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The granitoids and mineralization of the Eastern Belt of Peninsular Malaysia

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Abstract: The Malay Peninsula can be divided into three distinct mineral belts, viz. The Western Tin Belt, The Central Gold and Base Metal Belt, and the Eastern Tin Belt. The major granitoid bodies are concentrated in these belts, especially the Western and Eastern Belts.

The Eastern Belt extends from north Kelantan to the toe of the Peninsula. It is believed that the major components of these bodies were emplaced during Upper Carboniferous to Upper Jurassic times. The peak of the magmatic activity apparently coincides with the Upper Permian.

Granodiorite, adamellite, and granite represent the major components of the intrusives. Quartz diorites, which result from assimilation of country rocks by granitic magma, are particularly well developed along some border and roof zones of major intrusions. The granitic bodies are generally elongated in a north to northwesterly direction and parallel the regional strike of the country rocks. Locally, however, some parts of the intrusions trend in a northeasterly direction and exhibit discordant relationships with the invaded rocks. The major intrusives are thought to have been emplaced in the mesozone to epizone.

The granite-invaded sedimentary-volcanic country rocks are tightly folded and weakly to moderately regionally metamorphosed. Near the plutons the effects of contact metamorphism may be superimposed on those due to regional metamorphism. Joints and faults are common in the plutons; aplite, pegmatite, dolerite, and lamprophyre dykes are locally common and their emplacement is partly fault controlled.

The Eastern Belt is noted for its tin, tungsten, and iron mineralization. The mineralization is generally confined to the marginal and apical parts of the granitic intrusives, and fracture zones within the intrusives and contact aureoles. One of the unique characteristics of this belt is the development of the complex-tin-iron mineralization at Pelepah Kanan (Johore), Sungai Panching (Pahang), and Bukit Besi (Trengganu). The primary mineralization in the belt is spatially, and probably also genetically, related to the granitoids.

Alluvium derived from the Gambang Granite is significant for its relatively high contents of detrital xenotime.

INTRODUCTION

It was suggested by Scrivenor (1931) that structurally the Malay Peninsula consists of *en echelon* coulisses[1] of mountain ranges which are approximately parallel to the direction of elongation of the Peninsula. These coulisses, which consist mainly of granitoids, exhibit a clockwise rotation in their trend, swinging from northwest in the south to north near the Thai-Malaysian border (Fig. 1).

The granitoid bodies of Peninsular Malaysia are largely concentrated in a Western and Eastern Belt which are separated by a geologically very interesting but less prominent Central Belt. These granitoids display from near concordant and syntectonic to discordant and post-tectonic contact relationships.

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[1] A pattern resembling the wings of a theatre (a term introduced by Scrivenor in 1921).

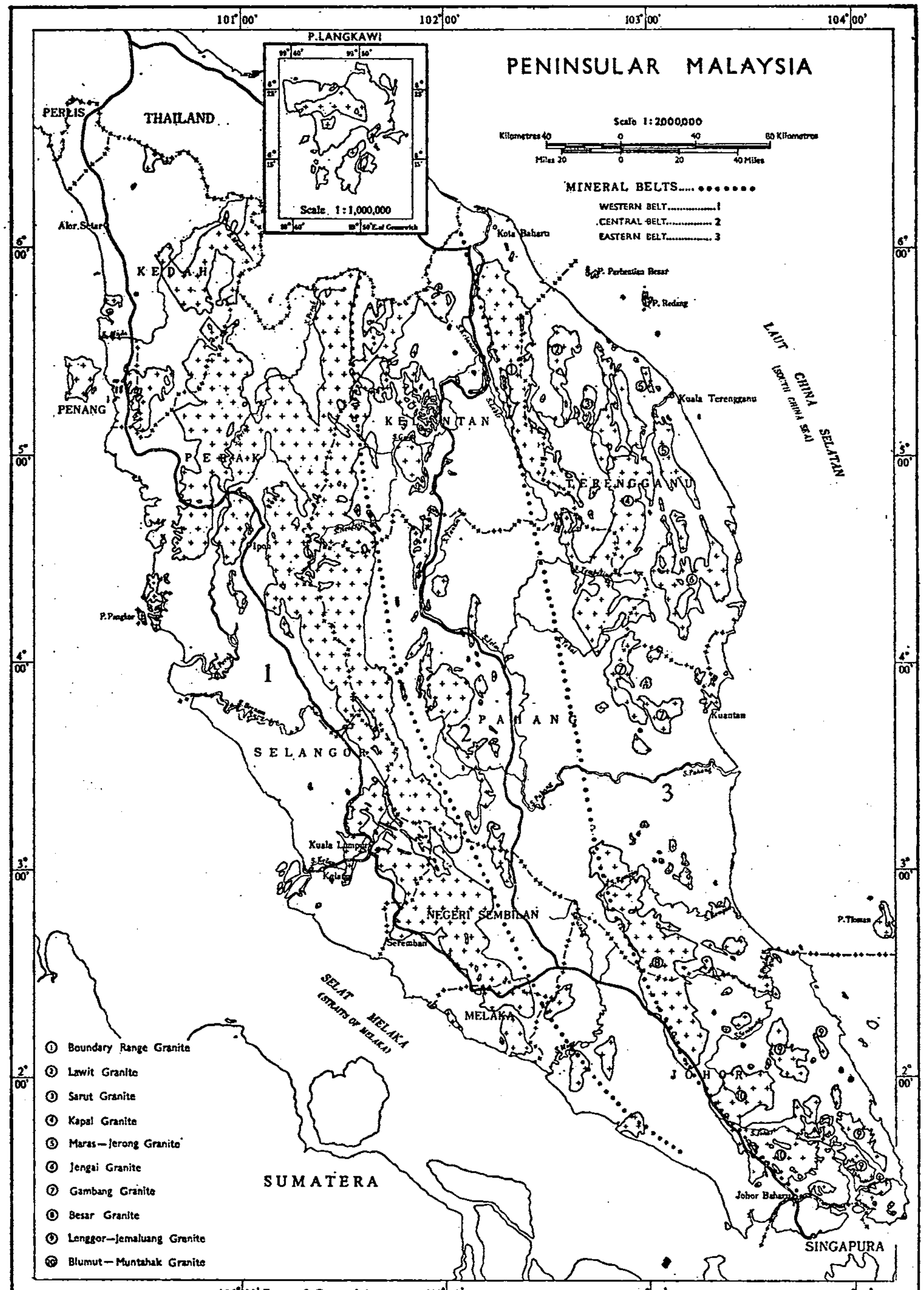


Fig. 1. Distribution of granitic bodies.

The granitoids of the Eastern Belt start in north Kelantan, about 19 km south of Kota Bahru, and trend southwards west of Gambang to the Johore Bahru - Kota Tinggi area at the toe of the Peninsula (Fig. 1). The southern limits of this belt, however, are not well defined. The belt is about 520 km long and its maximum width is 100 km.

In the vicinity of contact zones of the granitoid bodies effects of thermal metamorphism have been superimposed on the folded and weakly to moderately regionally metamorphosed sedimentary-volcanic rocks. Assimilation of these country rocks has taken place resulting in the formation of quartz diorites along the border and roof zones of some granitoid bodies. In places, the granitoids are cut by aplite, quartz, dolerite, pegmatite and lamprophyre dykes. Lamprophyres, in general, are ubiquitous in the northern parts of the belt.

The granitoid bodies of the Eastern Belt are cut by conspicuously parallel and subparallel joint sets in diverse orientations. Some of the sets are much weaker than others. At most localities, the joints appear to be part of a conjugate system of two or more sets. Faults and faulted contacts are common features of this belt, and some of these have been found to be favourable areas for mineralization. This belt is noted for its tin, tungsten and iron mineralization (Fig. 6). The mineralization generally occurs in and along the eastern fringes of the major granitoid outcrops. One of the important characteristics of this belt is the unique development of the complex tin-iron mineralization. The mineralization is thought to be related to the late phase acid granitoids which range in age from Upper Carboniferous to Upper Jurassic. No marked differences in contact features have been discerned between the older and younger granites.

DISTRIBUTION AND GENERAL CHARACTERISTICS OF GRANITOIDS

Granitic intrusives of the Eastern Belt underlie considerable parts of Kelantan, Trengganu, Pahang, and Johore (Fig. 1). They form discontinuous mountain ranges, which parallel the coast line. The area occupied by these granitoids is approximately 14,000 square kilometers. The major granitoid masses are roughly parallel to each other and trend north-northwest to north. The smaller satellitic masses are probably connected to the main bodies.

MacDonald (1967) and other geologists of the Geological Survey have attempted to name some of the major bodies, and some of these names have been updated. The distribution of the 10 major granitoid masses of this belt is shown in Figure 1. Only a general account on the distribution and characteristics of these masses is given here.

