.3 m.y. (late Pliocene), which is the best estimate for the age of emplacement of the Sydney monzonite. This remains a minimum age, however, as it is difficult to exclude the possibility that some argon loss may also have occurred from other minerals in the whole-rock samples.

Comparison of the estimated age of the Sydney monzonite (2.6 m.y.) with the age of hydrothermal alteration and mineralization in the adjacent Fubilan stock (1.1 to 1.2 m.y.) confirms the inferred intrusive relations, and shows a short but distinct time interval of 1.4 to 1.5 m.y. between the initial magmatic emplacement in the area and subsequent copper mineralization associated with the Fubilan porphyries. This interval of time separating the earliest known intrusion and later mineralization within the Fubilan porphyry copper complex is of the same order as the interval of 0.5 to 1.5 m.y. found in the Panguna porphyry copper orebody which is also Pliocene in age (Page &McDougall, 1972b). Another porphyry deposit within which separate events have been delineated is at Bingham, Utah, where a similar hiatus of 1 to 2 m.y. is revealed (Moore & Lanphere, 1971). At the Yanderra copper deposit in the Eastern Highlands of Papua New Guinea, the 13 m.y. host granodiorites are postdated by a mineralization/alteration episode which is 6 to 7 m.y. old (Page and McDougall, 1972a).

(ii) Mount Ian Gabbro

This hypabyssal stock, 5.8 km north-northeast of Mount Fubilan, consists of a central intrusion of pyroxene-biotite gabbro and a sub-circular surrounding mass of diorite and andesite porphyry. The complex intrudes sediments whose known age range extends from upper Eocene to middle Miocene (Davies and Norvick, in press).

Only one sample of the hornblende andesite porphyry or microdiorite has been dated, and a mid-Miocene age of 12.9 m.y. is indicated. Three biotite gabbros (including 70-5996, data of Page & McDougall, 1972a) from different localities within this intrusive gabbro unit yield much younger but fairly concordant biotite ages between 1.7 and 2.0 m.y. This late Pliocene age for the Mount Ian Gabbro strongly implies that there is no direct relation between it and the surrounding diorites and andesite porphyries.

The samples of Mount Ian Gabbro that were dated are fresh, unaltered biotite gabbros. Biotite and clinopyroxene form poikilitic intergrowths, and it is considered (contrary to the view expressed in Bamford, 1972) that the biotite is definitely a primary mineral. The mean age of the three samples from the Mount Ian Gabbro is 1.9 $\pm$ 0.2 m.y., and this value is regarded as a good minimum estimate for its age of emplacement.

(iii) Antares Monzonite

This group of intrusive monzonites, granodiorites and diorites crops out in at least four separate stocks (Fig. 1) at about 5°S, on both sides of the 141°E longitude border between Papua New Guinea and Irian Jaya (Davies & Norvick, in press; P.T. Kennecott Indonesia, written communication, 10 February 1971). Here again the field relations are clear, showing that the intrusions postdate the Darai Limestone, whose known stratigraphic age limits span from upper Eocene to middle Miocene (Davies and Norvick, in press). The intrusive sequence within and between the various stocks is not known.

Eight biotite and two hornblende K-Ar analyses from the nine separate localities are given in Table 1. The four monzonite samples from the Denam River area in Irian Jaya are distinctive in that they are weakly mineralized with pyrite and chalcopyrite. There is no evidence of recrystallization in these rocks, and the biotite and hornblende are both of primary igneous origin. Ages of three biotites from these samples (71-722, 71-723, 71-724) collected within 500 metres of each other are reasonably concordant between 2.9 and 3.1 m.y. (mean 2.95 ± 0.11 m.y.). The other biotite age of 2.4 m.y. is from a sample 1.8 km southwest of this group, and its apparently younger age may be real. The four biotite results together indicate that part of the Antares Monzonite finally cooled between 2.4 and 3.1 m.y., in the late Pliocene. However, the much older hornblende age (71-724) of 5.9 m.y. suggests that emplacement is at least as old as late Miocene, and that the late Pliocene biotite ages may reflect either some subsequent thermal event, perhaps related to mineralization, or that post-emplacement temperatures remained sufficiently high for argon diffusive loss from biotite. Presence of copper mineralization suggests, as the more likely hypothesis, that the stock may have been subjected to a later mineralizing event.

