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The pattern of K/Ar ages of biotites from the granites of Penang: its interpretation in the light of available Rb/Sr and U/Pb data

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Abstract: Available Rb/Sr whole-rock and zircon U/Pb data indicate that the granites of Penang Island were probably emplaced in the late Triassic between 22 Ma and 206 Ma. The results of K/Ar analysis of 31 biotite samples from the granites of Penang Island are presented.

A general decrease of apparent biotite ages in a south-south-easterly trend from 209 Ma to 160 Ma is evident. In the northern third of the island, the apparent biotite K/Ar ages of 209 Ma to 201 Ma are concordant with a published Rb/Sr isochron of 206 Ma. Apparent ages of 199 Ma to 179 Ma were measured from samples from the rest of the island except at the southeastern coast where 2 significantly younger ages of 170 Ma and 160 Ma were measured. This trend of younging apparent ages suggests rejuvenation on a regional scale.

INTRODUCTION

The island of Penang is situated just off the northwest coast of Peninsular Malaysia. Granites represent the only type of bedrock on the island, and these exhibit both textural and mineralogical variations. The geology of the island as outlined in Figure 1 is based on the work of J. Cobbing of the British Geological Survey and geologists of the Geological Survey of Malaysia, in particular, the work of W.S. Ong (1980).

The granites of Penang can be divided into two (2) plutons:-

(a) The southern half of the island, except for the southeastern protrusion is made up of a medium to coarse-grained muscovite-biotite granite. This pluton exhibits a faint foliation striking roughly north-south, outlined by crude, subparallel alignment of the K-feldspar megacrysts. In addition, mineral banding, also striking north-south is present occasionally.

(b) The northern half of Penang, including its southeastern toe and Pulau Jerejak is formed by the second pluton. Although this body shows considerable textural variations, two end members are distinguishable.

(i) In the northeastern portion and the southeastern toe of Penang, a coarse-grained megacrystic biotite-granite predominates. Similar exposures are seen along the southeastern cost of Pulau Jerejak. The distinctive texture of this so-called Bunga type as named by J. Cobbing is the linkage of large quartz globules in the groundmass to form chains.

(ii) The other end member is more restricted in distribution and crops out mainly in the northwestern part of Penang where it is represented by a medium to coarse-grained, sparsely megacrystic biotite-granite with traces of muscovite. This is referred to as the Ferringhi type by J. Cobbing, and differs from the Bunga type in that the quartz tend to form isolated grains within the groundmass.

Apart from these type localities, elsewhere on Penang and Pulau Jerejak, this pluton outcrops as a gradational type between the Bunga and Ferringghi end members. Microgranites of considerable areal extent are present in both plutons.

The influence of hydrothermal activity is widespread as is evident from the chloritisation of the biotites to varying degrees. Pneumatolysis, indicated by the presence of tourmaline is more localised. Structurally, two major trends of faulting have been noted, viz. north-south and northeast-southwest.

With regards to the relative ages of these two plutons, no clear evidence is available so far although previous workers in the area have suggested that the two-mica pluton in the south is the older of the two. The geological maps presented in Fig. 1, however, seems to indicate intrusion of the two-mica pluton into the Bunga/Ferringghi pluton, thus implying the latter to be the older.

PREVIOUS GEOCHRONOLOGICAL WORK

Bignell and Snelling (1977) included the Penang granites in their overall geochronological study of the Malayan granites. Analytical data for both K/Ar and Rb/Sr were presented for a total of fourteen samples from eleven localities on the island.

Two isochrons were defined from the Rb/Sr analyses, viz. (i) 294 ± 10 Ma, $R_i = 0.7105 \pm 0.0026$, and (ii) 206 ± 7 Ma, $R_i = 0.7088 \pm 0.0038$ (recalculated using the new constants recommended by Steiger and Jaeger, 1977). The older age was obtained from four whole rock samples from the southwestern block while the younger isochron was defined from three whole rock and mineral samples from the eastern block. The remaining Rb/Sr data plotted between these two isochrons, and were interpreted as indicative of either one or two intrusive events at about 252 Ma and 226 Ma or a younger intrusion at about 206 Ma characterised by high and variable ^{87}Sr : ^{86}Sr ratios ranging from 0.71 to 0.72.

Most of their K/Ar apparent ages on biotites and muscovites were grouped around 190 Ma. This observation was considered to further substantiate their views of an important intrusive episode during the Triassic/Jurassic period.

Besides the work of Bignell and Snelling, Liew (1983) included some U/Pb and Rb/Sr studies on granites for a PhD project at the National University of Australia, Canberra.

