GEOSEA V Proceedings Vol. II, Geol. Soc. Malaysia, Bulletin 20, August 1986; pp. 627–647

Status of uranium exploration in Peninsular Malaysia

CHU LING HENG AND FATEH CHAND
Geological Survey Malaysia
Tiger Lane, Ipoh, Malaysia

Abstract: Although preliminary attempts at identifying radiometric targets were made by the Geological Survey in the late 1950s, and even as recent as 1975, systematic exploration for uranium in Peninsular Malaysia however did not really get underway until the middle of 1977 when the Central Belt Project, a regional geochemical sampling programme, was launched. Since then this programme, which for the first time incorporates uranium analyses of geochemical samples has continued to assume an important role in assessing the mineral potential of the Project area covering some 31,000 km² in north-central Peninsular Malaysia. To complement this geochemical survey a helicopter-flown spectrometric and magnetic survey was conducted over the Project area in April 1980.

The granitoids are generally more responsive radiometrically and show a higher geochemical uranium contrast in comparison to other rock types. The recent discovery of uraniferous lithologies containing uraninite and uranium-bearing florencite and rhabdophane in the Boundary Range Granite, together with the known torbernite occurrence in the Main Range Granite, implies that the search for granite-hosted uranium mineralization deserves priority.

Contrary to earlier belief, the importance of the Mesozoic continental formations as possible uranium hosts appears to have been reduced, judging from their weak airborne radiometric and geochemical responses. On the other hand the Tertiary basins, not previously accorded attention, should be assessed for their uranium potential.

INTRODUCTION

Previous attempts at delineating uraniferous zones within Peninsular Malaysia were based on geological and preliminary, rather inconclusive, geophysical data. Following the implementation of the Central Belt Project by the Geological Survey in mid-1977 over north-central Peninsular Malaysia, uranium exploration has been conducted in a more systematic manner with a broader perspective through exploration geochemistry and a complementary airborne spectrometric and magnetic survey flown in mid-1980. The results of these two phases of the Project, together with the recent discovery of uraniferous lithologies over the Boundary Range Granite in Kelantan and the known occurrence of torbernite in the Main Range Granite, suggest that the search for possible granite-hosted uranium mineralization deserves priority in uranium exploration programme in Peninsular Malaysia.

URANIUM EXPLORATION PROGRAMMES

Previous work (1928-1975)

In Peninsular Malaysia, uranium mineralization was first recorded in 1928 at Gunung Bakau and later in 1938 from Sungai Chiling and Sangka Dua in Selangor (Fig.1). Here