The remaining samples come from the eastern part of the Antares Monzonite in Papua New Guinea, and are slightly more basic in composition than the western group. The rocks have a well crystallized granular texture and no visible sulphide mineralization. The K-Ar biotite ages range from 3.6 to 6.9 m.y., and the single hornblende age (70-5997 earlier reported by Page and McDougall, 1972a) is 4.9 m.y. There is no apparent relation between the ages and the various bodies sampled. The mineral ages reflect a complex (at least, bimodal) intrusive or cooling history from the late Miocene through to late Pliocene. The difference between the biotite and hornblende ages measured on the one sample (71-724) is consistent with the overall spread of the age pattern, and demonstrates a common observation (c.f. Hart, 1964) that at a given temperature hornblende is more retentive of argon than biotite.

It is concluded that the Antares Monzonite was emplaced between 5 and 7 m.y. ago, in the late Miocene, and that subsequent reheating (due to further local intrusion, mineralization or uplift) took place in the late Pliocene.

(iv) Star Mountains Intrusives

(a) Tifalmin Area

The igneous rocks grouped in this category (Davies and Norvick, in press) crop out in many small stocks and plugs between the village of Tifalmin and the border with Irian Jaya (Fig. 1). These high-level bodies are mainly of dioritic and granodioritic composition, generally are composite, and intrude limestones and mudstones, the youngest of which (Pnyang Formation) is middle Miocene (lower Tf Stage). The bodies are mainly multi-phase intrusive, but local extrusive volcanic components are also present. Most of the intrusions are mineralized with sulphides to some extent (R.L. Nielsen, pers. comm.).

The K-Ar age results are given in Table 1. Six samples from the Futik, Olgal and Rattatat prospects northwest of Tifalmin were collected from both drill core and outcrop. An unmineralized diorite sample (72-205) from the west margin of the Futik body yields a whole-rock age of 12.0 ± 0.3 m.y., and a biotite age of 7.1 ± 0.2 m.y.. The 12 m.y. (mid-Miocene) minimum age is the best estimate for the age of emplacement, and the much younger biotite age probably again indicates a degree of argon loss from that mineral. From the mineralized samples (72-203, 72-206, 72-207, 72-208) a clustering of Pliocene K-Ar ages (3.4 to 4.6 m.y.) is evident.

The hornblende andesite tuff (72-204) is a core sample from a body of breccia underlying the mineralized diorite intrusive. The breccia contains fragments of sedimentary material (some of which contains late Oligocene to early Miocene microfaunal assemblages) as well as diorite similar to the Futik diorite. This suggests that the breccia postdates the Futik intrusion, but as part of the breccia is altered and fractured at the contact with the intrusive, Nielsen (pers. comm.) considers that the breccia has been either intruded by diorite or, more likely, that the contact between them is a fault along which hydrothermal alteration has occurred. The two lines of field evidence are ambiguous, so the actual relation between the breccia and intrusive rocks remains equivocal. The K-Ar age of fresh hornblende separated from the andesitic tuff is 1.6 ± 0.1 m.y.. This breccia is therefore by far the youngest unit in the complex, and its apparent age suggests that the diorite has been thrust-faulted into its present position. Its barren nature and age relation to the other mineralized intrusives, as well as its fresh mineralogy and the texture of its partly glassy groundmass, are features which are analogous to the setting of the late-stage Nautango Andesite in the Panguna copper deposit, Bougainville.