Two whole-rock samples were analysed for Rb/Sr and the zircons from these two samples were used for the U/Pb determinations.

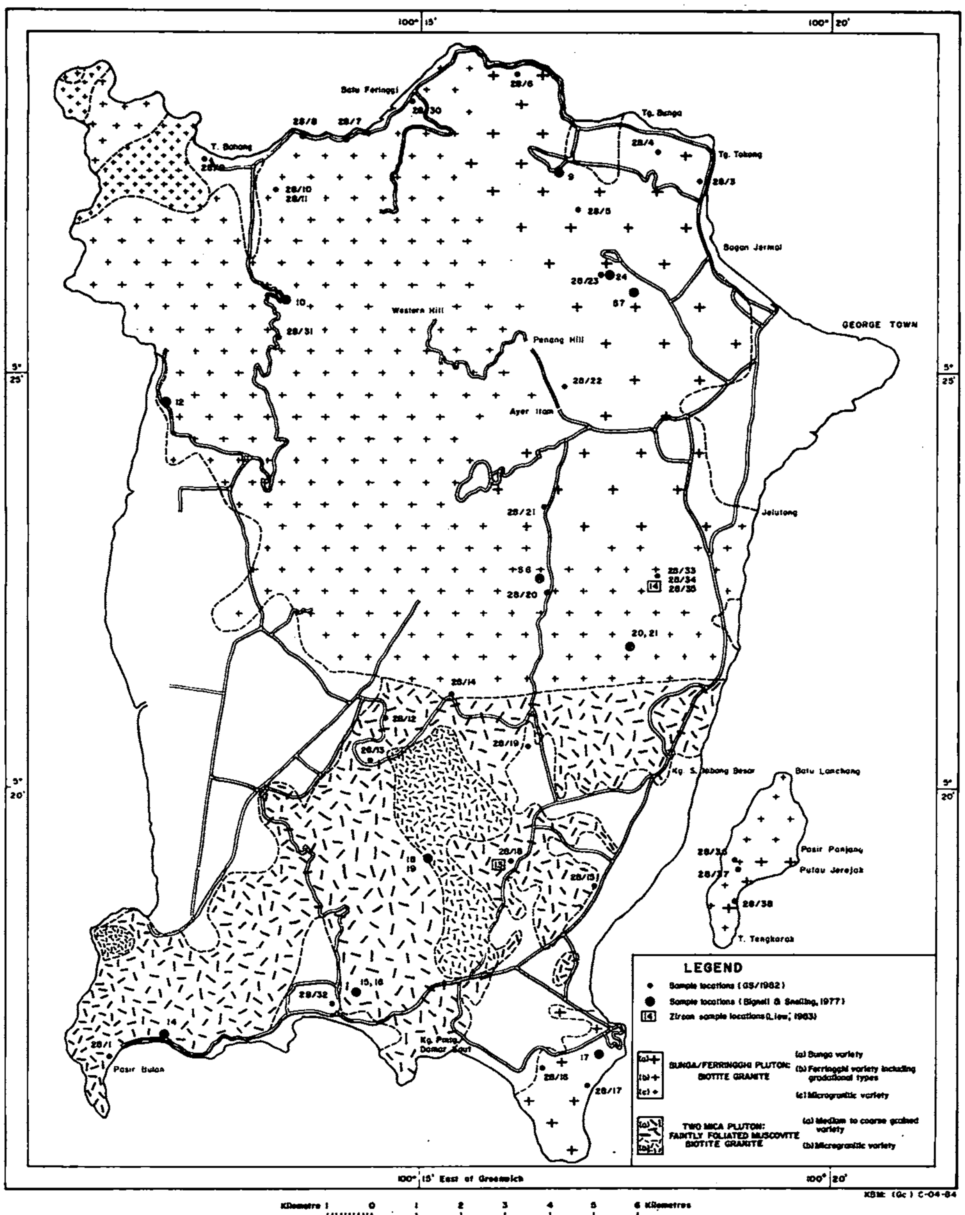

Fig. 1. Penang Island: Geologic Map and sample locations.

Liew's sample 13 plotted on Bignell and Snellings' older isochron of 294 Ma while his sample 14 plotted in between their two defined isochrons. The biotite fraction of sample 14 gave a Rb/Sr age of 190 ± 2 Ma based on an initial $^{87}Sr : ^{86}Sr$ ratio of 0.720.