Boundary Range Granite

This granitic mass extends from the Kelantan alluvial plain in the north to about latitude 4° 50' N, near Gunong Gagau. This is one of the largest and most prominent granitic bodies and forms mountainous country along the Trengganu – Kelantan boundary. This body is about 138 km long and has a maximum width of 20 km. It is bounded to the east and west largely by regionally and thermally metamorphosed Carboniferous and Permian sedimentary and volcanic rocks. In the southern part of the granitoid, roof pendants of these rocks are present. In similar areas quartz diorite and other hybrid rocks are common. A long narrow re-entrant of sedimentary rocks occurs along the western part of the granitoid.

MacDonald (1967) described this body as a granodiorite complex consisting of a number of compositional and textural variations. Significant differences in colour are known which range from the dark crimson granodiorite porphyries to granites and granodiorites displaying shades of pink, white and grey. Medium-grained microcline-microperthite-bearing granite, graphic granite, and medium-grained and sparsely porphyritic to porphyritic granodiorite, are also present.

The bulk of the Boundary Range granite consists of granodiorite and granite, the former being predominant. In the field it is difficult to differentiate these two types as all variations in composition and colour occur. Texturally, the medium-grained variety is predominant but variations between fine-grained and coarse-grained varieties are present. Their colour varies from grey to pink. Quartz, orthoclase, oligoclase/andesine, biotite and/or muscovite, and rare hornblende and pyroxene form the essential minerals. The Boundary Range granite has been referred to as the 'Hornblende Granite' of the Eastern Belt.

Microcline-microperthite-bearing granites are usually grey in colour, and in addition to quartz and perthite they contain plagioclase, biotite with zircon and apatite inclusions.

Numerous xenoliths occur in some parts of the granitoid but composition wise they are similar to quartz diorite. However, gradations from hornfels to quartz diorite have also been recorded. Quartz veins and lamprophyre dykes are common in the granitoid body.

Field relationships suggest that the granitoid/sediment contact is generally concordant, but minor variations have been noted where the granitoid truncates the sedimentary trend. Faulted contacts are also common.

Lawit Granite

The Lawit granite trends parallel to the Boundary Range granite and is separated from the latter by a septum of regionally as well as thermally metamorphosed sedimentary and volcanic sequence which is 9 to 19 km wide. The Lawit granite, which is wide at the northern end (maximum width of about 40 km), tapers towards the south to a width of about 1 km. The length of this granitoid is some 48 km and it has been named after Gunong Lawit (1518 m), the highest peak within the granitic mountain range. As in the case of the Boundary Range granite, roof pendants of sedimentary origin are present and they occupy the apical zones of the granitic body as well as the contact areas. Hybrid rocks have likewise been recorded.

The Lawit granite consists mainly of coarse-grained, non-porphyritic to porphyritic granodiorite. Quartz diorite, a marginal contaminated phase, occurs mainly at the northern margin where it crops out as a stock-like body. The quartz diorite is very similar to those associated with the Boundary Range granite.

The main rock type, granodiorite, is white-grey in colour with a mineral assemblage comprising mainly quartz, microperthite, plagioclase, and brown biotite. Where sparsely porphyritic the potash feldspar phenocrysts, usually orthoclase and less commonly microperthite, are white in colour and range from 1 cm to 5 cm in length.

Quartz occurring as small veins and irregular masses is common in this granitoid body. Two large quartz reefs are associated with the granite and intrusive into the sediments. One of the reefs forms a prominent ridge 45 m wide and 9 m high, and has been traced for nearly 1½ km. Aplite veins and dykes of lamprophyre are common in the granitoid body.

Metamorphic effects in the surrounding sediments as in the Boundary Range granite are of a low to medium grade. Thermal aureoles are usually limited and commonly consist of calc-silicate hornfels. However, in contrast to the Boundary Range granite, truncations of the sedimentary trend suggest that the Lawit granite is post-folding.

Sarut Granite

Of the major granitic bodies, the Sarut granite is one of the smallest, measuring 22 km long and 8 km wide. It is bounded to the north and south by the Nerus River and Trengganu River, respectively. This body is named after the highest peak in the range, Gunong Sarut (1228 m). Carboniferous sedimentary rocks form a re-entrant at the southern end of this granitoid where faulting has been observed. The regional sedimentary trend is truncated by this body; and the grade of metamorphism in the surrounding sediments is generally low.

The granitic rocks are coarse, equigranular, and composed essentially of quartz, orthoclase, albite, and biotite. Texture and composition vary similarly to those in the Boundary Range granite and the Lawit granite. Fairly large areas of microgranite, which are younger than the main granite, are also present in the body.

Kapal Granite

The Kapal granite, one of the largest granitic bodies in the Eastern Belt, extends from the Setiu River area in the north to Gunong Irong (1191 m) in the south. This body takes its name after Bukit Kapal (790 m) in the north but this hill is by no means the highest.

This pluton is about 161 km long, between 19 and 38 km wide, and has an arcuate trend varying from north-northeast to north-northwest. It splits and forms a narrow linear about 8 km wide extending from Bukit Keban in the south to Gunong Gagau in the north. This linear body, about 40 km long, could be the southerly extension of the Boundary Range granite whose continuity has been disrupted by younger overlying flat arenaceous rocks at Gunong Gagau. If so, then the Boundary Range granite and the Kapal granite merge at Bidai (579 m). Another feature noted is a narrow strip of Carboniferous sedimentary rocks (about 48 km long) extending from the Kuala Trengganu – Jerteh road in the north to just beyond the Trengganu River in the south.

The rocks of this pluton are essentially similar to the Boundary Range and Lawit granites. Contact relationships in the northern part of the body are variable, but the regional sedimentary trend is truncated. Towards the south, however, the trend is more conformable. The grade of metamorphism is low. Roof pendants and faulted contacts, along with quartz veins and lamprophyres, are common.

Maras/Jerong Granite

This granitoid, consisting of two disjointed bodies named after Bukit Maras (328 m) in the north and Bukit Jerong (353 m) in the south, is the most easterly of the granitic ranges in the Eastern Belt. These bodies are separated from the Kapal granite by Carboniferous sedimentary rocks ranging from 6 to 13 km in width. The relief in this area is generally low to moderate. The rocks of these masses are much alike those of the Kapal and Sarut granites. Small dykes of microgranite and quartz porphyry are fairly common and quartz veins abundant.

Jengai Granite

The Jengai granite forms a discontinuous 'U'-shaped body which is about 72 km long and 40 km wide. It trends southerly from Bukit Besi to Bukit Bundi.

The rocks of this pluton are variable in both texture and mineralogy, and in his detailed study Chand (in manuscript) subdivided the granitoids into four phases: the biotite-muscovite phase, the porphyritic phase, the biotite-hornblende phase, and the fine-grained phase.

The biotite-muscovite phase is medium-grained, non-porphyritic to sparsely porphyritic, and contains biotite and muscovite, either of which may predominate. It varies from light pinkish brown to light grey, depending on the amount of biotite present. In general the muscovite-rich variety is of granite composition, whereas the biotite-rich type is adamellitic to granodioritic.

The porphyritic phase varies in composition from an adamellite to granite proper. Its colour is variable and its texture, besides being porphyritic, is locally pegmatitic. Phenocrysts of perthitic microcline, up to 2 cm by 10 cm are set in a medium to coarse-grained groundmass. Quartz and plagioclase phenocrysts are present but rare. The groundmass consists of quartz microcline, orthoclase, plagioclase (oligoclase/andesine), and both primary and secondary biotite and muscovite.

The biotite-hornblende phase is grey, equigranular, granodioritic to adamellitic and commonly contains numerous xenoliths. In the field it is extremely difficult to differentiate the biotite-hornblende phase from the biotite-rich phase. They outcrop in close proximity and may be gradational into one another. Compositionally the hornblende-biotite phase is similar to the biotite-rich variety except for hornblende which constitutes up to not more than 5% of the rock.

The fine-grained phase forms small bodies, irregularly distributed within the Jengai granite. Some occur in marginal areas whereas others are in areas of intense fracturing. Texturally they are equigranular and the rock consists of quartz, microcline, plagioclase and biotite. Generally, muscovite and tourmaline are present suggesting that pneumatolytic activity has affected these rocks. Pyrite and topaz have also been recorded from such areas.

Quartz dioritic bodies at Bukit Kelip and Ulu Tembeling have also been observed.

The pluton contains roof pendants, which in places measure up to 6 km across and attain a maximum length of about 16 km. Xenoliths of various sizes are abundant. Associated with the pluton are numerous dykes which are mainly lamprophyres, aplites, dolerites and microdiorites.

Contact aureoles are generally narrow but where wider it is due to the suboutcropping of the granitic body as in the Bukit Lentor area. Pelitic hornfels and chiastolite slates are the most common rock types developed but quartzo-felspathic and calc-silicate hornfels are not uncommon.

The contacts of the pluton with the surrounding sediments are generally concordant. Only in areas of highly irregular granite margins does discordance occur. Faulting is widespread in this body.