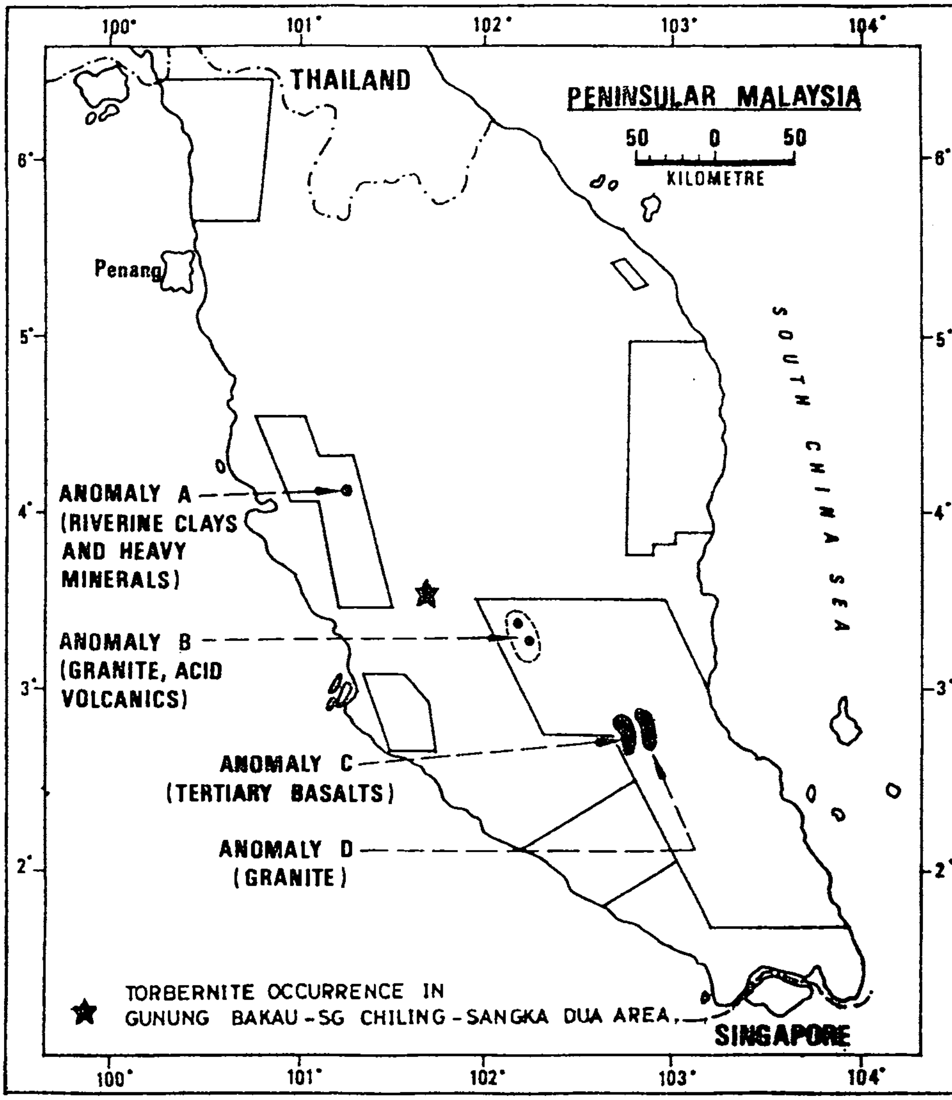

Fig. 1. 1956-57 Airborne areas showing some high radioactive anomalies (after AGOCS, 1958).

uranium occurs as torbernite associated with cassiterite in quartz veins in granite. The Gunung Bakau locality is the most significant occurrence known to date, and it was estimated in 1931 that about a pound of torbernite per month could be won from this working (Roe, 1951).

In 1956-57, an airborne magnetometer and scintillation counter survey was flown over six selected areas within the peninsula (Fig. 1). Some 41,000 km^2 were covered by the survey