In summary, the ages measured on the intrusions in the Tifalmin area indicate that at least part of the complex was emplaced in the mid-Miocene, and that this was later reheated or re-intruded by mineralized intrusives emplaced in the mid-Pliocene 3.4 to 4.6 m.y. ago. The final recorded event in the complex is that of the crystallization of a barren 1.6 m.y. old breccia-tuff body in the Pleistocene. Thrusting of this body to a position beneath the older Futik intrusion took place less than 1.6 m.y. ago, and thus substantiates the ideas of Davies and Norvick (in press) who regard the gravity-tectonics regime in this area as probably persisting to the present day.

(b) Mount Anju and Mount Frew Areas

Both of these porphyry stocks intrude the middle Miocene (lower Tf Stage) Pnyang Formation, and are located southwest of Mount Fubilan, about 10 km and 2 km respectively east of the Irian Jaya border. The Mount Anju stock is a sub-circular body which has intruded at very shallow levels and has domed the surrounding sediments. The present exposed surface of the stock is considered to represent the virtually uneroded roof of the intrusion. Hornblende separated from a single andesite sample gives an extremely young age of 0.97 ± 0.06 m.y. (Table 1). This age needs to be substantiated by analysis of further samples, as insufficient material remained for a duplicate determination. The proportion of radiogenic argon is notably small in the present analysis, but the result nevertheless supports the apparent youthfulness of the body as evidenced by its sub-volcanic setting and non-eroded roof. The indicated Pleistocene age of about 1 m.y. is close to that of the mineralized monzonites at the Fubilan copper deposit, 8.5 km to the northeast.

The Mount Frew body is largely composed of hornblende microdiorite and plagioclase andesite porphyry. Plagioclase separated from the andesite porphyry yields a late Miocene age of 7.2 ± 0.2 m.y.. Hornblende ages from two microdiorite samples are much younger, but in good agreement at 2.2 and 2.4 m.y. (late Pliocene). These limited data may indicate that the intrusive complex was emplaced in two stages, at about 7.2 m.y. and 2.3 m.y.. An alternative and preferred explanation is that the plagioclase age is too old owing to the presence of excess argon, and that the late Pliocene age given by the hornblendes more closely represents the actual time of emplacement.

(v) Tabe and Bolivip Stocks

The Tabe and Bolivip Stocks are small intrusions about 5 to 8 km across, and are located 50 km east-southeast and 25 km south of Telefomin respectively (Fig. 1). They are largely composed of quartz-feldspar-hornblende porphyry. The Bolivip Stock intrudes Mesozoic sediments as well as the upper Eocene to middle Miocene Darai Limestone. The Tabe Stock also intrudes Mesozoic rocks and is inferred to be of the same age (post-Darai Limestone) as the Bolivip Stock.

The K-Ar results (Table 1) on hornblende from the Tabe Stock indicate an age of approximately 5 m.y. (early Pliocene). The two total-rock ages are much younger and do not agree within experimental error, suggesting that the total rocks have lost radiogenic argon. A single hornblende date from the Bolivip Stock is 2.7 ± 0.2 m.y., which taken at face value indicates a time of implacement in the late Pliocene. Further detailed work on each of these intrusions would be necessary to determine whether the apparent spread in ages is real, or whether it is due to partial updating as a result of uplift or some other later geological event.

CONCLUSIONS

This K-Ar age study of intrusive porphyries in the Star Mountains of Papua New Guinea and Irian Jaya demonstrates that nearly all of the igneous activity in the area took place between 7 m.y. and 1 m.y. ago, from latest Miocene through to Pleistocene time. These results (summarized in Table 2) are consistent with field stratigraphic control as the youngest sediments intruded by the porphyries are of middle Miocene (lower Tf Stage) age.