His U/Pb results indicated reverse discordant patterns for both populations of zircons that may be attributed to old inherited zircon components. For sample 13, intercepts of the best straight line from four zircon points with the concordia curve yielded ages of $215 \pm {}^{5}_{6}$ Ma and 1560 ± 150 Ma. Conventionally, the lower intercept of $215 \pm {}^{5}_{6}$ Ma would suggest the time of zircon crystallization. A comparison of this lower intercept was made with a previous K/Ar age on the muscovite of Bignell and Snelling (196 ± 5 Ma), and Liew concluded that the emplacement of his Sg. Ara granite which is equivalent to our two-mica granite occurred sometime between 196 Ma and 215 Ma. He believed that the zircon system has not suffered any recent Pb loss on account of the observation that the U/Pb zircon age is of the same order but slightly older than the K/Ar muscovite age.

Both Pb loss and inheritance features were recognised from the U/Pb patterns of the zircons from sample 14. It was suggested that an emplacement age between 209 Ma (approximate concordant U/Pb age) and 222 Ma ($^{207}Pb/^{206}Pb$ age of the 2552 ppm U brown zircon fraction) be accepted from the data availabe for the Gelugor adamellite (equivalent to our gradational Bunga/Ferringhi type).

In summary, Liew's U/Pb zircon data have failed to support granite ages older than 222 Ma in Penang.

PRESENT WORK

For the present study, a total of thirty-one sample (30 kgs. each) were collected and conventional methods of sample treatment involving heavy liquids and magnetic separation were employed to obtain biotite concentrates. The 60 to 80 ASTM mesh size was selected for isotopic age determinations. Potassium analyses were carried out in duplicate using a Beckmann flame photometer (Purdy and Jaeger, 1976). The argon isotopic compositions were measured by the isotope dilution technique with a VG MM 1200 mass spectrometer operating in the static mode (Flisch, 1982), employing an enriched ^{38}Ar spike. K/Ar ages were computed using the IUGS recommended constants (Steiger and Jaeger, 1977). The error on the potassium determinations is about 1% while that for the K/Ar age computations is less than 1.5% at the 95% confidence level.

RESULTS

Table I summarises the K/Ar analytical results, and the areal distribution of the apparent biotite ages is shown in Figure 2.

The first striking feature in Figure 2 is a general decrease of apparent biotite ages in a south-southeasterly direction from 209 ± 2 Ma to 160 ± 2 Ma. This trend can be seen to transect all lithologic boundaries, thus suggesting influence of a regional nature. In the northern third of the island apparent ages of between 201 ± 2 Ma to 209 ± 2 Ma were measured, whereas lower values ranging from 191 ± 2 Ma to 199 ± 2

TABLE I

ANALYTICAL DATA AND K/AR BIOTITE AGES OF GRANITES FROM PENANG ISLAND, PENINSULAR MALAYSIA.

Sample No.	% K	ppm $^{40}Ar_{rad}$	% $^{40}Ar_{rad}$	Age in Ma (± 1σ)
BUNGA TYPE				
28/3	7.39	0.1106	96	204 ± 2
28/4	7.30	0.1091	95	204 ± 2
28/5	7.26	0.1074	97	202 ± 2
28/6	7.26	0.1075	97	202 ± 2
28/16	6.97	0.0864	97	170 ± 2
28/17	7.17	0.0832	94	160 ± 2
28/21	6.44	0.0861	95	183 ± 2
FERINGGHI TYPE				
28/7	6.75	0.1012	93	204 ± 2
28/8	6.37	0.0980	96	209 ± 2
28/9	6.52	0.0981	95	205 ± 2
28/10	5.99	0.0917	97	208 ± 2
28/11	6.24	0.0929	97	203 ± 2
BUNGA/FERINGGHI GRADATIONAL TYPE				
28/14	6.77	0.0949	96	192 ± 2
28/20	5.95	0.0861	93	197 ± 2
28/22	6.18	0.0912	96	201 ± 2
28/23	6.56	0.1005	94	208 ± 2
28/30	6.67	0.1019	97	208 ± 2
28/31	6.80	0.1014	96	203 ± 2
28/33	5.34	0.0705	94	181 ± 2
28/34	6.27	0.0902	96	196 ± 2
28/35	6.56	0.0837	95	175 ± 2
28/37A	6.57	0.0901	97	188 ± 2
28/37B	6.81	0.0890	96	179 ± 2
28/38	5.80	0.0759	90	179 ± 2
TWO-MICA TYPE				
28/1	7.35	0.1025	94	191 ± 2
28/12	6.52	0.0951	95	199 ± 2
28/13	4.60	0.0621	94	185 ± 2
28/15	7.17	0.0974	95	186 ± 2
28/18	5.74	0.0754	95	180 ± 2
28/19	6.58	0.0911	96	189 ± 2
28/32	6.95	0.0932	95	184 ± 2