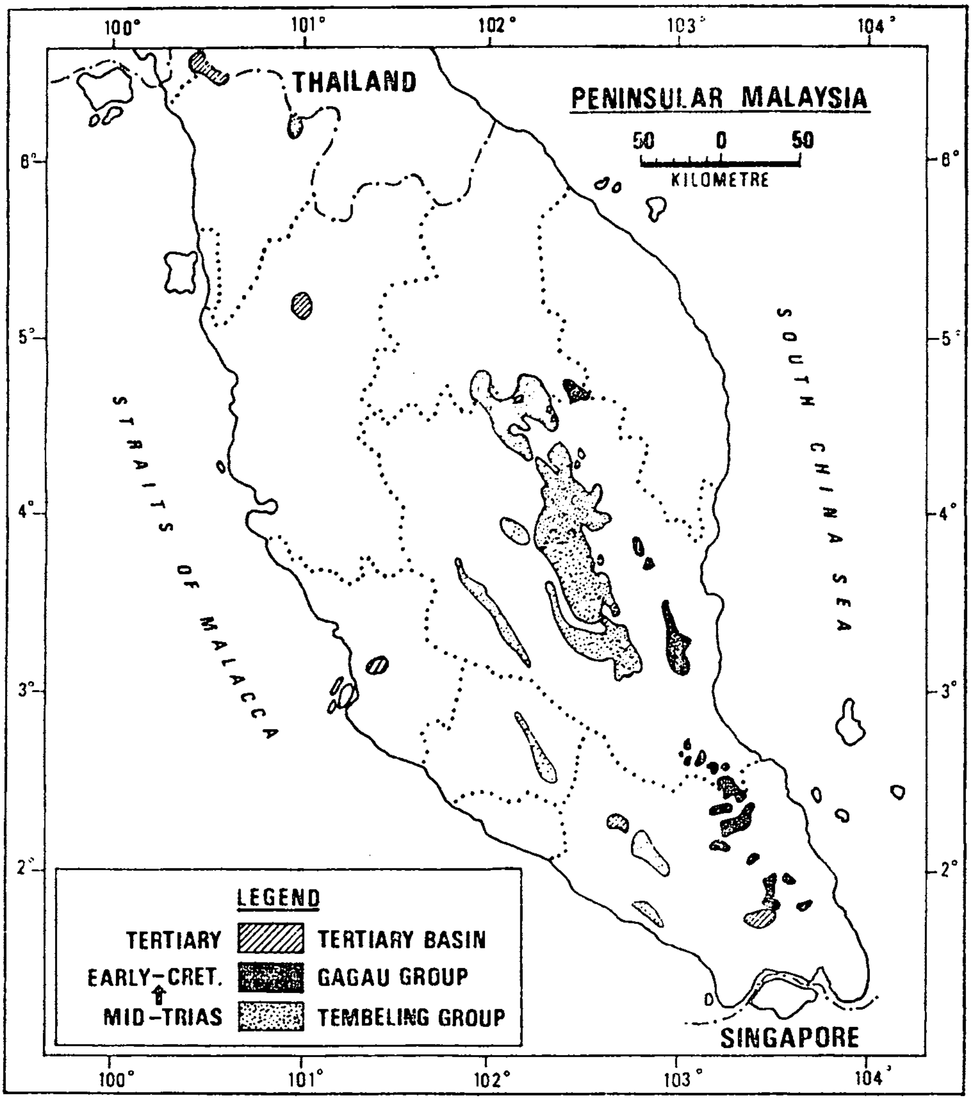

Fig. 2. Distribution of Upper Mesozoic continental rocks and Tertiary basins.

which was conducted under the auspices of the Colombo Plan (Agocs, 1958). Of the numerous radioactive anomalies outlined, only a few showed total count rates greater than three to six times the background, most of them being apparently caused by the high potassium content of granitoids and acid volcanic. No uranium mineralization is known to be associated with these radiometric anomalies, although uranothorite has been recorded in the Benom-Telor area in Pahang.

