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ISOTOPE GEOCHRONOLOGY IN THE INDONESIAN TIN BELT

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ABSTRACT

Granitic rocks on Belitung (Billiton), Bangka and the Tuju islands (Pulau Tudjuh) have a Rb-Sr isochron age of 217 ± 5 Ma with initial ^{87}/Sr^{86}Sr = 0.7152 ± 0.0029 (15 whole-rocks and 4 biotites). K-Ar ages of four hornblendes and two biotites average 214 ± 4 Ma. The granitic complex on Karimata has a Rb-Sr isochron age of 74 ± 2 Ma with initial ^{87}Sr/^{86}Sr = 0.7101 ± 0.0025 (8 whole-rocks), while an associated amphibolite has a K-Ar age of 78 ± 5 Ma. (Rb-Sr ages based upon $d = 1.39 \times 10^{-11}$/a; errors at 95% confidence level.)

The granites have intruded into flysch-type sediments containing Norian fossils, while the regional stratigraphic and tectonic relationships strongly suggest that they are overlain by fossiliferous sediments of probably Rhaetian age. The age of 217 ± 5 Ma can thus be taken as the minimum age of the Norian, probably as representing the Norian/Rhaetian boundary. Cassiterite mineralisation is associated with both Upper Cretaceous and Upper Triassic granitic masses, but major tin deposits are related only to Upper Triassic plutons.

INTRODUCTION

Isotope geochronological investigations have been carried out on samples from plutonic complexes and associated volcanics on the islands of Karimata, Belitung (Billiton), Bangka and the Tuju islands (Pulau Tudjuh). The locations of the islands are shown in figure 1. The study was made in connection with off-shore tin exploration on the Indonesian part of the Sunda shelf between Sumatera (Sumatra) and Kalimantan (Indonesian Borneo), and its purpose was to obtain a better understanding regarding the genesis of tin mineralisation and the distribution of the tin deposits. A total of 26 rock samples, collected by one of the authors (E.H.B.) from ten different magmatic complexes, have been analysed (table 1). Six of the complexes are accompanied by rich tin deposits, while the other four show only traces of tin mineralisation.

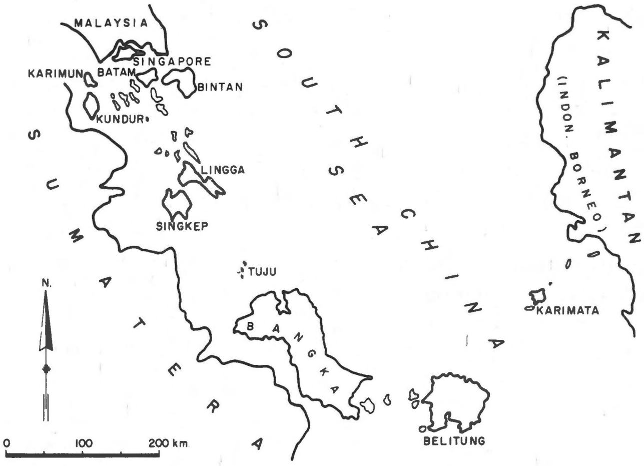

Fig. 1
The Indonesian part of the S.E. Asian tin belt and adjacent areas.

GEOLOGICAL SETTING AND PREVIOUS GEOCHRONOLOGICAL WORK

The Indonesian tin deposits belong to the major tin belt stretching through SE Asia from Burma through Thailand and West Malaysia to the islands of Bangka and Belitung in Indonesia. This belt is characterised by a range of plutonic bodies and associated volcanics. The strike of folding of the intruded sediments follows in general the main direction of the tin belt.

The geology of West Malaysia and Singapore has recently been the subject of a volume of papers edited by Gobbett & Hutchison (1973). As presently understood, the Malay Peninsula was the scene of marine geosynclinal sedimentation, plutonism and volcanism from Late Cambrian to Triassic times. Sedimentation was terminated in Upper Triassic time by a major orogenic episode during which granitic magmatism was wide-spread, resulting in high-level intrusions often associated with tin mineralisation. The Upper Triassic episode was succeeded by a regime of

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essentially continental conditions, particularly characterised by widespread molasse- type sediments in the Jurassic. In Late Cretaceous time minor granite bosses intruded at a high crustal level.

Singapore island is underlain mainly by sedimentary sequences belonging to the Jurong Formation. A twofold division can be made in this Formation, viz. the lower Gunong Pulai Member (flysch-type geosynclinal sediments and volcanics) and the upper Bukit Resam and Pasir Panjang Members (essentially late-tectonic molasse-type sediments). An Upper Triassic age is postulated for the Bukit Resam and Pasir Panjang Members from their fossil contents. These sediments are also correlated, on the basis of similar facies and lithology, with the lower part of the Tembeling Formation (Upper Triassic to Lower Cretaceous) of the central Malay Peninsula. The Gunong Pulai Member is intruded by a hornblende adamellite of which the biotite yields a K-Ar age of 224 ± 9 Ma (Bignell & Snelling, 1972), while the occurrence of granitic pebbles in a conglomerate from the Bukit Resam Member indicates that its deposition post-dates a phase of granite emplacement.