The ages show that many of the mapped porphyry bodies are in fact multiple intrusions of more than one age. In the case of the monzonites and diorites in the vicinity of Mount Fubilan, a definite two-stage history involving initial emplacement at about 2.6 m.y. and a subsequent mineralization alteration episode at 1.1 to 1.2 m.y. is evident. A similar but less firm interpretation applied to the Star Mountains Intrusives in the Tifalmin area suggests that the mid-Pliocene mineralized diorites postdate unaltered diorites which are perhaps as old as mid-Miocene. Likewise, a two-fold division of K-Ar ages is found in the Antares Monzonite pluton: biotites from mineralized monzonites all give ages (2.4 to 3.1 m.y.) in the late Pliocene, whereas unmineralized rocks from elsewhere in the pluton are distinctly older, of late Miocene to early Pliocene age. In some cases too few data are available to resolve whether discordant ages are geologically significant or whether they merely reflect partial loss of argon. Only further analyses in such intrusions would permit a more definite interpretation.

The prevalence of Pliocene and Pleistocene igneous activity in this part of the island of New Guinea deserves some comment. The ages of emplacement of the intrusions reported in this paper cover some 5 or 6 million years, and appear to represent a distinctive time regime of igneous activity. The only other intrusive body in the area is the basement Strickland Granite which is of late Permian - early Triassic age (Page, in press; Davies and Norvick, in press), and hence quite unrelated to the intrusives discussed here.

The local episodicity of mid-Miocene igneous activity in the Central New Guinea Highlands (Page, in press) Eocene-Oligocene activity in North New Guinea Ranges (Hutchison, in press), and late Oligocene activity in New Britain (Page and Ryburn, in press, would appear to be again exemplified by the predominantly Pliocene-Pleistocene activity in the Star Mountains. The Quaternary volcanism evident at Mount Hagen and other large stratovolcanoes in the western and southern highlands of the Papua New Guinea mainland has been considered to occupy a unique tectonic (post-orogenic) setting. The ages of this volcanism are known to go back to at least 0.2 m.y. (Page and Johnson, 1974). The Pleistocene ages of some of the sub-volcanic stocks in the Star Mountains (e.g. Mount Fubilan, Mount Anju) suggest that the rather conspicuous Quaternary volcanism of the Highlands may merely belong to a single episode and tectonic regime which began in the Pliocene. If this inference from the age comparisons were to be substantiated by detailed geochemical comparisons, it is likely that the roots of such Quaternary stratovolcanoes would attract considerable economic interest.

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Table 1. K-Ar ages of intrusive porphyries in the Star Mountains