Gambang Granite

The name Gambang granite has been given by the writers to the granite body tha occurs near the township of Gambang, which is well known for its tin mining activity. To the northwest lies its continuation which Lee (1974) has named the Berkelah granite. These two bodies are separated by about 1½ km–wide belt of Carboniferous sediments. Similar smaller bodies occur to the north of Gambang at Sungai Lembing, Bukit Paloh, and Kuantan.

Fitch (1952) and Lee (op cit) have recorded the presence of grey, non-pophyritic to porphyritic, biotite granitic phases. However, in view of their irregular distribution it is not possible to separate them.

These granitic bodies are usually grey and medium-grained, and the dominant minerals are quartz, orthoclase, plagioclase, and biotite. Where porphyritic, phenocrysts of orthoclase and less commonly quartz up to 5 cm in length have been recorded. In composition they are granodioritic, rarely adamellitic or dioritic. Hornblende is present in variable amounts.

Pink to light grey granite and adamellite form less dominant varieties. In places the granite have been greisenized.

Dykes of microgranite, aplite, quartz porphyry, and dolerite are common within the Gambang granite but they are usually narrow and of restricted length. Grade of metamorphism of the country rocks is similar to that found in aureoles associated with Kapal and Jengai granites.

Besar Granite

The Besar granite, named for exposures on Gunong Besar, a prominent 1036 m-high mountain, is one of the largest bodies in the Eastern Belt. This elongate pluton is about 127 km long, between 19 and 32 km wide, and trends northwest. The smaller, sub-parallel isolated bodies to the east of the pluton are probably contiguous with the main body.

The pluton is composed of a limited variety of granitic rock types. The most typical of these are medium-to coarse-grained, pink to greyish-pink rocks containing prominent pink feldspar phenocrysts. They range in composition from granite to adamellite and in places to granodiorite. The rock is usually moderately porphyritic with only local equigranular phases. As a general rule, the porphyritic phases are coarser than the eqiugranular varieties. The feldspars are orthoclase and plagioclase (oligoclase-andesine) in variable proportions. The chief ferromagnesian minerals commonly occurring together, are biotite and hornblende.

Though the main mass shows limited compositional variations, the characteristic rock type in the central portion of the pluton, particularly near Gunong Besar, is adamellite. Granite and some microgranite occur mainly in the northern part of the pluton, whereas granite is the main rock type in the southern part. Some of the smaller bodies tend to be granodioritic. Aplite, quartz porphyry, pegmatite, granophyre and quartz veins have been injected into the granitic body.

The intrusion of the granitoid caused mild thermal metamorphism of the country rocks. Xenoliths of sediments and volcanics are common and irregularly distributed throughout the body, and are not restricted to the contact zones. The western flank of the pluton is overlain by younger, nonconformable Triassic sediments. To the east it is flanked by older Permian sedimentary-volcanic rocks. The irregular eastern contact is repeatedly offset along west-northwest trending faults. Where not faulted the contact is irregular and lobed.

Lenggor/Jemaluang Granite

This granitoid consists of several disjointed bodies which trend northwesterly and intrude Permian volcanic-sedimentary rocks. The larger body, named after exposures in the Sungai Lenggor area, is about 35 km long and 16 km wide. The Jemaluang granite, named after the township of Jemaluang, consists of a number of irregular smaller bodies exposed east and southeast of the larger body towards the toe of the Peninsula. It is possible that several of these granitoid bodies may be only partly exposed, perhaps cusps of the larger mass. The relief where the bodies occur is generally low to moderate.

The texture of the Lenggor/Jemaluang granite body, varies from equigranular to strongly porphyritic and the grain size from fine to coarse. Predominant varieties are medium-grained and adamellitic, but areas of granite, granodiorite, granite porphyry, and subordinate quartz diorite as a marginal phase are also present, as well as younger injections of quartz veins, microgranite, granophyre, lamprophyre, dolerite, and aplite.

The granitic rocks are generally white-grey to grey, though pink and mesocratic and, in places, melanocratic varieties are not uncommon. The porphyritic types commonly contain pink as well as grey feldspar phenocrysts up to 3 cm or more in length. All the granitic rocks contain quartz, plagioclase (essentially oligoclase), K-feldspars in various proportions and biotite generally as the chief mafic mineral. In places subhedral hornblende crystals are also present in small amounts along with biotite.

The Lenggor/Jemaluang pluton commonly caused discordant contact aureoles in the Permian sediments to the east and west. Local xenoliths of biotite and quartz hornfels mostly represent partly assimilated sedimentary inclusions or granitized sediments. Most of the xenoliths are lenticular and where the granitic rocks are crowded with sedimentary xenoliths they pass into a strongly biotitic facies. The intermediate rocks are thought to have been derived from the assimilation of country rock and consequent basification of the pluton.

Faults within the granitic mass trend between west-northwest and north.

Blumut — Muntahak Granite

This batholithic mass is the largest of the granitic bodies in the southernmost part of the belt. It trends approximately northwest, and is named after two well-known peaks, Gunong Blumut (1010 m) in the north and Gunong Muntahak (634 m) towards the south. The mass intrudes volcanics and sedimentary rocks of Permian age east and northeast of the body.

The granitoids of this pluton have been described by Burton (1973) and other members of the Geological Survey. Marked variation in texture is exhibited by the granitoids. The rocks grade from fine to coarse-grained and range from slightly to strongly porphyritic. The bulk of the rock is medium to coarse-grained. The colour varies from pinkish-grey to speckled grey and to almost pink; evenly coloured rocks with light pink to pink feldspars and colourless to glassy quartz are also common.

Medium to coarse-grained, pinkish-grey biotite granite is the most abundant variety near Gunong Blumut. The granite, however, commonly grades to adamellite. A fairly large area south of the peak is underlain mainly by adamellite, which is rather coarse-grained, generally equigranular, and exhibits porphyritic texture in many places. The Gunong Muntahak area is underlain largely by fine to coarse-grained, grey and pink granite. In areas east of the peak granodiorite is present.

All the granitic rocks contain quartz, plagioclase, and K-feldspar. Plagioclase is largely albite to andesine in composition, though oligoclase predominates in the granite. K-feldspar is essentially orthoclase, which is generally perthitic, but microcline-microperthite is also present. Biotite is the chief mafic mineral. Hornblende is irregularly distributed, but usually not abundant.

Late intrusives and injections of quartz, feldspar, granite, and quartz-feldspar porphyrites, lamprophyre, microdiorite, micrograpite, aplite and quartz veins occur within the pluton.

The granitoid mass is generally concordant with the Permian sediments in the northeast. The contacts are parallel to the regional tectonic trend of the Peninsula. Cupolas and apophyses intrude the sediments. Xenoliths of hornfels, probably granitised sediments are generally circular to ovoid. The xenoliths are dark and generally exhibit fairly sharp contacts with the host rock. In places the contact between the granitoid and the adjoining sediments is a zone of mild hybridization. Permian sediments, altered by low-grade contact metamorphism, form fairly large roof pendants in the granitoids near Gunong Muntahak. Faulting is widespread, trending between west-northwest and north.

PETROCHEMISTRY

Chemical analyses of 26 granitoids of the Eastern Belt are presented together with their Niggli molecular norms is Table 1. The rocks range generally from granodiorite with about 65% SiO_2 to the predominant granite with about 75% SiO_2. The variation diagram (Fig. 2) shows that a large number of the analysed samples fall within a limited range of 73 to 77% SiO_2. Except for minor variations, the curves of the oxides appear regular. As SiO_2 increases Al_2O_3, CaO, and femic oxides ($FeO + Fe_2O_3 + MgO + MnO$) all decrease. K_2O increases regularly with SiO_2 to 73% SiO_2 and is nearly constant for higher SiO_2 valves. K_20 is nearly always more abundant than Na_20. The Na_20 valves have a considerable spread but the general trend is quite similar to K_2O. The alkali-lime index (Peacock, 1931) is 63.3, in the calcic range.