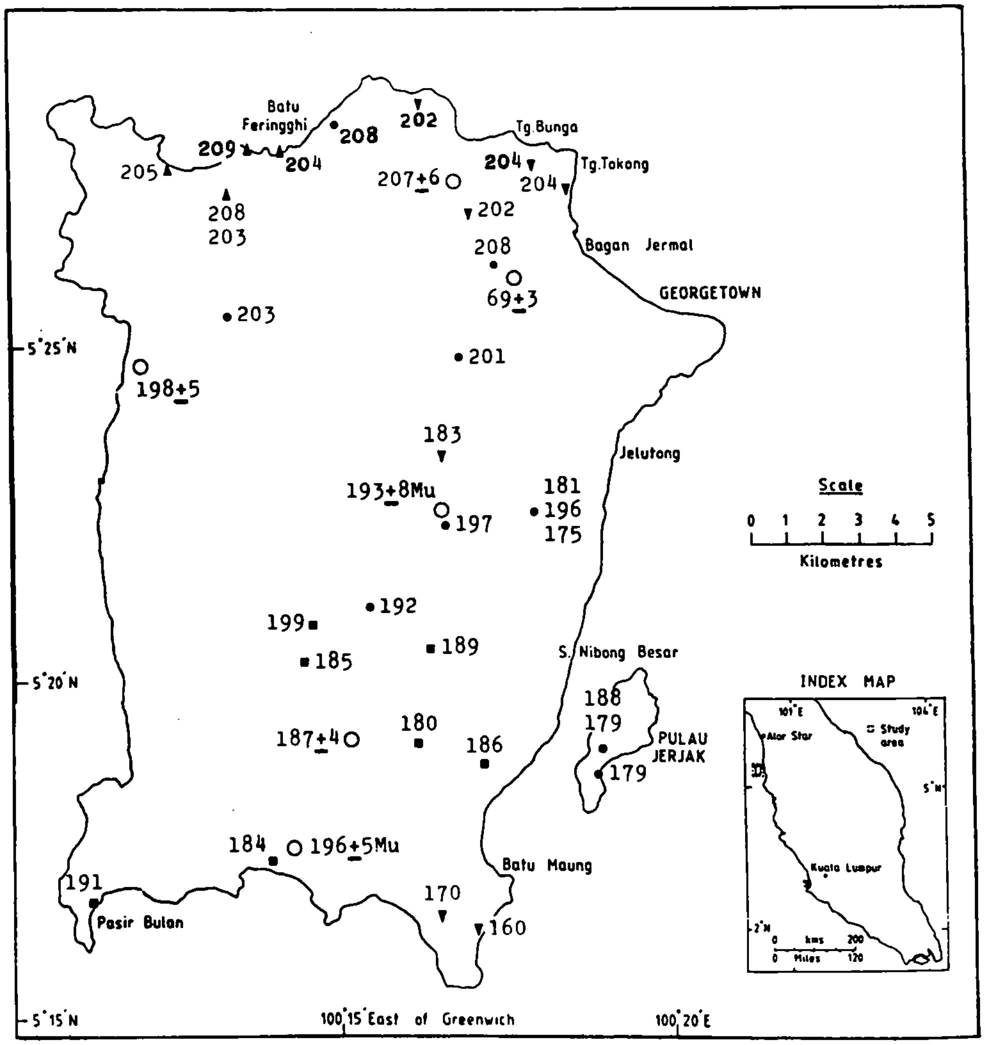

Fig. 2. Distribution map of K/Ar ages (in Ma) on micas. Filled inverted triangles = Bunga type; Filled upright triangles = Ferringghi type; Filled circles = Bunga/Ferringghi gradational type; Filled squares = two-mica granite; Open circles = ages from Bignell & Snelling, 1977 (recalculated using the new constants recommended by Steiger and Jaeger, 1977). Samples 28/11, 28/18, 28/33 and 28/37 A are finer grainer varieties. Mu denotes a muscovite age; all other ages are of biotites. Unless otherwise shown, the error in the age computation is ±2 Ma.

Ma were obtained in the middle third and the southwestern coast, except for sample 28/21 which gave an apparent age of 183 ± 2 Ma. Apparent ages for the remaining southeastern portion including Pulau Jerejak fall between 160 ± 2 Ma and 189 ± 2 Ma.