Sample No.	Field No.	Locality	Rock Type	Material Dated	K%		Radiogenic Ar^{40} $\times 10^{-10}$ mole/gm	100 × Radiogenic Ar^{40} / Total Ar^{40}	Calculated age m.y.
SYDNEY TYPE MONZONITE INTRUSIVE									
72-198	7152 1598		Monzonite	Whole rock	3.028 3.025	3.027	0.1187	17.7	2.20 ± 0.07
				Biotite	7.663 7.663	7.663	0.1508	16.5	1.11 ± 0.11
72-199	7152 1599		Monzonite	Whole rock	2.987 2.984	2.986	0.1342 0.1318	21.9 21.3	2.52 ± 0.20 2.48 ± 0.07
				Biotite	7.762 7.784	7.773	0.1674	22.4	1.21 ± 0.08
72-200	7152 1600		Monzonite	Whole rock	2.997 2.991	2.994	0.1286 0.1289	19.5 17.0	2.41 ± 0.19 2.42 ± 0.08
				Biotite	7.699 7.721	7.710	0.2153	32.6	1.57 ± 0.14
72-201	7152 1601	Harvey Creek, south of Mt. Fubilan	Monzonite	Whole rock	2.984 2.982	2.983	0.1347	19.7	2.53 ± 0.07
				Biotite	7.742 7.725	7.734	0.2022	28.1	1.47 ± 0.10
72-216	7152 1300		Monzonite	Whole rock	2.887 2.862	2.875	0.1516	32.8	2.96 ± 0.06
				Biotite	7.868 7.972	7.920	0.2094	33.1	1.49 ± 0.10
72-215	7152 1299		Monzonite	Hornblende	0.547 0.530	0.539	0.0299	9.5	3.11 ± 0.24
72-202		1.6 km NE of Mt. Fubilan, at Sulphide Creek, near DDH 6	Recrystallized Monzonite	Biotite	6.834 6.874	6.854	0.3657 0.3765	23.1 36.7	1.34 ± 0.09 1.38 ± 0.07
MOUNT IAN GABBRO									
70-5996	7052 0054		Biotite Diorite	Biotite	7.747 7.720	7.734	0.2547 0.2848	37.3 28.4	1.85 ± 0.03 2.07 ± 0.05
71-729	M.I. - 1	1.5-3.0 km SSE of Mount Ian	Gabbro	Biotite	7.564 7.584	7.574	0.2236	22.8	1.66 ± 0.06
72-224	7152 1680		Gabbro	Biotite	7.902 7.928	7.915	0.2731	26.7	1.94 ± 0.04
71-899	M.I. - 2	2.4 km SE of Mount Ian	Andesite	Hornblende	1.110 1.086	1.098	0.2525	26.5	12.9 ± 0.5
ANTARES MONZONITE									
71-722	DCL - 1	Headwaters of the Denam River, Irian Jaya - 13km west of Papua New Guinea border	Biotite monzonite	Biotite	7.670 7.713	7.692	0.4210	30.6	3.07 ± 0.10
71-723	DCL - 2		Biotite monzonite	Biotite	7.604 7.618	7.611	0.3859	42.8	2.85 ± 0.06
71-724	DCL - 3	Headwaters of the Denam River, Irian Jaya - 13km west of Papua New Guinea border	Biotite monzonite	Biotite	7.658 7.641	7.650	0.3978	52.8	2.92 ± 0.04
				Hornblende	0.481 0.480	0.481	0.0504	22.8	5.9 ± 0.9
71-725	DW		Biotite monzonite	Biotite	7.641 7.684	7.663	0.3311	46.8	2.43 ± 0.06
7152 192	7152 1921	Head of Ok Worp R., on Irian Jaya Border	Quartz diorite	Biotite*	6.979 6.932	6.956	0.0609 0.0642	50.3 58.5	4.92 ± 0.3 5.18 ± 0.3
7152 1978	7152 1978	Head of Ok Bon R.	Quartz diorite	Biotite*	7.500 7.505	7.503	0.0529 0.0479	59.5 66.7	3.97 ± 0.3 3.59 ± 0.3
72-209	7152 0585	Ban R., S of Buselmin	Diorite	Biotite	7.579 7.539	7.559	0.4867	46.3	3.61 ± 0.11
72-211	7152 0569	Tinger R.	Diorite	Biotite	7.364 7.319	7.342	0.9040	44.3	6.9 ± 0.2
70-5997	7052 0055	Head of Bun River	Diorite	Hornblende	1.031 1.018	1.025	0.0891	34.0	4.88 ± 0.11
STAR MOUNTAINS INTRUSIVES, TIFALMIN AREA:									
72-205		Futik Pad 43	Quartz diorite	Whole rock	1.418 1.401	1.410	0.3028	52.9	12.0 ± 0.3
				Biotite	6.685 6.704	6.695	0.8479	59.8	7.1 ± 0.2
72-203		Futik DDH-1 (230'-253')	Hornblende Andesite dyke (weakly mineralized)	Whole rock	1.790 1.787	1.789	0.1387	43.4	4.3 ± 0.1
72-206	7152 1585	DDH-3 (370'-470')	Mineralized quartz diorite	Whole rock	1.682 1.682	1.682	0.1183	42.1	3.9 ± 0.1
72-207	22	Rattatat River	Mineralized quartz diorite	Whole rock	1.638 1.645	1.642	0.1348	66.7	4.6 ± 0.1
72-208		Olgal R., DDH-4 (160'-250')	Mineralized microgranodiorite	Whole rock	3.488 3.485	3.487	0.2110	64.5	3.4 ± 0.1
72-204		Futik DDH-1 (825'-827')	Andesite tuff	Hornblende	1.628 1.656	1.642	0.0474	22.7	1.6 ± 0.1
STAR MOUNTAIN INTRUSIVES, MT. ANJU AND MT. FREW AREAS:									
72-222	7152 1663	Mt. Anju	Hornblende andesite	Hornblende	1.557 1.565	1.561	0.0270	8.9	0.97 ± 0.06
72-221	7152 1661	Mt. Frew	Hornblende microdiorite	Hornblende	1.197 1.201	1.199	0.0513	18.7	2.40 ± 0.07
71-733	M.F. - 4	Mt. Frew	Hornblende microdiorite	Hornblende	1.133 1.123	1.128	0.0449	9.4	2.24 ± 0.22
71-735	M.F. - 6	Mt. Frew	Andesite porphyry	Plagioclase	0.400 0.402	0.401	0.0516	42.1	7.2 ± 0.2
TABE STOCK:									
7152 1274	7152 1274		Dacite porphyry	Hornblende*	0.351 0.352	0.352	0.0310	19.1	4.95 ± 0.25
7152 1288	7152 1288	West of Strickland R.	Dacite porphyry	Whole rock*	0.900 0.899	0.900	0.0327	41.8	2.04 ± 0.2
7152 2329	7152 2329		Dacite porphyry	Whole rock*	0.895 0.886	0.891	0.0234	36.6	1.48 ± 0.2
BOLIVIP STOCK:									
7152 1528	7152 1528	East of Bolivip	Dacite porphyry	Hornblende	0.668 0.670	0.669	0.0324	17.1	2.72 ± 0.2