TABLE 1

CHEMICAL ANALYSES AND NIGGLI MOLECULAR NORMS OF GRANITOIDS OF THE EASTERN BELT OF PENINSULAR MALAYSIA

Weight Percentage

	1	2	3	4	5	6	7	8
SiO_2	67.50	66.24	73.46	76.02	71.86	76.50	68.42	77.64
Al_2O_3	15.20	14.48	14.81	12.03	14.26	12.62	10.19	11.34
Fe_2O_3	1.91	2.28	1.25	1.33	0.99	0.48	5.40	0.94
FeO	1.43	2.84	1.17	0.64	1.43	1.04	3.76	1.60
MgO	1.39	1.35	0.37	0.10	0.46	0.20	1.14	–
CaO	2.25	5.60	0.84	0.88	1.48	0.24	3.70	0.76
Na_2O	3.92	1.99	3.18	3.34	3.43	3.47	3.14	2.84
K_2O	4.79	2.80	4.10	4.31	4.65	4.65	2.91	4.52
H_2O^-	–	0.94	0.17	0.05	0.46	0.19	0.16	0.28
H_2O^+	–	0.36	0.55	0.49	0.03	0.41	0.50	0.36
TiO_2	0.69	0.50	0.32	0.24	0.30	0.07	0.43	Trace
P_2O_5	0.06	0.12	0.04	0.03	0.06	0.01	0.06	–
MnO	0.07	0.07	0.10	Trace	Trace	Trace	0.08	0.08
CO_2	0.03	0.40	0.08	0.08	0.08	0.04	0.14	–
	99.24	99.97	100.44	99.54	99.49	99.92	100.03	100.36

Niggli Molecular Norms

	1	2	3	4	5	6	7	8
Quartz	18.61	29.48	34.76	36.50	28.39	35.13	30.53	39.29
Orthoclase	28.57	17.18	24.64	26.15	28.02	28.00	17.89	27.32
Albite	35.54	18.56	29.04	30.80	31.41	31.75	29.34	26.09
Anorthite	9.83	23.18	3.46	3.76	6.57	0.89	5.33	3.11
Corundum	–	–	4.32	0.59	1.36	1.73	–	0.74
Magnetite	2.02	2.48	1.33	1.01	1.06	0.51	5.88	1.01
Ilmenite	0.97	0.72	0.45	0.34	0.43	0.10	0.62	–
Apatite	0.13	0.26	0.09	0.06	0.13	0.02	0.13	–
Calcite	0.08	1.05	0.21	0.21	0.21	0.10	0.37	–
Diopside	0.69	1.80	–	–	–	–	9.86	–
Hypersthene	3.57	5.28	1.70	0.28	2.42	1.76	–	1.99
Hematite	–	–	–	0.28	–	–	–	–

Rock	Granitoid Mass	Location	Specimen No.
1. Granite	Lenggor/Jemaluang	Pulau Tioman, Pahang	GS 012029
2. Granodiorite	Blumut-Muntahak	S. Panti, Johore	MR 170205/126
3. Granite porphyry	Blumut-Muntahak	Ulu Sedili, Johore	MR 097217/126
4. Biotite granite	Blumut-Muntahak	Ulu Sedili, Johore	MR 103254/126
5. Biotite granite	Blumut-Muntahak	Ulu Sedili, Johore	MR 259311/126
6. Granite	Blumut-Muntahak	Tengkil, Johore	125/35A
7. Granodiorite	Blumut-Muntahak	G. Blumut, Johore	125/1080
8. Alkali granite	Blumut-Muntakak	G. Blumut, Johore	011001

TABLE 1

CHEMICAL ANALYSES AND NIGGLI MOLECULAR NORMS OF GRANITOIDS OF THE EASTERN BELT OF PENINSULAR MALAYSIA (contd)

Weight Percentage	9	10	11	12	13	14	15	16	17
SiO_2	76.42	74.72	73.60	71.70	74.80	67.50	65.52	68.66	74.55
Al_2O_3	11.06	12.84	13.59	14.80	12.60	15.60	16.39	14.77	14.78
Fe_2O_3	0.60	0.39	0.79	0.60	0.69	0.45	0.80	0.84	0.58
FeO	2.37	1.58	1.86	2.78	1.11	3.91	3.02	3.30	1.35
MgO	Trace	0.62	0.32	Trace	0.11	0.53	2.10	1.10	0.45
CaO	0.52	1.09	0.85	1.01	1.12	2.74	4.68	3.02	0.38
Na_2O	3.62	3.31	3.40	3.14	3.75	3.02	3.35	2.39	2.97
K_2O	4.10	4.34	4.25	4.14	4.76	3.97	2.23	3.83	4.21
H_2O^-	0.22	0.17	0.20	0.26	0.09	0.28	(	(	(
							(0.95	(0.94	(0.73
H_2O^+	0.27	0.13	0.15	1.34	0.76	0.60	(	(	(
TiO_2	0.06	0.13	0.16	0.31	0.10	0.37	0.48	0.47	0.15
P_2O_5	0.05	0.04	0.50	0.07	Trace	0.17	0.12	0.16	0.19
MnO	0.03	0.15	0.04	0.07	0.02	0.09	0.05	0.03	0.03
CO_2	0.12	0.12	0.36	0.04	0.08	0.26	0.10	0.05	0.07
	99.44	99.63	100.07	100.26	99.99	99.49	99.79	99.56	100.44

Niggli Molecular Norms	9	10	11	12	13	14	15	16	17
Quartz	35.53	32.88	33.68	32.23	30.33	25.12	21.73	29.17	37.30
Orthoclase	24.91	26.13	25.69	25.69	28.61	24.12	13.41	23.39	25.30
Albite	33.43	30.29	31.01	29.05	34.29	27.88	30.61	22.18	27.13
Anorthite	1.54	4.47	–	4.43	3.55	11.15	22.19	14.08	0.20
Corundum	0.13	1.21	3.73	4.01	–	2.65	0.53	1.92	5.84
Magnetite	0.64	0.42	0.84	0.65	0.73	0.48	0.85	0.91	0.62
Ilmenite	0.09	0.18	0.23	0.44	0.14	0.53	0.68	0.68	0.21
Apatite	0.11	0.09	–	0.15	–	0.36	0.25	0.35	0.40
Calcite	0.31	0.31	0.92	0.10	0.21	0.68	0.26	0.13	0.18
Diopside	–	–	–	–	1.27	–	–	–	–
Hypersthene	3.31	4.02	3.10	3.67	0.82	7.02	9.49	7.19	2.82
Hematite	–	–	–	–	–	–	–	–	–

Rock	Granitoid Mass	Location	Specimen No.
9. Biotite granite	Blumut-Muntahak	G. Blumut, Johore	GS. No. 29869
10. Biotite granite	Blumut-Muntahak	Bukit Jengeli (West) Johore	GS. No. 30097/125/576
11. Biotite granite	Lenggor-Jemaluang	Bukit Lotong, Johore	GS. No. 30078/125/442A
12. Biotite granite	Lenggor-Jemaluang	Ulu Endau, Johore	013011
13. Biotite granite	Gambang	Bukit Ubi, Kuantan, Pahang	GS. No. 27421/65(a)
14. Biotite granite	Gambang	Sg. Linchong, Bukit Paloh Kuantan, Pahang	GS. No. 29858
15. Biotite granite	Jengai	Ulu Paka, Trengganu	GS. No. 30084
16. Biotite granite	Jengai	Ulu Paka, Trengganu	GS. No. 30083
17. Biotite granite	Jengai	Ulu Paka, Trengganu	GS. No. 30092

TABLE 1

CHEMICAL ANALYSES AND NIGGLI MOLECULAR NORMS OF GRANITOIDS OF THE EASTERN BELT OF PENINSULAR MALAYSIA (contd)

Weight Percentage

	18	19	20	21	22	23	24	25	26
SiO_2	76.13	67.60	75.54	76.14	75.78	73.70	63.70	76.70	76.20
Al_2O_3	12.79	15.00	12.13	13.02	13.28	13.30	15.30	12.20	12.80
Fe_2O_3	0.37	1.04	0.36	0.11	0.39	0.54	0.97	0.57	0.92
FeO	1.32	3.07	2.15	1.22	1.15	0.91	4.06	1.64	0.92
MgO	0.29	0.88	Trace	0.18	0.13	0.06	2.72	0.11	Trace
CaO	0.09	3.02	0.82	0.30	0.49	0.78	4.29	0.08	0.67
Na_2O	2.24	3.48	3.42	3.54	3.57	4.17	3.35	3.75	3.33
K_2O	5.23	3.95	4.26	4.56	4.56	5.12	2.90	3.71	4.66
H_2O^-	(	0.10	0.19	(	(	0.13	0.24	0.08	0.21
	(0.73			(0.66	(0.40				
H_2O^+	(	1.12	0.24	(	(	0.91	1.66	0.80	0.67
TiO_2	0.14	0.45	0.12	0.06	0.06	0.10	0.57	0.12	0.15
P_2O_5	0.15	0.12	0.07	0.01	0.02	Trace	0.15	0.08	0.03
MnO	0.03	0.09	0.05	Trace	Trace	0.05	0.10	0.06	0.01
CO_2	0.07	0.07	0.12	0.08	0.07	0.04	0.07	0.09	0.05
	99.58	99.99	99.47	99.88	99.90	99.81	100.08	99.99	100.62

Niggli Molecular Norms

	18	19	20	21	22	23	24	25	26
Quartz	39.98	21.88	34.80	34.53	33.68	26.29	14.01	37.49	35.52
Orthoclase	31.93	23.86	25.64	27.45	27.36	30.73	17.06	22.39	28.02
Albite	20.78	31.95	31.29	32.39	32.55	38.04	29.95	34.40	30.43
Anorthite	–	13.95	2.91	0.93	1.89	2.49	18.07	–	2.86
Corundum	3.88	–	0.94	2.14	1.99	–	–	2.25	1.39
Magnetite	0.40	1.11	1.45	0.11	0.41	0.57	1.01	0.61	0.98
Ilmenite	0.20	0.64	0.17	0.09	0.08	0.14	0.79	0.17	0.21
Apatite	–	0.26	0.15	0.02	0.04	–	0.31	–	0.06
Calcite	0.18	0.18	0.31	0.20	0.18	0.10	0.18	0.16	0.13
Diopside	–	0.09	–	–	–	0.95	1.36	–	–
Hypersthene	2.52	6.06	2.34	2.12	1.81	0.68	17.25	2.43	0.60
Hematite	–	–	–	–	–	–	–	–	–