In Indonesia the tin belt continues from the Riau (Riouw) Archipelago via the islands of Lingga, Singkep and Tuju, to Bangka and Belitung. The geology of these islands has been the subject of local investigations by the "Dienst van het Mijnwezen in Nederlandsch Oost Indië" and by mining companies in connection with exploration for tin and bauxite.

In the Riau and Lingga archipelagoes (fig. 1) a weakly folded sedimentary sequence occurs, consisting of sandstones, shales and minor conglomerates (Bothé, 1928; Roggeveen, 1931; Adam, 1950), which apparently resembles the Pasir Panjang Member of Singapore island. The conglomerates contain occasionally pebbles of radiolarian chert and granite. This epicontinental or molasse facies sequence, which has E-W trending fold axes (T.T. Bartels, personal communication), was designated as the Bintan Formation by Jongmans (1951). On the basis of scarce fossils in shales on Lingga (Bothé, 1928) and in particular a fossil flora in shales on Bintan (Jongmans, 1951) an Upper Triassic, probably Rhaetian age is assigned to this Formation. Elsewhere the Riau and Lingga archipelagoes are occupied by a sequence of acid metavolcanics and phyllites, which differ tectonically from the Bintan Formation in being much more intensely folded and having a strike of folding following the main NW-SE trend of the tin belt. The volcanics can possibly be correlated with silicified quartz porphyries on SW Lingga. Local occurrences of metamorphic limestones and micaschists in the western part of the Riau Archipelago (Adam's "Oerformatie") are believed to belong to an older formation (Roggeveen, 1931; Adam, 1950). Granites are present on Batam, Bintan, Karimun and Kundur. On the former two islands the granites have been interpreted by Adam and Bothé as being intrusive into the sequence of acid metavolcanics and phyllites. There is no direct field evidence regarding the relations between the granites and the Bintan Formation (L.J. Fick, personal communication).

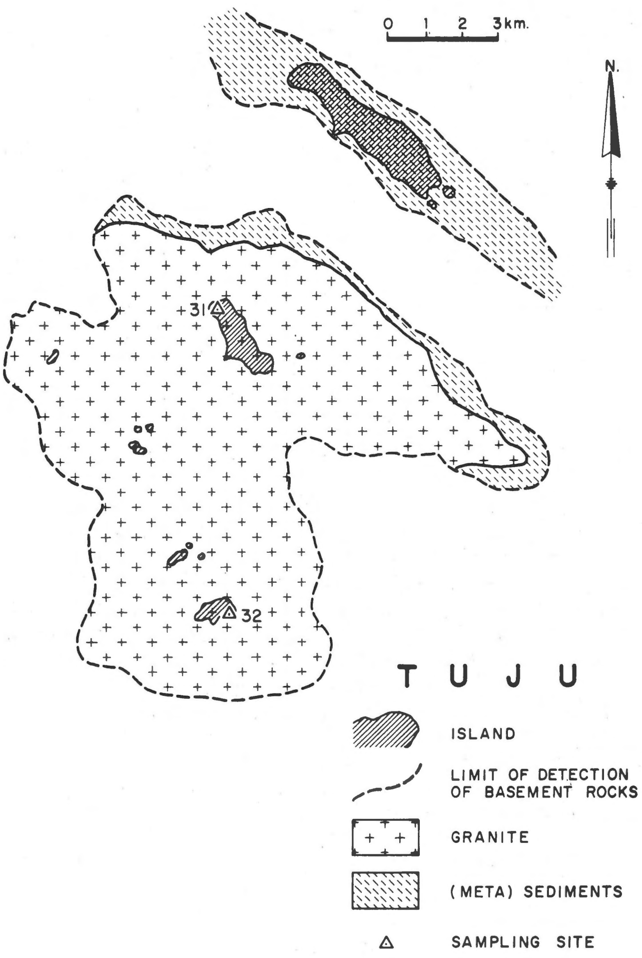

Fig. 2
Geological sketch map of the Tuju Archipelago, based upon submarine acoustic profiling and drilling, showing the locations of the analysed samples.

Singkep (fig. 1) is essentially made up of an intrusive granite surrounded by contact-metamorphic sediments, mainly micaschists and shales of unknown age (Wilhelm, 1928). Isotopic age determinations on xenotime, monazite and zircon separated from the Singkep granite yielded highly discordant U-Th-Pb ages, between about 100 Ma and 300 Ma (Schürmann et al., 1956, 1960). Edwards & McLaughlin (1965) concluded that the monazites from the granite approximate 220 Ma, the xenotimes 205 Ma, and the zircons 195 Ma.

The Tuju islands between Singkep and Bangka (fig. 2) constitute the uppermost peaks of a granite body about 10 × 15 km in size, largely covered by the sea. A ridge of gently folded sediments (mainly red sandstones with shales and a few conglomerate beds) is present on the island of Pekadjang near the northeastern margin of the granite. From

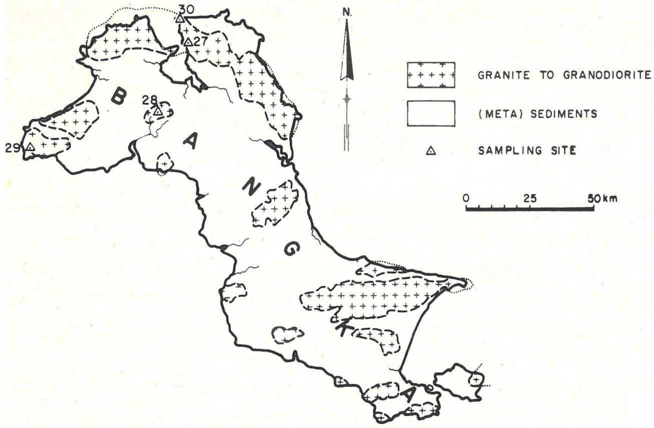

Fig. 3
Geological sketch map of Bangka (after Zwartkruis, 1962), showing the locations of the analysed samples.