* Six samples, K-Ar analyses by A.W. Webb, A.M.D.L., Adelaide

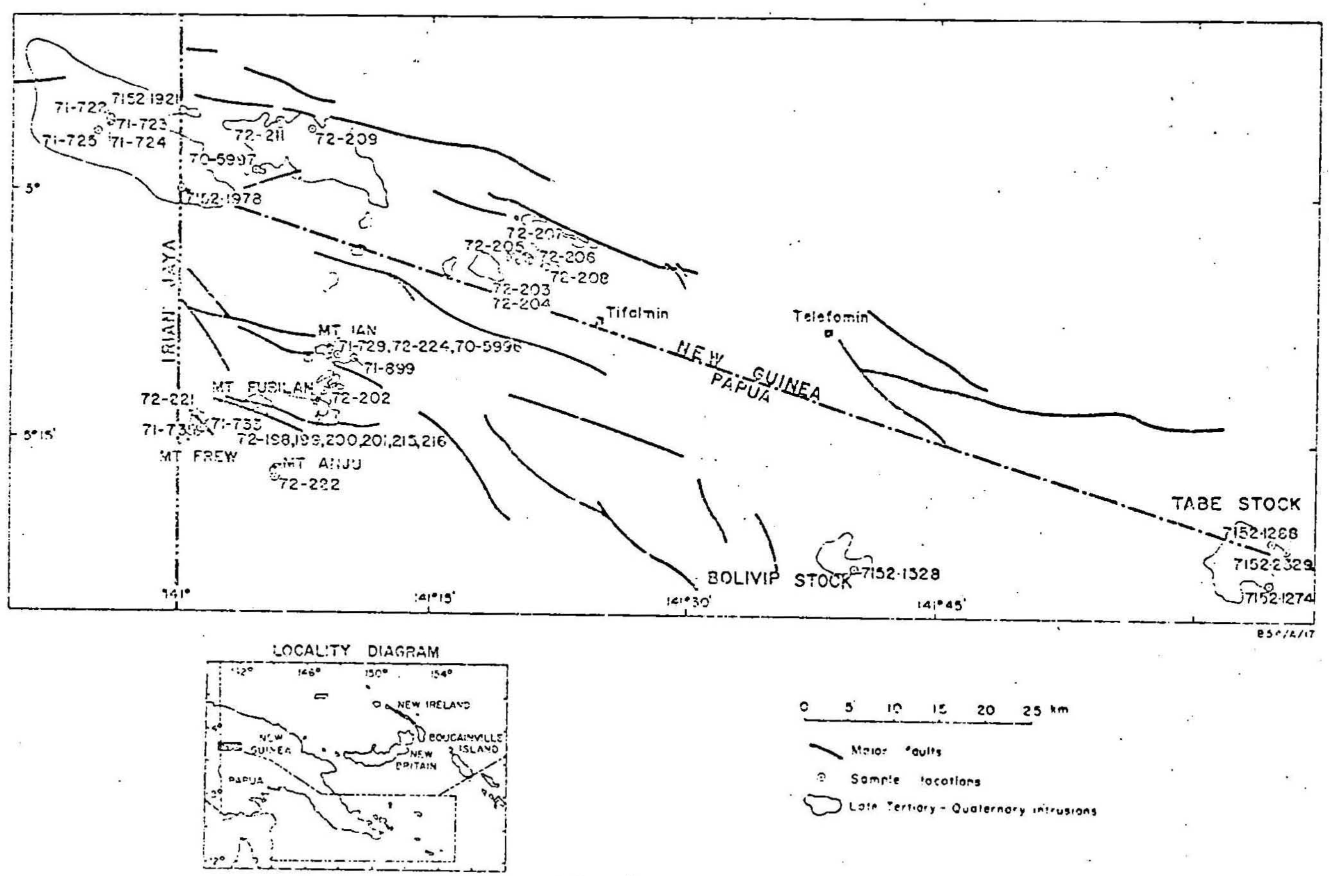
Table 2. Summary of K-Ar ages of intrusive porphyries in the Star Mountains.