Rock	Granitoid Mass	Location	Specimen No.
18. Biotite granite	Jengai	Ulu Paka, Trengganu	GS. No. 30093
19. Biotite granite	Jengai	Ulu Sg. Kemaman, Trengganu	GS. No. 27423/65(b)
20. Biotite granite	Maras-Jerong	24 ms. Trengganu-Jeranggau Rd. Trengganu.	29865
21. Biotite granite	Kapal	Ulu Paka, Trengganu.	GS 30080
22. Biotite granite	Kapal	Ulu Paka, Trengganu.	GS 30081
23. Biotite granite	Kapal	Kuala Brang, Trengganu	GS No. 27420/64(a)
24. Hornblende granodiorite	Boundary Range	G. Gagau, Pahang	GS No. 27437/65(1)
25. Sheared granite	Boundary Range	Ulu Sg. Rek, Kelantan	012038
26. Biotite granite	Boundary Range	Bt. Yong, Kelantan	GS 27065

Analyses by Geological Survey of Malaysia and norms computed per kindness of Dr. C.S. Hutchison, University of Malaya.

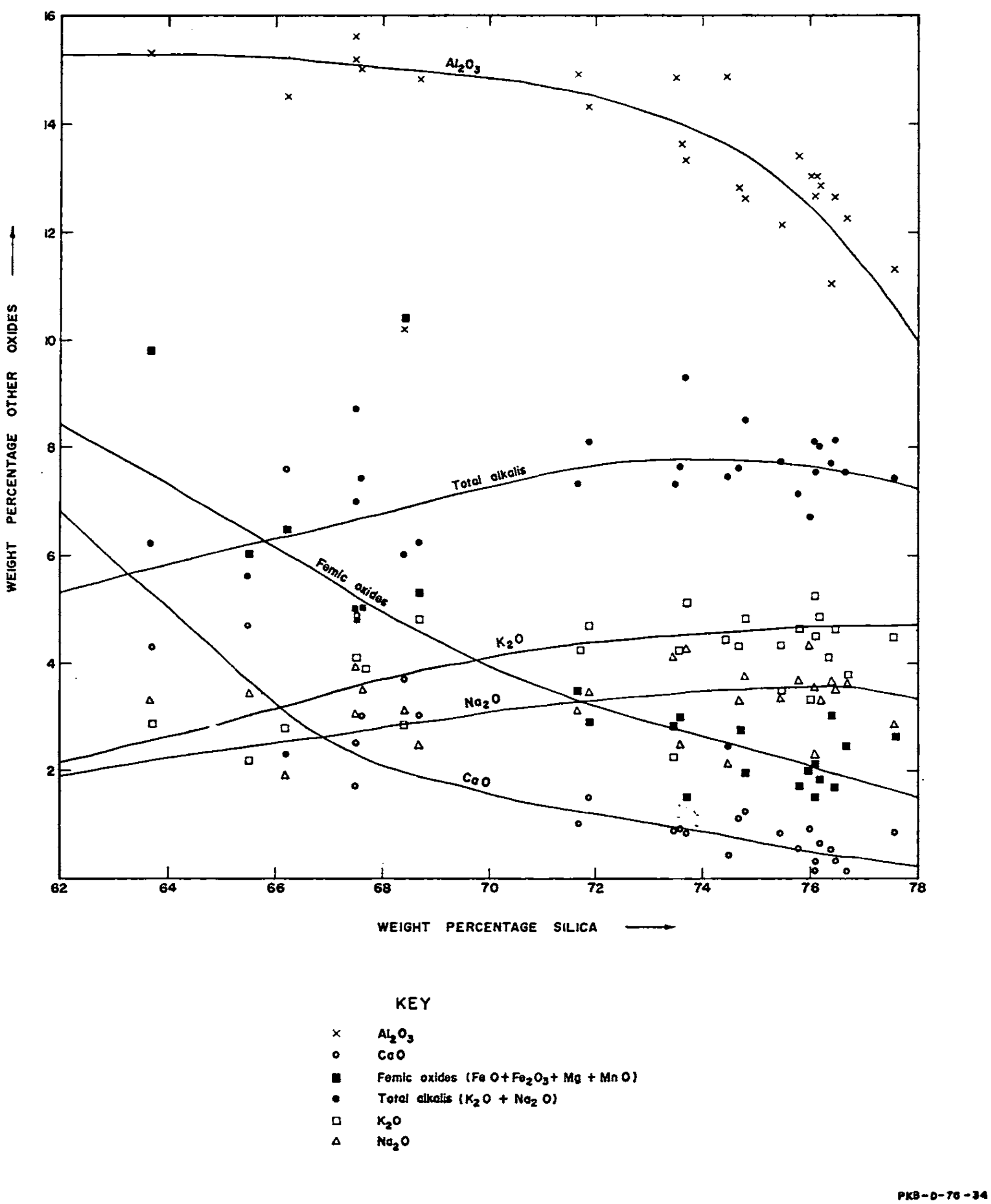
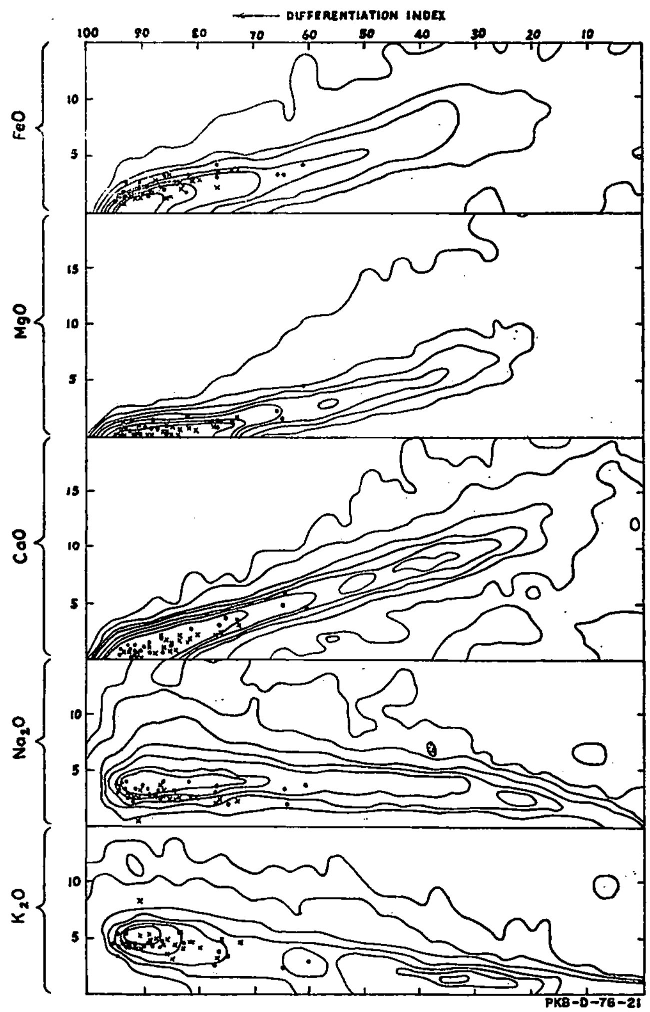


Fig. 2. Variation diagram for granitoids of the Eastern Belt.