their lithology and fossil flora (one of the authors, E.H.B., observed remnants of tree trunks similar to those described from Bintan and Sugi in the Riau Archipelago) these sediments may be correlated with the Bintan Formation. Core drillings have shown that micaschists occur close to the granite boundary, but it could not be ascertained whether they represent the contact-metamorphic Bintan Formation or some older sequence (Bon, 1969).

The greater part of Bangka (fig. 3) is occupied by a rather monotonous sequence of low-grade metamorphic sediments of geosynclinal flysch facies: predominantly shales and sandstones, and minor amounts of greywackes, limestones, chert layers with radiolaria, basic volcanics, and conglomerates (van Bemmelen, 1949, p. 315; de Roever, 1951). Among the conglomerates pebbles of an older granitic rock have been encountered (de Roever, 1951). Two fossil-bearing limestone lenses have been reported, one containing Permian fusulinids, the other containing fossils indicative of an Upper Triassic (Norian) age (Westerveld, 1936; de Neve & de Roever, 1947; de Roever, 1951). On the extreme northern promontory of the island (Tanjung Menkudu) one of the authors (E.H.B.) observed remnants of limonitized tree trunks in a sandy formation which, together with a strong similarity in lithology and the gentle character of the folding, makes correlation with the Bintan Formation very likely (Bon, 1970). The flysch-type sequence, on the other hand, is steeply folded in a number of irregularly plunging and rising synclines and anticlines (Katili, 1967); this difference in tectonic style indicates a tectonic break between both formations. The Permian to Norian flysch-type deposits have been intruded and contact-metamorphosed by granitic masses (van Bemmelen, 1949; Zwartkruis, 1962; de Roever, personal communication). The relationships of the granitic masses to the Bintan Formation cannot be ascertained.

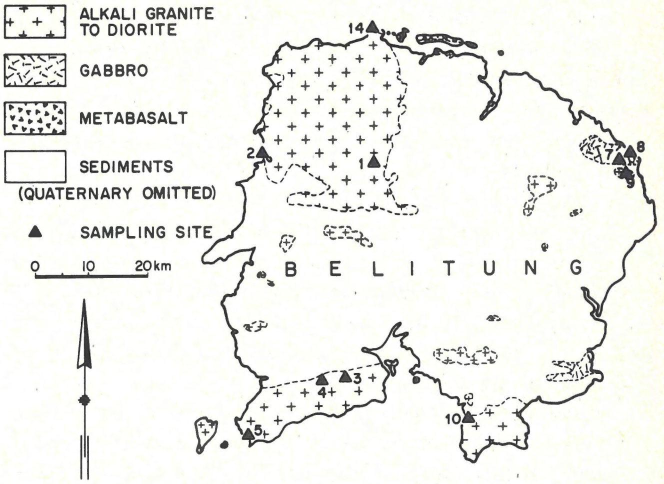

Fig. 4
Geological sketch map of Belitung (after van Overeem, 1960), showing the locations of the analysed samples.

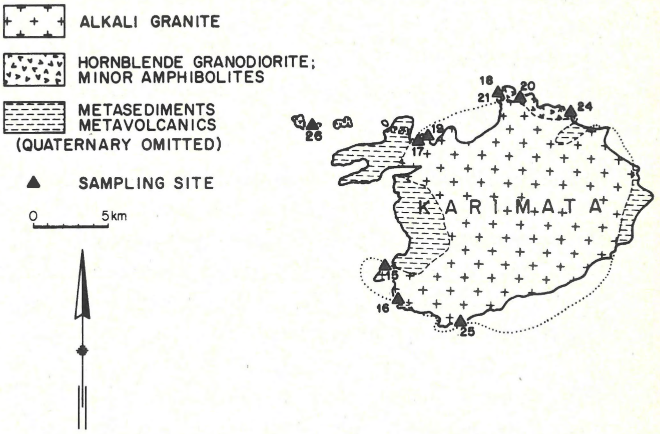

Fig. 5
Geological sketch map of Karimata (Bon, 1971), showing the locations of the analysed samples. The dotted line indicates the submarine extension of the alkali granite massif, based upon acoustic profiling and drilling.

On Belitung (fig. 4) the country rocks consist of a sedimentary sequence similar to the major flysch-type formation of Bangka. Scarce fossils indicate a doubtful Stephanian to Middle Permian age. This sequence has been intruded and contact-metamorphosed by granitic to dioritic and gabbroic masses (Aleva, 1960; van Overeem, 1960). Previous age determinations on a granite sample from the Tanjung Pandang massif in NW Belitung gave biotite K-Ar and Rb-Sr ages of 182 ± 5 Ma and 213 ± 6 Ma, respectively, and a K-feldspar Rb-Sr age of 217 ± 7 Ma (Edwards & McLaughlin, 1965; the Rb-Sr ages are recalculated with the decay constants used in this paper).