Rock Unit, District	Emplacement Age of Igneous Rock in the same Intrusive Complex (m.y.)	Age of Mineralization m.y.	Epoch
Mount Fubilan Monzonites	2.6 ± 0.3	1.1 - 1.2	Pleistocene
Mount Ian Gabbro	1.9 ± 0.2		
Antares Monzonite	4.9 - 6.9	2.4 - 3.1	late Pliocene
Star Mountains Intrusives			
- Tifalmin	12.0, 1.6	3.4 - 4.6	mid-Pliocene
- Mt Anju	0.97		
- Mt Frew	2.3		
abe Stock	5.0		
Bolivip Stock	2.7		

FIGURE CAPTIONS

Figure 1 Locality map of the Star Mountains region showing the extent of late Tertiary and Quaternary intrusive rocks and localities of dated samples.

Figure 2 Histograms of ages of late Tertiary and Quaternary intrusions in the Star Mountains.



IRIAN JAYA
NEW GUINEA
PAPUA
Tifalmin
Telefomin
MT IAN
MT FUBILAN
MT FREW
MT ANJU
BOLIVIP STOCK
TABE STOCK
72-211
72-209
72-207
72-205
72-206
72-208
72-203
72-204
71-899
72-202
72-221
72-222
7152-1328
7152-1288
7152-2329
7152-1274
141°
141°15'
141°30'
141°45'
5°
5°15'
LOCALITY DIAGRAM
NEW IRELAND
BOUGAINVILLE ISLAND
NEW BRITAIN
NEW GUINEA
PAPUA
0 5 10 15 20 25 km
Major faults
Sample locations
Late Tertiary - Quaternary intrusions