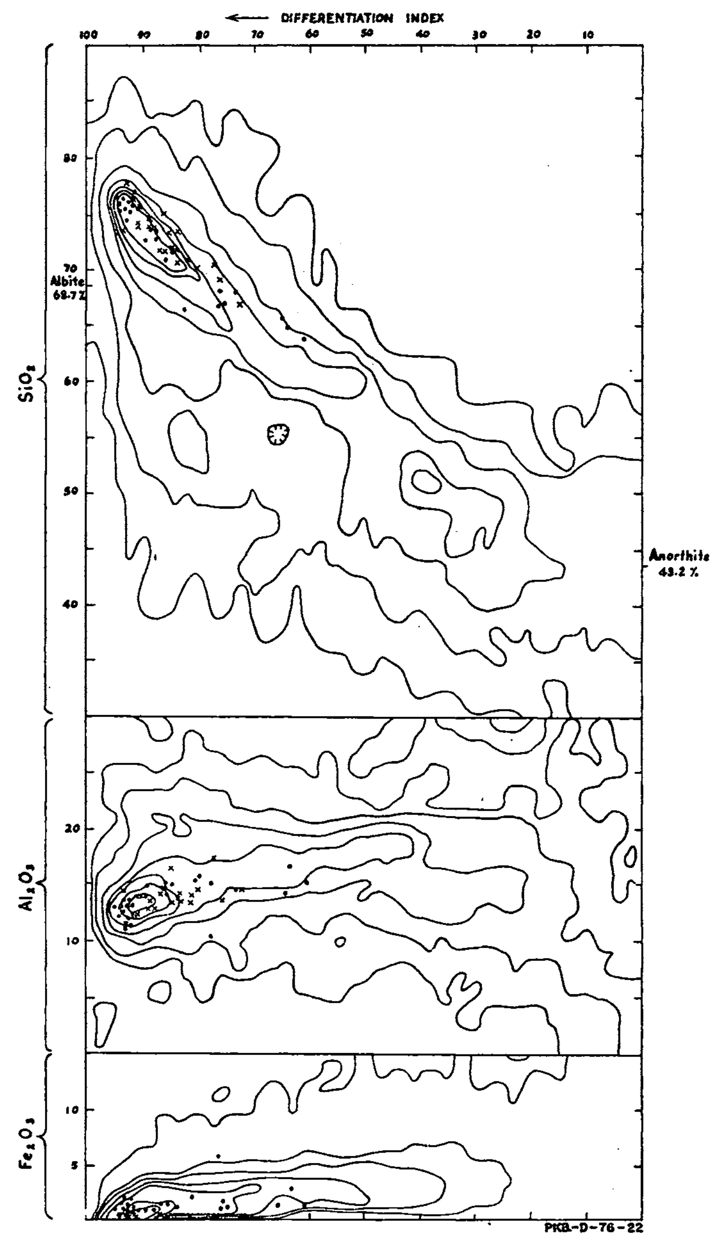
In Figures 3a and 3b the major oxide percentage of the Eastern Belt granitoids and the Western Belt (Main Range) granitoids have been plotted as ordinates and Differentiation Index (D.I) as abscissae, and these data have been superimposed on Thornton and Tuttle's (1960) frequency distribution diagrams. The variation diagrams reveal that the oxide: D.I. values of the Eastern Belt granitoids are very similar to those of the Main Range granitoids, and that all are very close to the established universal average for granites.



X Western Belt (Main Range) granitoids

• Eastern Belt granitoids

Fig. 3a. Differentiation Indices and chemical variation of the granitoids from the Eastern & Western Belts of Peninsular Malaysia.



X Western Belt (Main Range) granitoids

• Eastern Belt granitoids

Fig. 3b. Differentiation Indices and chemical variation of the granitoids from the Eastern & Western Belts of Peninsular Malaysia.

The plot of normative Qtz-Ab-Or (Fig. 4) reflects the limited compositional range of most of the samples, and these values fall close to the centre. This according to Tuttle and Bowen (1958) is indicative of general liquid crystal equilibrium during emplacement, and suggests a magmatic origin for these granitoids.

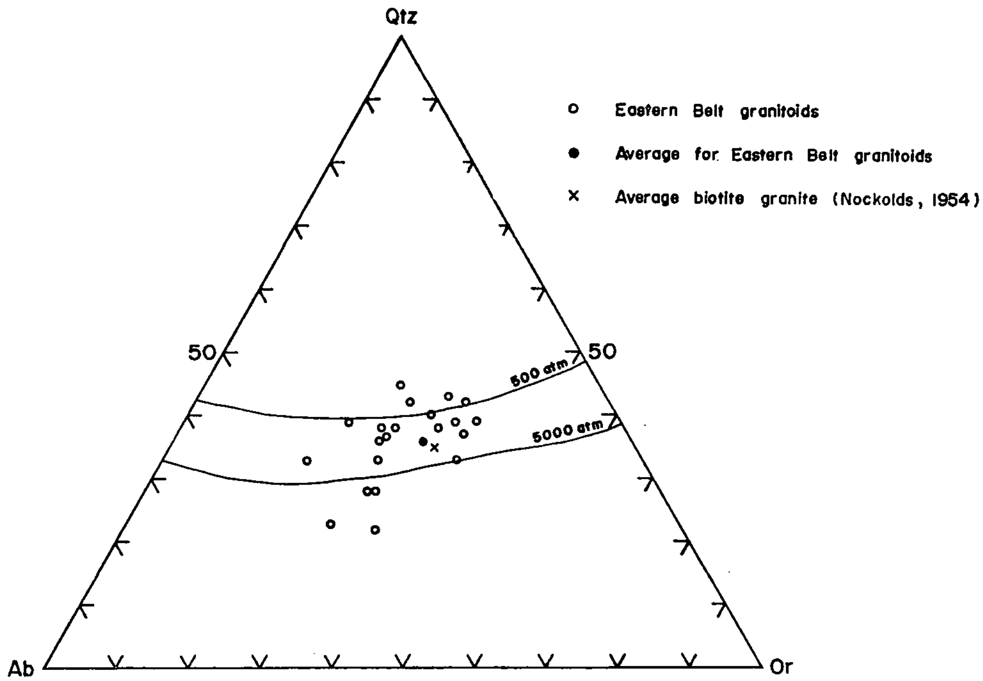


Fig. 4. The salic normative constituents of the Eastern Belt granitoids plotted in the system $NaAlSi_3O_8 - KAlSi_3O_8 - SiO_2$. The boundary curves and Minima at 500 and 5000 kg/cm water vapour pressure are also shown (Tuttle & Bowen, 1958.)

AGES

Radiometric dating of granitic rocks has been undertaken mainly by the Institute of Geological Sciences, United Kingdom, on behalf of the Geological Survey of Malaysia. Almost all the major granitoid bodies of the east coast have been dated, but more dates are required to give a true and meaningful picture. Not all the samples analyzed have been subjected to the same method of analyses. For details see Table 2 and Figure 5.

From the data available it appears that the oldest granitoids are of Upper Carboniferous to Middle Permian, and it is thought that the Jengai and Kapal granitic masses lie predominantly within this range. Late Permian to Early Triassic ages have been recorded for the Maras/Jerong and Gambang granites. Granitoids of east Johore also come under this category. Besides these, Late Triassic ages and one Late Jurassic age have been obtained from the Boundary Range granite. No Late Cretaceous to Tertiary ages have been recorded in the East coast area.

TABLE 2

RADIOMETRIC DATES OF EASTERN GRANITOIDS

Reference on figure	GSM. Sp. Rep. No.	State	Locality	Lat. N	Long. E	Material	Mineral	Methods: K/Ar, Rb/Sr others	Age (million years)
1	27065	Kelantan	Bukit Yong	5.44.30	102.26.15	Granite	Biotite	K/Ar	140 ± 8 m.y.
2	27420	Trengganu	Kuala Brang	5.02.00	102.55.45	Biotite granite	K-feldspar	Rb/Sr	215 m.y.
3.	29865	Trengganu	24 mls. K. Trengganu – Jerangau Rd.	5.2.5	103.7.10	Granite	Biotite	K/Ar	241 m.y.
4.	30083	Trengganu	Sg. Kijing	4.26.17	103.11.35	Biotite granite	Biotite	K/Ar	258 ± 4 m.y.
5.	30084	Trengganu	Sg. Tebak	4.25.00	103.14.35	Biotite granite	Biotite	K/Ar	262 ± 4 m.y.
6.	27423	Trengganu	Ulu Sg. Kemaman	4.17.15	103.13.00	Biotite granite	Biotite	K/Ar	260 ± 10 m.y.
	„	„	„	„	„	„	Whole rock	Rb/Sr	300 m.y.
7.	27437	Pahang	Gunong Gagau	4.45.10	102.37.45	Hornblende granodiorite	Hornblende	K/Ar	200 ± 8 m.y.
8.	29858	Pahang	Sg. Linchong (Bt. Paloh)	4.5.30	103.6.20	Biotite granite	Biotite	K/Ar	240 ± 8 m.y.
	„	„		„	„	„	Whole rock, plagioclase, biotite and K-feldspar	Rb/Sr	240 m.y.
9.	27421	Pahang	Bukit Ubi (Kuantan)	3.49.00	103.19.00	Biotite granite	Biotite	K/Ar	215 ± 8 m.y.
10.	30078	Johore	Bt. Lutong	2.05.35	103.43.20	Biotite granite	Biotite	K/Ar	237 ± 6 m.y.
11.	29869	Johore	Gunong Blumut	2.2.30	103.33.45	Biotite granite	Biotite	K/Ar	232 m.y.
12.	30097	Johore	Bt. Jengeli West	1.57.30	103.36.40	Biotite granite	Biotite	K/Ar	231 ± 6 m.y.
13.	30077	Johore	Bt. Batu Tongkat	1.59.15	103.30.45	Biotite granite	Biotite	K/Ar	233 ± 6 m.y.
14.	27417	Johore	Bukit Lanchu	1.30.45	103.50.45	Granite	Biotite	K/Ar	214 ± 10 m.y.
	„	„	„	„	„	„	„	„	218 ± 10 m.y.
	„	„	„	„	„	„	K.feldspar, whole rock, biotite and plagioclase	Rb/Sr	215 ± 10 m.y.
15.	30108	Johore	Jemaluang Quarry	2.15.30	103.50.20	Biotite-Muscovite Granite	Biotite	K/Ar	234 m.y.