The main island of the Karimata Archipelago (fig. 5) consists of a large body of alkali granite with minor amounts of granodiorite, amphibolite and rhyolite. This granitic complex is surrounded by a contact-metamorphic zone of hornfelses and quartzites. The metamorphic rocks are believed to represent the equivalents of sedimentary rocks on the neighbouring smaller islands, which are correlated with the Bintan Formation on the basis of the strong resemblance in lithology (Bon, 1971). This would indicate that the Karimata granite is younger than the Bintan Formation.

Summarising, it may be concluded from the available data that the country rocks in the Indonesian tin province can be divided into three groups:

1. Micaschists and metamorphic limestones in the western part of the Riau Archipelago, believed to represent a regional metamorphic series of Paleozoic age. The micaschists on Singkep, in Pulau Tuju and on Bangka may possibly be correlated with this series.
2. A thick, steeply folded sequence of low-grade metamorphic flysch-type sediments on Bangka and Belitung (Bangka Formation), spanning a time interval from the Permian (possibly the Upper Carboniferous) up to the Norian. Pebbles of granitic rock occur in conglomeratic layers, but this older granite is nowhere exposed in Indonesia. Possibly, the acid metavolcanics and phyllites in the Riau Archipelago and the silicified quartz porphyries on SW Lingga can be correlated with this sequence.
3. The Bintan Formation, a sequence of non-metamorphic, weakly folded sediments of epicontinental or molasse facies deposited in Upper Triassic, probably Rhaetian time. This Formation occupies parts of the Riau Archipelago, northeastern Lingga, Pulau Tuju, northern Bangka, and probably the Karimata Archipelago.

The plutonic masses evidently post-date the Bangka Formation (sequence of flysch-facies sediments on Bangka and Belitung, and the series of acid metavolcanics and phyllites in the Riau and Lingga archipelagoes). With the exception of Karimata, where the granite seems to be younger than the Bintan Formation, there is as yet nowhere any direct field evidence which reveals the relationship of the plutonic masses to the Bintan Formation. However, on the basis of the apparent tectonic break between the Bintan Formation and the older sequences of flysch-facies sediments and acid metavolcanics/phyllites, the epicontinental or molasse facies of the Bintan Formation, and its probable correlation with the Upper Triassic Pasir Panjang Member of the Jurong Formation on Singapore Island (Burton, 1973), it is believed that the Bintan Formation post-dates the main phase of plutonism except the emplacement of the Karimata granite. As a Rhaetian age can probably be assigned to the Bintan Formation and as it is clear from the relationships on Bangka that the magmatism is younger than the Norian, it seems probable that the plutonic bodies and associated volcanics, with the exception of the Karimata granitic complex, were emplaced in late Norian or early Rhaetian time.

THE PLUTONIC COMPLEXES AND ASSOCIATED TIN MINERALISATIONS

The only elaborate petrological study on the plutonic complexes in the Indonesian tin province so far carried out is that of Aleva (1960) on the Belitung complexes. According to this study the plutonic rocks occur as batholithic masses, stocks and dikes intrusive into the sedimentary sequence. Aleva recognised four main groups of plutonic rocks, viz. gabbroic, granodioritic, adamellitic and granitic. All these rocks have in common the wide-spread occurrence of strongly zoned plagioclase, with differences in the anorthite content between core and rim of as much as 70%. Moreover, there is a conspicuous hiatus in the zonation of the plagioclase crystals, the compositional range An_{75} to An_{45} being absent. Aleva also pointed to the peculiar texture of the more calcic rocks, the so-called "intersertal-oikocrystalline texture", characterised by a network of early crystallised minerals (pyroxene, hornblende, zoned calcic plagioclase, and biotite) and a filling of the meshes with quartz and potassium feldspar.

In order to explain the hiatus in the zonation of the plagioclase crystals, Aleva invokes a mechanism of mixing of a partially crystalline gabbroic magma and a magma of granitic composition. After an initial stage of relatively rapid cooling and partial solidification of the gabbroic magma, during which the normally zoned calcic cores of the plagioclase crystals developed, there was a mixing of the partially crystalline gabbroic magma with granitic magma, causing an abrupt change in the composition of the residual liquid part of the magma. The relatively rapid cooling and solidification of the magma, now having a much more acid composition, was then resumed. The "intersertal-oikocrystalline texture", being essentially a filling of the meshes between earlier crystallised gabbroic minerals by granitic components, may also be explained by this mechanism.

Most of the plutonic complexes in the area under investigation have a granitic composition (alkali granites, granites, granodiorites, and diorites), but the acidic to intermediate rocks are intimately associated locally with substantial amounts of gabbroic (basaltic) rocks. Both the Karimata granitic complex and the plutonic bodies on the western islands clearly intruded at a high crustal level. For the genesis of the granitic rocks the authors favour processes of fractional melting of continental crust, possibly along zones of high heat-flow from the mantle (cf. Bowden, 1970), and at least in part induced by heat from ascending basaltic magmas (cf. Blake et al., 1965; Berthelsen, 1970; Elders et al., 1972; Verschure & Bon, 1972). Regarding the genesis of the granitic masses in the Malaysian part of the tin belt, Hutchison (1973b) also concluded that processes of fractional melting of crustal rocks by ascending mafic magmas have played a role, thus explaining phenomena of back-veining in the gabbroic rocks and the presence of mafic enclaves in granitic rocks, showing all stages of assimilation. Similar phenomena have also been observed in plutonic complexes on the Indonesian tin islands. A process of hybridisation of an already partially crystallised gabbroic magma with a granitic magma as postulated by Aleva (1960) for he plutonic complexes on Belitung, could be explained by effective mixing of a gabbroic magma with its contact-anatectic products.