Fig. 1

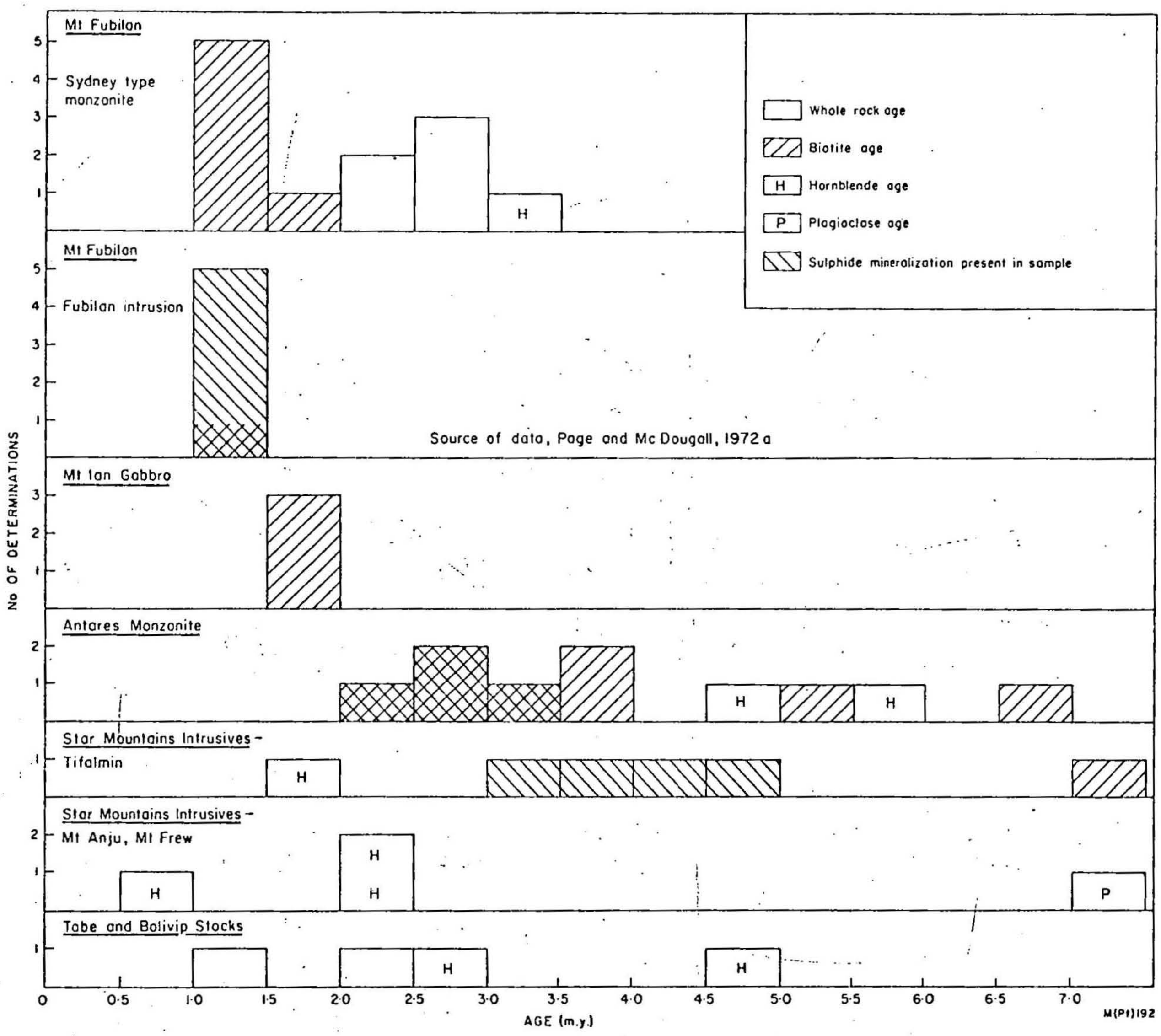

Mt Fubilan
Sydney type monzonite
Mt Fubilan
Fubilan intrusion
Whole rock age
Biotite age
Hornblende age
Plagioclase age
Sulphide mineralization present in sample
Source of data, Page and Mc Dougall, 1972 a
Mt Ian Gabbro
Antares Monzonite
Star Mountains Intrusives – Tifalmin
Star Mountains Intrusives – Mt Anju, Mt Frew
Tabe and Bolivip Stocks
No OF DETERMINATIONS
AGE (m.y.)
M(Pt)192

Fig. 2