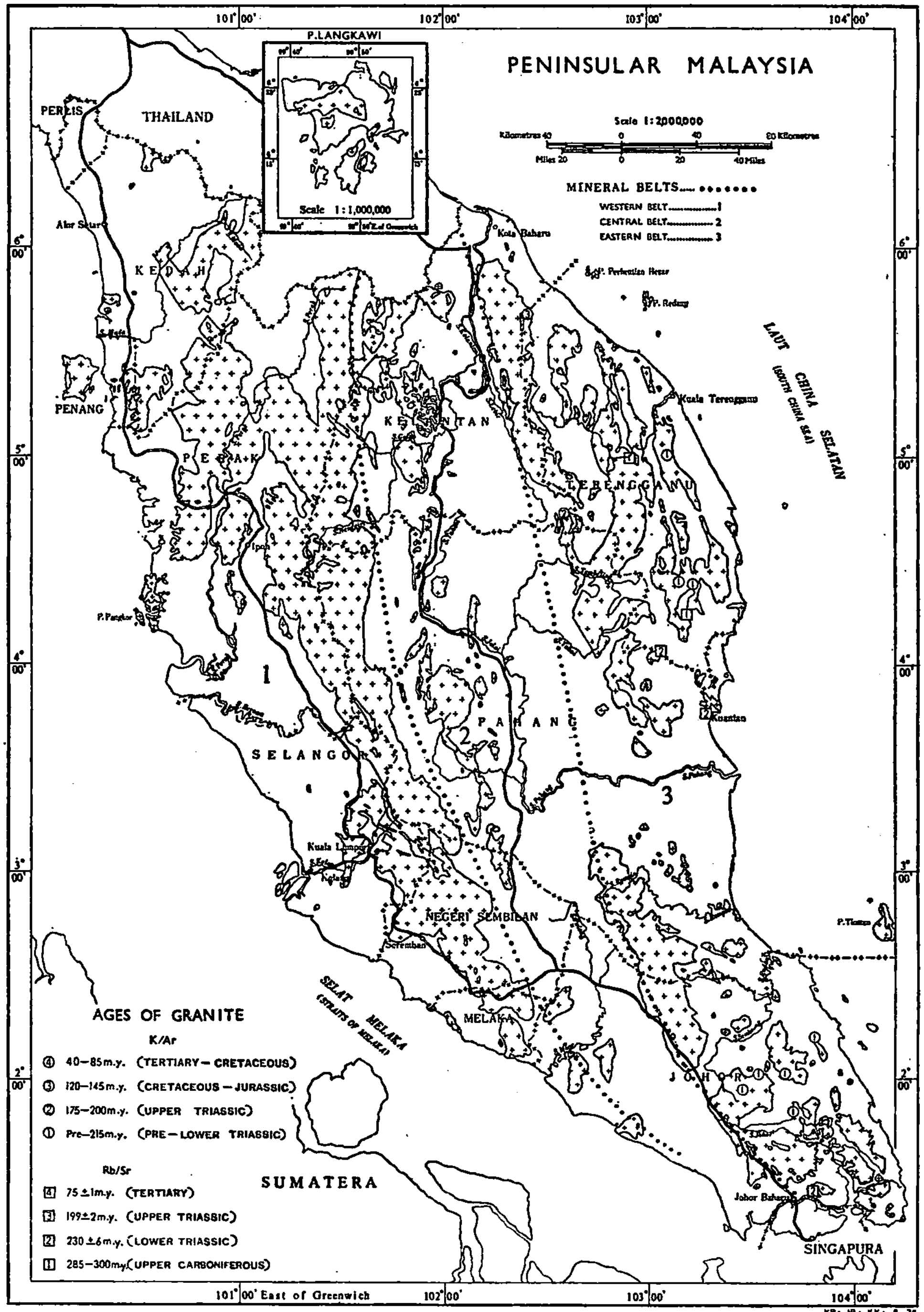


Fig. 5. Ages of granitic bodies in the Eastern Belt

Stratigraphic evidence, in many places, supports these findings. However, the majority of the dates were derived from K/Ar work and may be related to major uplifts. This probably explains the scatter around peak periods. Rb/Sr ages would give dates closer to actual intrusive events. The 15 samples dated suggest a Late Permian peak for magmatic activity for the granitoids of the Eastern Belt.

MINERALIZATION

Scrivenor (1928) divided the Malay Peninsula into three mineralization belts, viz: the Western Tin Belt; the Eastern Tin Belt; and the Central Gold Belt. Although boundaries of these belts have been somewhat oversimplified, the basis for this division is valid and now supported by more recent data obtained by the Geological Survey from greater and more detailed field investigations.

Associated with the Eastern Belt granitoids is iron, tin, and tungsten mineralization (Fig. 6). Within the belt the mineralization generally occurs in and along the eastern margins of the granitic intrusives, spatially related to the granitoid/sediment contacts. A similar but richer belt is associated with the granitoids of western Peninsular Malaysia. These two belts are separated by a smaller Central Belt which supports basemetal, gold and other sulphide mineralization. Though the bulk of Malaysia's mineral wealth is derived from tin (cassiterite), it has to be stressed that this comes from stanniferous alluvial placers in the environs of primary tin mineralization.

Iron mineralization is strongly developed within the Eastern Belt where three major and several small deposits have been exploited. Of these the largest are at Bukit Besi, Bukit Ibam and Machang Satahun. These ore bodies and others, such as, at Kuala Brang, Ulu Sungai Paka and Pelepah Kanan, lie close to, if not actually on, contact zones between granitic and sedimentary rocks. The spatial relationship between iron deposits and granitic rocks suggests that the mineralizing fluids were most likely derived from the intruding granitoids. The iron-ore bodies consist essentially of magnetite and martite that has been derived from magnetite by alteration, as well as some primary hematite and large amounts of secondary "iron oxides" resulting from the oxidation of pyrite and pyrrhotite. A detailed study by Hill (in Bean, 1969) in Bukit Besi has shown that the iron mineralization is epigenetic and the deposit was formed as a result of pyrometasomatic processes. In Machang Satahun, though only secondary iron oxides including manganiferous limonites were mined, this deposit is thought to have resulted from the weathering and oxidation of primary iron oxides that developed as a result of replacement of the country rock.

The deposits both at Bukit Besi and Machang Satahun along with those at Pelepah Kanan, Kemasik, Bukit Bangkong and Sungai Panching are stanniferous. In certain places the cassiterite is present in sufficient concentration to make them worth working for their tin content (e.g. Bukit Besi, Pelepah Kanan, Machang Satahun). At Pelepah Kanan and Kemasik however, the tin content throughout the mass of otherwise potential iron ore has rendered these deposits of no value. Further technological/metallurgical advances, however, may make the deposits exploitable.

Skarn development and the presence of other contact metamorphic rocks, as at Bukit Besi, Sungai Panching, and Pelepah Kanan are further evidence that the iron and tin mineralization along this belt are genetically related to the granitoids.

Primary tin mineralization is common in the belt and it is invariably related to the granitoids. The deposits have developed generally along fissures, faults and in open