Cassiterite mineralisation occurs in greisens and veins within most of the granitic masses, especially close to the contacts. On Bangka there is also widespread tin mineralisation in the contact-aureoles surrounding the granites, in veins and as impregnations in the country rocks; the aureoles have a width of 1.5 to 2.5 km (Westerveld, 1941; Cissarz & Baum, 1960). The country rocks on Belitung are locally intensely veined with quartz and magnetite-cassiterite veins (Aleva, 1960; van Overeem, 1960). Although a few primary occurrences are being worked, most exploitable cassiterite deposits in the Indonesian tin province are eluvial and/or alluvial, formed by secondary enrichment as the result of deep chemical weathering followed by elutriation (Krol, 1960; van Overeem, 1960; Aleva et al., 1973). Granites devoid of important tin deposits still show minor cassiterite mineralisation; this applies both to the sterile granites within the tin province sensu stricto and to the Karimata granite.

EXPERIMENTAL PROCEDURES

Splits of crushed and pulverised whole-rock samples were analysed for their Rb and Sr contents and Rb/Sr ratios by X-ray fluorescence spectrometry, or by standard isotope dilution techniques (employing calibrated spikes enriched in ^{87}Rb and ^{84}Sr, respectively), or by both methods. The separated biotites were measured by isotope dilution only. A Philips PW 1450/AHP automatic hardware programmed X-ray spectrometer was used, equipped with a 2.7 kW Mo X-ray tube and a LiF (200) analysing crystal. The samples were measured as pressed-powder pellets. Mass absorption corrections for both sample and external standard were based upon the total intensity of the Compton scattering of the Mo Kα primary beam. The isotope measurements were made on a 20 cm, 60° Nier-type mass-spectrometer with digital output, utilising thermal ionisation and multiplier detection. The Sr ratios are normalised to ^{88}Sr/^{86}Sr = 8.3752 and adjusted to ^{87}Sr/^{86}Sr = 0.7081 in the Eimer & Amend SrCC$_3$ standard.

The Rb-Sr isochrons and the errors were computed by means of least-squares regression analyses as the best-fitted straight line through the ^{87}Sr/^{86}Sr-^{87}Rb/^{86}Sr data points, following the computation method of York (1966, 1967). To each pair of coordinates the relative weight was assigned based upon estimated relative errors of 0.2 percent and 1.0 percent for the measured ^{87}Sr/^{86}Sr and ^{87}Rb/^{86}Sr ratios, respectively. The error for the isochron ages and the initial ^{87}Sr/^{86}Sr ratios are quoted with 95 percent confidence limits as calculated from the analytical data.

Potassium was analysed by flame photometry with a lithium internal standard and a CsAl buffer. Argon was extracted in a bakeable glass vacuum apparatus and determined by standard isotope dilution techniques (using ^{38}Ar as a tracer) in a Reynolds-type glass mass-spectrometer; the measurements were made by the static method.

For the age calculations the following constants were used:

^{87} RB: $\lambda_e = 1.39 \times 10^{-11}$/a;
^{40} K : $\lambda_e = 5.85 \times 10^{-11}$/a,
$\lambda_\beta = 4.27 \times 10^{-10}$/a, and
abundance ^{40}K = 0.0118 percent total K.

Where necessary, ages quoted from other authors have been recalculated.

RESULTS AND DISCUSSION

The analysed samples and locations are listed in table 1. The Rb-Sr data are presented in table 2 and plotted in the ^{87}Sr/^{86}Sr-^{87}Rb/^{86}Sr diagram of figure 6. In table 3 the K-Ar data and calculated ages are given. From these results the following age data emerge:

(1) The plutonic masses of Belitung, Bangka and the Tuju Islands have a Rb-Sr isochron age (whole-rocks and biotites) of 217 ± 5 Ma with initial ^{87}Sr/^{86}Sr = 0.7152 ± 0.0029.

(2) Four biotites and two hornblendes from these masses have K-Ar ages averaging 214 ± 4 Ma.

(3) A diorite and an amphibolite from NE Belitung have (apparent) whole-rock K-Ar ages of 120 Ma and 180 Ma, respectively.

(4) The granitic complex of Karimata has a Rb-Sr isochron age (whole-rocks) of 74 ± 2 Ma with initial ^{87}Sr/^{86}Sr = 0.7101 ± 0.0025.

(5) An amphibolite associated with the granitic complex on Karimata has a whole-rock K-Ar age of 78 ± 5 Ma.