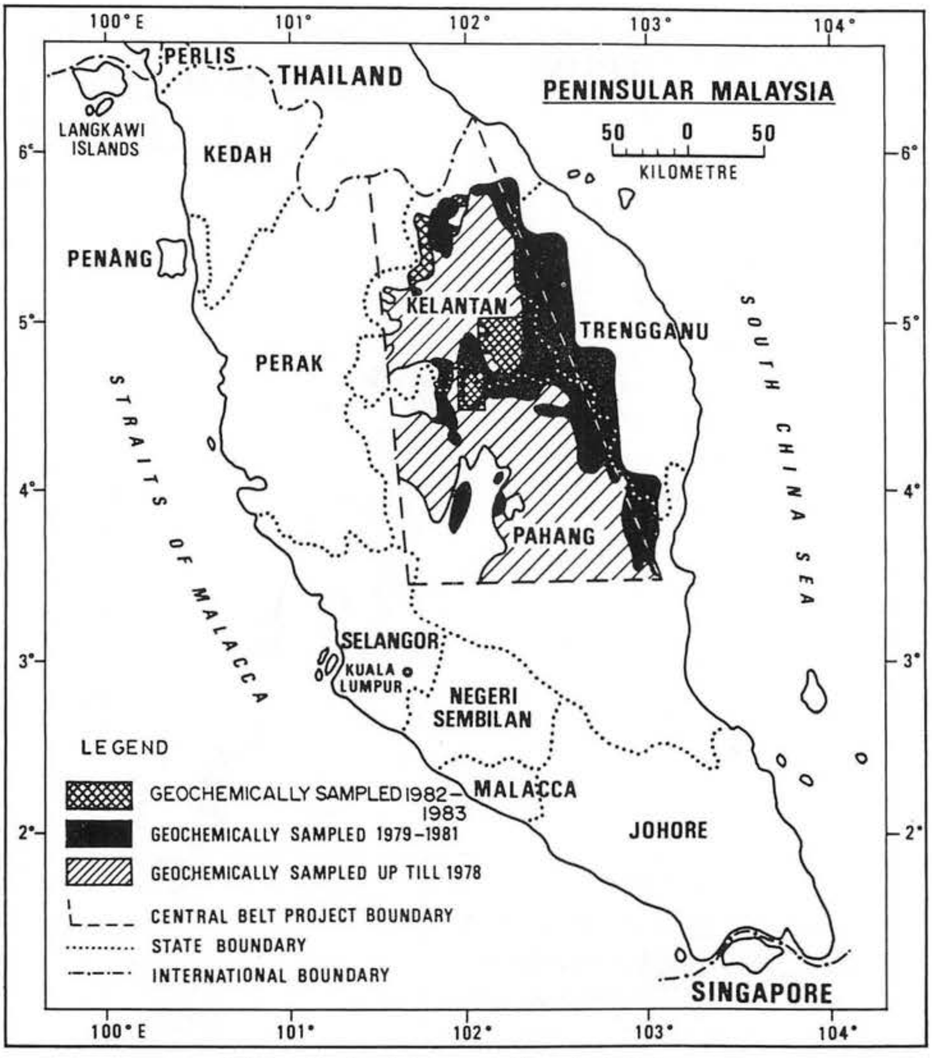

Fig. 3. Geochemical coverage, Central Belt Project.

In the late 1950's Anglo-Oriental Malaysia Ltd. acquired a number of prospecting licences for uranium exploration in Selangor and Pahang. However, the results were discouraging.

A reconnaissance assessment of the uranium potential of the Mesozoic continental formations in central Peninsular Malaysia (Fig.2) was jointly undertaken by the Geological Survey of Malaysia and AGIP Nucleare Australia Pty. Ltd. in 1975. The lithological characteristics of the relevant formations were appraised, rock samples collected for laboratory studies, and spot radiometric readings taken. It was concluded that the continental formations appear to be favourable hosts for sandstone-type uranium mineralization, and that their potential would be best evaluated through downhole logging techniques (de Keyser, 1976).

Present work (since mid-1977)

In mid-1977 the Geological Survey of Malaysia, with technical aid from the Canadian International Development Agency (CIDA), launched a regional stream sediment geochemical sampling programme (the Central Belt Project) covering approximately 31,000 km^2 in north-central Peninsular Malaysia (Fig. 3). The Project area covers largely the states of Kelantan and Pahang. Prior to the implementation of the Project exploration geochemistry was undertaken concurrently on a small scale with the Survey's mapping programme and also by private companies over selected areas. Uranium was not a target element, but following the inception of the Project, uranium has become one of the 14 elements routinely analysed for in the various sample media including stream waters (Table 1). The large area extent of the Project necessitated an arbitrary demarcation of the area along the Kelantan-Pahang interstate boundary in order to facilitate a more manageable geochemical sampling programme. The Survey's Kelantan office was responsible for activities north of the boundary while the Pahang office managed the southern half. Although geochemical procedures adopted were similar for both offices, statistical treatment and evaluation of data were done separately and presented in two separate reports (Geological Survey Malaysia Geochemical Report 1 and 2, Chu *et al.*, 1982 and Lee *et al.*, 1982) which dealt with geochemical data

TABLE 1

ELEMENTS AND PARAMETERS DETERMINED FROM SAMPLING MEDIA

Stream sediments: (-80 mesh)	Cu, Mo, Pb, Zn Ag, Co, Ni, Fe, Mn	AAS after digesting with hot 3:1 HCl-HNO_3 mixture (50%)
	W, As, Sn	Colorimetry
	U	fluorimetry
	Hg	cold-vapour AA
Rocks: (crushed to –150 mesh)		Same elements as above, except Ba in place of Hg. Au by fire-assay pre-concentration followed by AAS
Stream concentrates: (crushed to -150 mesh)		Similar to stream sediments except Fe, Hg, Mn. Au determined.
Stream waters:	U	fluorimetry (after acidification to pH 2)
	F	selective-ion electrode
	pH	pH meter
	Specific Conductivity	conductivity meter

accumulated up to the end of 1978. The 1979-81 data are currently being evaluated. Since mid-1979 there has been some unavoidable sampling spillage, caused by security constraints, across the eastern limit of the Project area. Reconnaissance sampling for 1982-83 is mainly concerned with the re-sampling of certain selected areas. In addition a few priority areas were chosen for detailed follow-up.