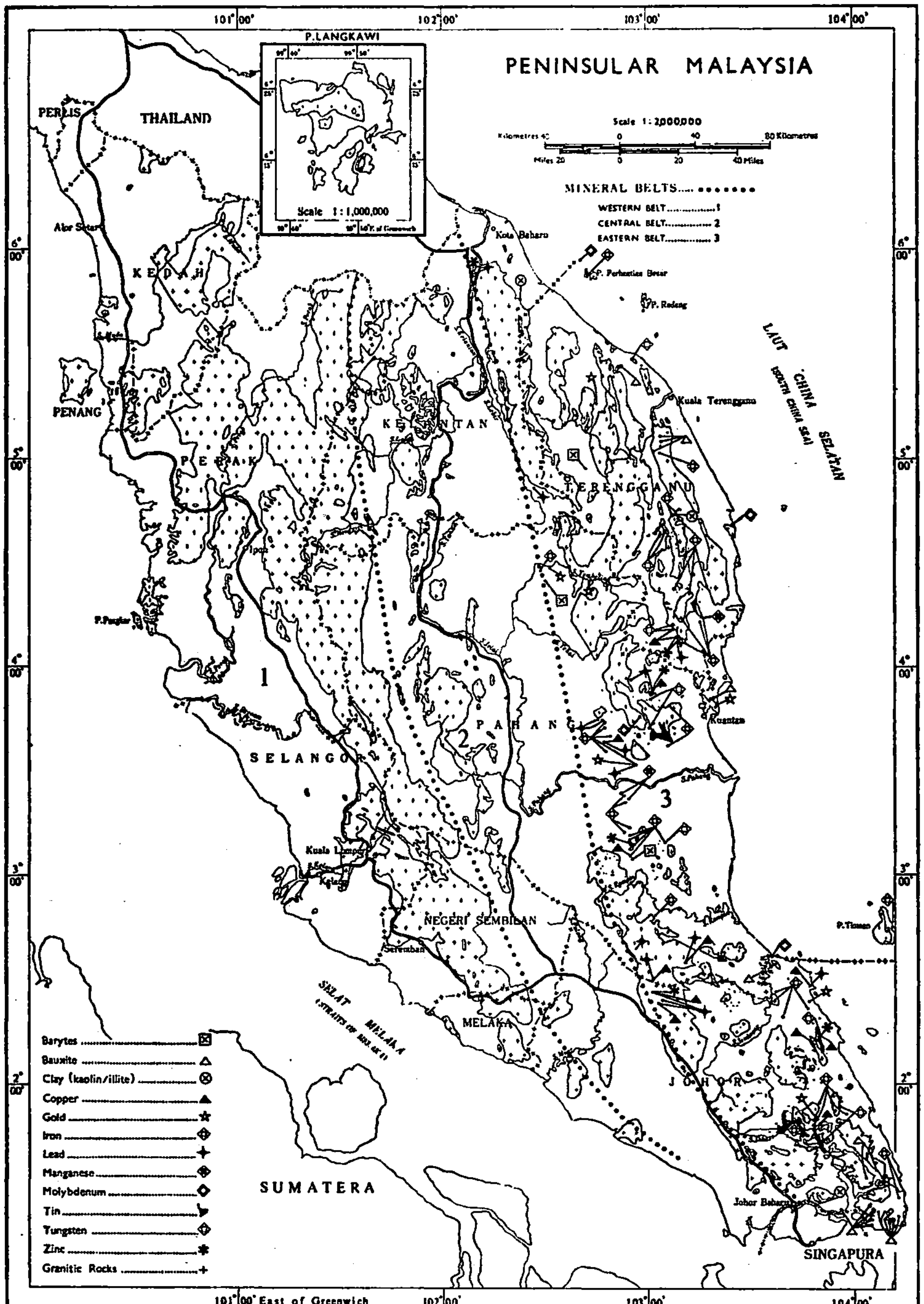


Fig. 6. Distribution of the mineral deposits and occurrences in the Eastern Belt.

spaces which gave rise to veins, lodes and massive replacements of pneumatolytic and/or hydrothermal origin. Faulting, probably post-intrusive movements on pre-existing faults, seems to have also played a major role in the original deposition of the primary deposits. In places, such as the Kota Tinggi area of Johore, tin concentrations appear to be localized in zones where the transverse faults intersect.

The lode-tin deposits generally form quartz cassiterite and, to a lesser extent cassiterite-greisen veins. Most of the lodes are in metasedimentary rocks underlain by a granitic body or close to a granite contact, or the flanks of granitic cusps. Often the contact-aureole rocks have been partly greisenized.

The lode-tin deposit at Sungai Lembing is by far the most important economically. The lodes are the best developed in Peninsular Malaysia and most form fissure fillings and replacement veins essentially of quartz-cassiterite in Lower Carboniferous shale, which is in contact with granitic rock. Some ores also occur in greisen. The deposit, which is the largest in Southeast Asia, is the country's only underground mine. It is in fact the world's largest underground tin mine and has about 200 miles of working and galleries.

Similar mineralization is known but on a smaller scale in the Bundi and Bukit Payong areas. Minor amounts of sulphides of copper, lead, zinc, and silver are associated with the deposits at Sungai Lembing and Bundi; in fact small quantities of chalcopyrite, with significant gold values, are recovered as a by-product of tin ore from Sungai Lembing. The Bukit Payong deposit is associated with minor amounts of wolframite. Other outstanding examples of tin-lode deposits are at Sungai Tebak, Bukit Lentor, Gunong Muntahak, and the Sungai Ayam - Kajang areas. At Ulu Sungai Kelah (a tributary of Sungai Tebak), lodes in granite have been recorded.

Secondary tin deposits, formed by weathering and erosion of the primary lodes which themselves would probably not be economic, have contributed largely to the development of valuable placers in the eastern mineralized belt. Most of the placers were derived from low-grade lodes and stockworks consisting essentially of stanniferous quartz veins and greisens. The margins of granitoids seem to be especially favourable places for placer deposits, especially where streams have followed fairly long distances along such margins. The placer deposits of this belt, unlike the western mineralized belt, are small and not large enough to sustain dredges. Almost all the tin ore is being mined by gravel-pump methods. Associated with the stanniferous alluvial deposits are other heavy minerals, such as, ilmenite, zircon, monazite, xenotime and wolframite which are being recovered as by-products of tin-mining operations. Xenotime forms an important by-product of tin placers in the Gambang area, where it is associated with the Gambang granite. In the south of the belt xenotime is to a lesser extent associated with the Blumut-Muntahak and Lenggor/Jemaluang granites.

The only indications of tin off the east coast of the Peninsula is an alluvial placer in Pulau Aur, an island 73 km east of Mersing, which is underlain by granitic rocks. Grab samples of marine sediments off the coast have shown some high tin values between Pulau Tioman and a point some 40 km off Kuantan. The submarine stanniferous occurrences suggest that buried granitoid cusps exist in the offshore areas. These granitoids probably represent the eastern extremity of the granitoid batholiths of the Eastern Belt.

Reconnaissance prospecting of beach sand deposits along the Kelantan - Pahang coastline has disclosed only poor values in cassiterite and other associated heavy minerals.

Tungsten mineralization associated with the Eastern granitoids is well documented in the Geological Survey records. Several deposits have been exploited from time to time, of which that at Bukit Lentor is probably the largest. In this area quartz-wolframite lodes fill fissures in metasedimentary rocks which are underlain by a granitic cusp. The nearest exposed granitic body is several miles away but chiastolite in the slates suggests the granitoid lies at a shallow depth. These wolframite lodes are close to the summit of the hill, and primary tin mineralization has been recorded along the flanks by Chand (in manuscript) who reported both vertical and lateral zoning. Similar wolframite lodes are known also at Chendrong, Buloh Nipis, Sungai Pohoi, Jemaluang, and Sungai Jengai. Minor amounts of scheelite have been recorded in some of these lodes and also at Pelepah Kanan. The deposits in the Sungai Jengai area lie close to contact zones, both in the sediments and the granite. Associated with this mineralization are also zones of greisenization.

As noted the mineralization associated with the Jengai granite forms two linear zones, namely a tin-tungsten-bearing zone extending from Bukit Lentor to Bukit Bundi, and a tin-iron-bearing zone from Bukit Besi through Machang Satahun to Sungai Panching. Besides the numerous occurrences of tin, iron, and tungsten in the Eastern Belt, base metals, gold, bismuth, barite, and bauxite have also been noted.

The granitoids also yield a number of non-metalliferous products. Bauxite derived partly from bauxitization of granitic rocks is mined in the low-lying areas at the toe of the Peninsula in Tanjong Penggerang and laterite derived from the granitoids is used for surfacing secondary roads. The granitic rocks are also quarried for road-metal and building stones. Kaolin has been obtained from the granitoids particularly in the Jemaluang area. Gravel and sand deposits, derived from erosion of granitic rocks, are used for construction purposes, and massive quartz in vein form cutting through the granitoids has been found to be suitable for the manufacture of glass and associated products.

CONCLUSIONS

Emplaced within the older sedimentary-volcanic rocks in the Eastern Belt are a variety of acid granitoid bodies, ranging in age from Late Carboniferous to Late Jurassic, which collectively form what may be termed provisionally an elongate composite batholith. Compared to the Western Belt, the granitoid bodies in the Eastern Belt were probably emplaced at progressively lower levels. These granitoids impressed remarkably little thermal metamorphism on the host country rocks, rarely more than low to moderate metamorphic grade. Faults are conspicuous in the granitoids, and some of these fractures are now occupied by late-phase acid igneous injections, greisen zones, quartz and other mineralized veins.

A close spatial relationship exists between marked primary concentrations of tin and other deposits with the granitoid bodies of this belt. The mineral deposits are mostly confined to a few places, and in general follow the fringes of the batholiths, close to the contacts. Unlike the Western Belt, many of the granitic cusps and ridges are still buried with the likelihood that many of the associated tin lodes are largely intact. From the results of recent work carried out by the Survey, the number of new occurrences of tin (cassiterite) in this belt is quite impressive, and provide prima facie evidence of areas favourable for tin deposits. In some mineralized areas that have been studied in some detail, tin is usually found in and near fine-grained granites. Some parts of the granite/sediment contacts, and margins of satellite stocks including sub-outcropping granitic cusps, are also known particularly for the presence of primary tin, tungsten, iron and other mineralization.

On the basis of known mineralized occurrences, exploration, principally geochemical and geophysical, probably will be intensified in the belt in years to come. The region is well suited to evaluation through sediment and heavy mineral stream analysis, having generally a moderate relief, discrete, well-defined drainage basins, and a low contamination factor.

Finally, in order to effectively delineate areas with primary tin and other mineralization it is essential that granite/sediment contacts, including re-entrants, be mapped on a detailed scale. More structural studies of the belt in general are also warranted and, in particular, the relationship between the distribution of primary and secondary tin deposits and faults need to be clarified.

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