So far, very few reliable isotopic dates are available in the Triassic and Jurassic for rocks that are well defined stratigraphically (see the discussion by Lambert, 1971). The base of the Triassic seems to be fairly well established at about 245 Ma, on the basis of the Rb-Sr isochron age of 231 ± 16 Ma determined for small granitic plutons cutting the Lower to Middle Triassic Broowena Formation in Queensland, Australia (Webb & McDougall, 1967). Other possibly relevant data quoted by Lambert are K-Ar measurements on igneous rocks from North Vietnam, indicating an age of 238 ± 20 Ma for intrusions of Upper Permian or Lower Triassic age, and an age of 210 ± 10 Ma for Upper Triassic (pre-Norian) intrusions (both ages based upon fairly old Russian data). Borsi & Ferrara (1967) measured a Rb-Sr isochron age of 243 ± 3 Ma for the reportedly post-Carnian Predazzo granite in the Dolomites, Italy, but such a high age for an Upper Triassic (or younger) granite is

TABLE 1
Analysed samples and locations*

Sample Nr.	Rock	Location
Belitung		
71 Bil 1	Porphyric two-mica alkali granite	Tanjung Pandan Massif, Kampong Tunkusan, N.W. Belitung
71 Bil 2	Two-mica alkali granite	Tanjung Pandan Massif, Tanjung Pandan, N.W. Belitung
71 Bil 3	Hornblende-biotite granodiorite	Beluru-Belitung Massif, Kampong Kundur, S.W. Belitung
71 Bil 4	Idem	Beluru-Belitung Massif, about 500 m W of Parang Buloh, S.W. Belitung
71 Bil 5	Idem	Beluru-Belitung Massif, on coast at Tanjung Kiras, S.W. Belitung
71 Bil 7	Idem	Burung Mandi Complex, on road about 2 km S of Tanjung Letang, N.E. Belitung
71 Bil 8	Hornblende-biotite diorite	Burung Mandi Complex, beach Tanjung Letang, N.E. Belitung
71 Bil 9A	Tourmaline-bearing porphyric greisen	Gunung Batu Besi Massif, Bukit Pantjur Batu, N.E. Belitung
71 Bil 9B	Porphyric two-mica alkali granite	Idem
71 Bil 10	Porphyric hornblende-biotite granite	Kelumpang-Batu Hitam Massif, Air Dukun, S.E. Belitung
71 Bil 14	Metabasalt (pillow lava)	Tanjung Siantu, N.W. Belitung
Karimata		
73 Bil 15	Alkali granite	Gunung Kalap, S.W. Karimata
73 Bil 16	Granophyric alkali granite	On coast of S.W. Karimata
73 Bil 18	Hornblende-biotite granodiorite	Tanjung Senna, N.Karimata
73 Bil 19	Alkali granite	Telok Lising, N. Karimata
73 Bil 20	Porphyric rhyolite	To the east of Tanjung Senna, N. Karimata
73 Bil 21	Amphibolite	Tanjung Senna, N. Karimata (same site as 73 Bil 18)
73 Bil 24	Hornblende-biotite granodiorite	Tanjung Nanka, N. Karimata
73 Bil 25	Tourmalinised alkali granite	Tanjung Dungu, S. Karimata
73 Bil 26	Hornblende-biotite granodiorite	Bulu Kecil, a small island NW of Karimata
Bangka		
73 Bil 27	Porphyric biotite granite	Mantung, N. Bangka
73 Bil 28	Hornblende-biotite granodiorite	Kelapa, N. Bangka
73 Bil 29	Tourmalinised porphyric two-mica granite	Mentok, N.W. Bangka
73 Bil 30	Porphyric biotite granite	Tanjung Penyusuk, N. Bangka
Pulau Tuju		
73 Bil 31	Granophyric alkali granite	Northwestern cape of the island of Cebia (Tjebia)
73 Bil 32	Biotite granite	Southeastern coast of the island of Penyaman.

* See also figures 2, 3, 4 and 5.

at odds with all other dates in the Triassic time-scale (see Lambert, 1971). Another interesting date is the Rb-Sr isochron age of 190 ± 9 Ma of a tuff from the Triassic Falla Formation in the Queen Alexandra Range, Antarctica, which Formation contains *Dicroidium odontopteroides* (Faure & Hill, 1973); this plant is known from Rhaetian sediments at several localities in Gondwanaland (Gothan & Weyland, 1953; Andrews, 1960).

The Rb-Sr isochron and K-Ar mineral ages of the plutonic masses on Belitung, Bangka and the Tuju Islands are in excellent agreement with each other. From the discussion of the geological setting it is clear that this plutonism is post-Norian and most probably pre-Rhaetian. The age of 217 ± 5 Ma can thus confidently be taken as the minimum age of the Norian, and probably as approximating the Norian/Rhaetian boundary. As follows from the foregoing discussion, this age fits in very well with the scarce reliable dates of the Triassic time-scale.

The Rb-Sr isochron age of the granitic complex on Karimata is likewise in very good agreement with the K-Ar age of an associated amphibolite, indicating an Upper Cretaceous age. Lambert (1971) considers ages of 72 Ma and 77 Ma as the best approximations for the bases of the Maestrichtian and the Campanian, respectively. The Rb-Sr isochron age of 74 ± 2 Ma thus places the emplacement of the Karimata granitic complex in the Campanian. Clearly, this plutonic mass forms part of the magmatic province of western Kalimantan and western Serawak, characterised, according to Hutchison (1973a), by Late Cretaceous granites. For example, Haile & Bignell (1971) report K-Ar biotite ages of 84 ± 2 Ma and 73 ± 2 Ma for adamellites from the Tambelan and Bunguran Islands between Serawak and the Malay Peninsula.