The K/Ar ages of biotites from this study generally agreed with those of Bignell and Snelling (recalculated using the new constants of Steiger and Jaeger, 1977) except for their anomalously young biotite age of 69 ± 3 Ma for sample S7. Comparing with their Rb/Sr results, concordant K/Ar biotite ages were encountered only in the northern part where they have defined a 206 ± 7 Ma isochron. However, no K/Ar biotite ages comparable to their older 294 ± 10 Ma isochron have been measured in the southern part of Penang.

Liew's U/Pb zircon age of sample 14 agreed with the K/Ar ages from the northern portion of the island, but no K/Ar ages comparable to his U/Pb zircon age of sample 13 have been determined so far for the southern pluton.

INTERPRETATION

Before attempting to interpretate the overall results, a few general observations merit mention:

(a) U/Pb ages on zircons would appear to be the most reliable data as this system of determination represents the most stable of the three methods applied to date in Penang. The two U/Pb zircon ages of Liew's study showed only a slight difference, thus suggesting very close events in time.

(b) In considering the rate of decrease of apparent K/Ar biotite ages, there seems to be an increase in a south-southeasterly direction.

(c) Comparing the apparent K/Ar ages of muscovites and biotites in Penang, it appears that the northern ages are in concordance whereas significant differences can be seen in the southern part of the island.

In interpreting the geochronological data available to date, the following two hypotheses have been considered:

(a) Hypothesis I:

This hypothesis presupposes the earlier emplacement of the northern Bunga/Feringghi pluton. Subsequent intrusion of the two-mica pluton in the south caused a rejuvenation in the K/Ar mica ages. A lateral thermal event which had its centre in the southeastern toe of Penang could have caused further disturbances which resulted in the pattern of distribution of apparent K/Ar mica ages seen presently.

However, this hypothesis could not explain the Rb/Sr data for the two-mica pluton in the southern part of Penang. Undoubtedly, the isochron defined by Bignell and Snelling here is reproducible as is evident from the Rb/Sr point of Liew's sample 13. Recent Rb/Sr work by the British Geological Survey on samples sent by the Geological Survey of Malaysia for geochemical assays have indicated isochrons comparable to that of Bignell and Snelling, viz. 265 Ma (personal communication, J. Cobbing). Although these samples are admittedly not specifically prepared for age-dating purposes, nevertheless, they do serve to provide an order of magnitude of the Rb/Sr age for this southern pluton.

This anomalously old Rb/Sr age could be attributed to inheritance arising from the assimilation of wall rock components rich in assimilation of wall rock components rich in radiogenic ^{87}Sr (Roddick and Compston, 1977). In addition, Brooks and Compston (1965), have documented the presence of high and non-uniform Sr initial ratios for a S-type granite in Tasmania. It is believed that this non-uniformity is the cause of the scatter in the whole-rock Rb/Sr plot such as that of Bignell and Snelling, thus invalidating the resulting isochron age.

Besides the anomalously old Rb/Sr isochron age, this hypothesis could also not explain the foliation observed in this supposedly younger pluton.

(b) Hypothesis II:

This hypothesis assumes the emplacement first of the southern two-mica pluton, and then the Bunga/Ferringghi pluton at about 209 Ma (Liew's U/Pb zircon age of sample 13 and the oldest K/Ar biotite age in the northern part) followed by a subsequent thermal event, centred around the south-eastern tip of Penang which was responsible for the resetting of the K/Ar mica systems leading to the present resultant pattern of apparent K/Ar ages.

To explain the older Rb/Sr isochron of 294 ± 10 Ma (Bignell and Snelling, 1977), it is necessary to further assume that either (i) the U/Pb zircon age of 215 Ma be considered as indicating a minimum age for the southern pluton, and that Pb loss has led to this apparently younger age, or (ii) the Rb/Sr isochron age be considered as anomalously old due to reasons discussed earlier. In the latter case, the age of the two-mica pluton would be in the region of $215 \pm ^{5}_{6}$ Ma.

In addition to this, in order to explain the juxtaposition of the two plutons, especially at the southeastern toe of Penang and on Pulau Jerejak, it would be necessary to postulate the existence of a dextral wrench fault.

CONCLUSION

To summarise, there is no evidence to date to support the validity of the Rb/Sr isochron age of 294 ± 10 Ma for the two-mica pluton. As such, we believe that this age is anomalously old.

The two intrusive events were very closely related to each other in time and probably occurred between the late Triassic and early Jurassic periods.

Until more data becomes available, we wish to keep our minds open without committing ourselves to favour any one of the two hypotheses presented here.

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