The K-Ar whole-rock dates of 120 Ma and 181 Ma observed on NE Belitung (a diorite and an amphibolite, respectively) are believed to have no geochronological significance, possibly reflecting partial resetting of the K-Ar clocks due to a weak thermal event induced by the Upper Cretaceous plutonism east of the tin province sensu stricto. The slightly too young K-Ar age of 182 ± 5 Ma reported for a

TABLE 2
Rb-Sr whole-rock and biotite data.

Sample Nr.[1]	$^{87}Sr/^{86}Sr$[2]	Rb/Sr[3] (Wt/Wt)	Rb (ppm Wt)		Sr (ppm Wt)		$^{87}Rb/^{86}Sr$	
			XR[3]	ID[4]	XR[3]	ID[4]	XR[3]	ID[4]
Belitung								
71 Bil 1	0.7798*	7.542	441		58.5		22.0	
71 Bil 2	0.7805*	7.702	374		48.6		22.5	
71 Bil 3	0.7230*	1.131	250		221		3.28	
71 Bil 3 Bio	1.181*$^{+}$			645*		12.8*		153
71 Bil 4	0.7217*	0.9065	202		223		2.63	
71 Bil 4 Bio	1.043*$^{+}$			667*		17.8*		112
71 Bil 5	0.7186*	0.8297	198		239		2.41	
71 Bil 7	0.7224*	0.6643	114		172		1.93	
71 Bil 9A	8.394*$^{+}$		966	981*	1.50	1.90*	(3271)**	2620
71 Bil 9B	0.918^{+}		568			23.8		70.6***
71 Bil 10	0.7412*	3.203	288		89.8		9.31	
Karimata								
73 Bil 15	0.8658^{+}	53.79	571	572*	10.6	10.7	158	157
73 Bil 16	1.309^{+}	216.4	531	528	2.44	2.81	(677)**	577
73 Bil 18	0.7137*	0.6224	201		323		1.80	
73 Bil 19	0.7483	12.89	321		24.9		37.5	
73 Bil 20	0.7707*$^{+}$	19.41	281	285*	14.5	14.5*	58.7	57.3
73 Bil 24	0.7115	0.1985	118		592		0.575	
73 Bil 25	1.410*$^{+}$	241.4	592	597*	2.45	2.74*	(1187)**	675
73 Bil 26	0.7090*	0.2107	146		691		0.610	
Bangka								
73 Bil 27	0.7439*	3.074	369		120		8.94	
73 Bil 28	0.7351	1.270	221		174		3.69	
73 Bil 28 Bio	1.623^{+}			647		6.95		294
73 Bil 29	0.8532	14.66	621		42.4		43.1	
73 Bil 29 Bio	1.922^{+}			2056		17.1		390
73 Bil 30	0.7771	6.294	399		63.5		18.4	
Pulau Tuju								
73 Bil 31	0.8892*$^{+}$	20.36	469	466*	23.1	23.5*	60.1	58.5
73 Bil 32	0.7337*	2.610	324		124		7.58	

[1] Bio, biotite; all others, whole-rocks.

[2] Normalised to $^{88}Sr/^{86}Sr = 8.3752$ and adjusted to $^{87}Sr/^{86}Sr = 0.7081$ in the Eimer & Amend $SrCO_3$ standard. Analyses marked $^{+}$ were calculated from isotope dilution runs; all others represent direct measurements on unspiked samples.

[3] X-ray fluorescence spectrometry. Mean of duplicate analyses.

[4] Isotope dilution analysis.

* Mean of duplicate analyses.

** Not used for isochron calculation.

*** Combination of Rb X-ray fluorescence and Sr isotope dilution analysis.

biotite from granite on NW Belitung (Edwards & McLaughlin, 1965) could also be attributed to such a regional resetting. The western-most exposure of Upper Cretaceous igneous rocks is found on Karimata, some 125 km NE of Belitung, but it is quite conceivable that more plutonic bodies of Upper Cretaceous age are concealed beneath the sea between Karimata and Belitung.

The initial $^{87}Sr/^{86}Sr$ ratio of the Belitung/Bangka/Tuju plutonic suite is rather high (0.7152 ± 0.0029), indicating that the magmas were already enriched in radiogenic strontium at the time they crystallised. This enrichment supports a hypothesis regarding the genesis of the magmas involving partial melting of crustal material.

Finally, it may be noted that although important tin mineralisation seems to be restricted to granites of Upper Triassic age, there is also minor tin mineralisation in the Upper Cretaceous Karimata granite (Bon, 1971). Apparently, all granites generated in this crustal segment, whatever their age, are to a greater or less extent enriched in tin.

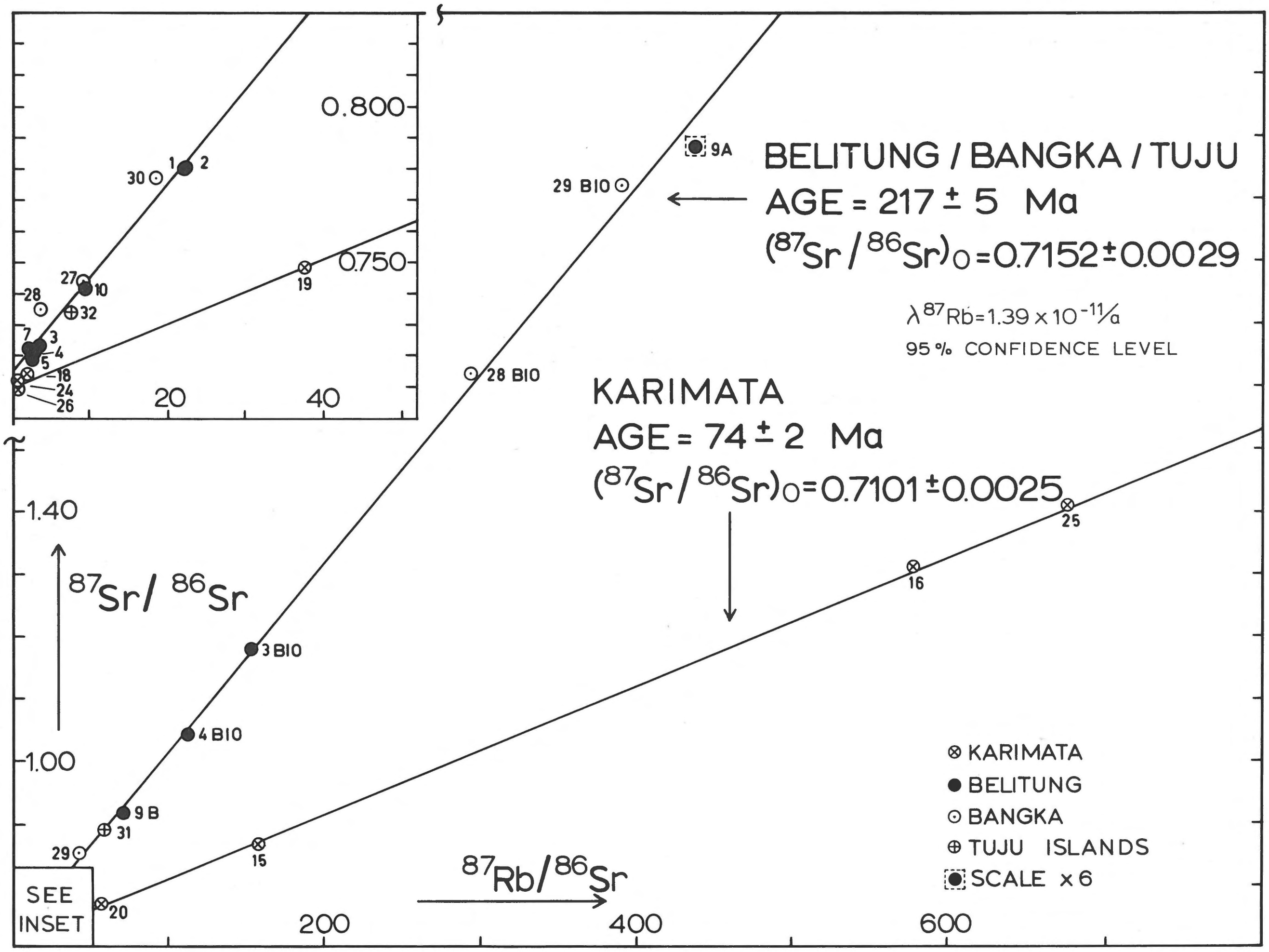

Fig. 6
Rb-Sr isochron plots of the Belitung/Bangka/Tuju and the Karimata granitic rocks. The numbers correspond to the sample numbers in table 1. Bio, biotite; all others, whole-rocks.

TABLE 3
K-Ar data.

Sample Nr.1)	K (% Wt)	Radiogenic ^{40}Ar (ppm Wt)2)	Age (Ma)
Belitung			
71 Bil 3 Bio	6.59*	0.105*	213 ± 10
71 Bil 3 Hbl	0.653*	0.0110***	224 ± 20
71 Bil 4 Bio	6.34*	0.101**	212 ± 10
71 Bil 4 Hbl	0.787*	0.0125*	213 ± 7
71 Bil 8 WR	1.06*	(9.2×10^{-3})*	120 ± 4
71 Bil 14 WR	0.419	(5.6×10^{-3})*	181 ± 5
Karimata			
73 Bil 21 WR	1.27*	(7.2×10^{-3})**	78 ± 5
Bangka			
73 Bil 28 Bio	6.60*	0.105**	213 ± 6
73 Bil 29 Bio	6.52*	0.103*	211 ± 10

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1) Bio, biotite; Hbl, hornblende; WR, sieve fraction whole-rock + 125-250 μm.

2) The concentration of atmospheric ^{40}Ar in the total amount of ^{40}Ar lies between about 5 and 10% for all analyses except 71 Bil 8 WR (17%), 71 Bil 14 WR (28%) and 73 Bil 21 WR (around 20%).

* Mean of duplicate analyses.

** Mean of triplicate analyses.

*** Mean of quadruplicate analyses.

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NOTE ADDED IN PROOF

Crinoid fragments and a relatively well preserved crown were recently discovered on eastern Belitung by Prof. K.F.G. Hosking (Universiti Malaya, Kuala Lumpur). According to Dr. H.L. Strimple (University of Iowa, personal communication) this crinoid can probably be attributed to the genus *Moscovicrinus*, indicative of an Upper Carboniferous age. This would provide the first definite proof of pre-Permian strata on Belitung.