To complement the ground geochemical survey a helicopter-flown magnetic and spectrometric survey was conducted over the Project area in April 1980. This work was undertaken by Compagnie Generale de Geophysique (CGG). Production flying totalling 57,356 line kilometres was completed by November, 1980.

DATA TREATMENT AND EVALUATION

Geochemical survey, Central Belt Project

Statistical evaluation of stream sediment and heavy mineral concentrate data was done graphically according to the method proposed by Sinclair (Sinclair, 1974). Threshold was conventionally chosen at the mean plus two standard deviations level which was read off the background plot at the 97.7 percentile level. Figures 4 and 5 depict the stream sediment and heavy concentrate cumulative plots for uranium for Kelantan and Pahang. While the uranium background in stream sediments for both states is 0.30 ppm, the threshold level for Kelantan is slightly higher (3.70 ppm against 3.20 ppm). The mean plus three standard deviations level, considered a highly anomalous statistical parameter, is correspondingly higher for Kelantan (14.0 ppm against 11.0). These values are low since the uranium content of all bedrock types is low, practically all averaging 0.30 to 0.40 ppm U. Furthermore organic matter, a good scavenger, was negligible in all samples since it is quickly oxidised or consumed by organisms in the local tropical environment. For completeness statistical levels derived for all the elements analysed from the stream sediments are shown in Table 2.

Better uranium contrast is shown by the heavy mineral concentrates. Statistical parameters are again higher in Kelantan where the threshold is 170 ppm U compared to 64 ppm U for Pahang. Fe-Mn oxide and hydroxide scavenging is probably largely responsible for the elevated leacheable uranium values noted, although uranium contribution from the commonly associated resistates zircon, thorite, uranothorite, monazite, sphene, apatite cannot be ignored.

Stream water sampling was undertaken only on a restricted scale; the water results were not treated statistically and thus not presented in Geochemical Reports 1 and 2 (Chu *et al.*, 1982 and Lee *et al.*, 1982).

Airborne magnetic and spectrometric survey

The airborne data were processed and evaluated by CGG at Massy, France. During the interpretation stage two geologists from the Geological Survey went to France for three months for training as well as to supply the necessary background geological information required for data interpretation. A series of isogam and isorad maps were subsequently produced. These are available at the Ipoh Laboratories.

TABLE 2.
STATISTICAL LEVELS FOR STREAM SEDIMENTS

ELEMENT	DETECTION LIMIT (ppm)	STATISTICAL LEVELS							
		KELANTAN				PAHANG			
		$\overline{X}$	$\overline{X}+S$	$\overline{X}+2S$	$\overline{X}+3S$	$\overline{X}$	$\overline{X}+S$	$\overline{X}+2S$	$\overline{X}+3S$
Ag	0.1	0.16	0.26	0.43	0.71	0.05[2]	0.20	0.40	1.2
As	5	4[2]	11	26	70	4[2]	9	24	62
Co	1	5	10	20	40	3	7	15	31
Cu	1	12	22	46	91	9	20	42	90
Fe	1%	2.1%	3.5%	6.0%	0.5%	1.7%	3.2%	5.6%	10.3%
Hg	0.02	0.06	0.16	0.40	1.10	0.08	0.18	0.44	1.05
Mn	1	240	540	1200	2600	145	330	780	1820
Mo	0.5	1.4	2.1	3.2	5.0	1.1	1.8	2.7	4.2
Ni	1	5	12	30	75	3	6	13	26
Pb	1	16	35	70	160	17	35	78	155
Sn	10	9[2]	17	30	54	8[2]	18	40	90
U	0.5	0.30[2]	1.10	3.70	14.00	0.30[2]	0.95	3.20	11.00
W	4	1.4[2]	4	11	31	0.11[2]	0.90[2]	7.4	60
Zn	1	40	76	140	280	19	38	76	150

$\overline{X}$ = mean; S = standard deviation.

[1] Values are expressed in parts per million (ppm) unless otherwise indicated.

[2] Extrapolated value; below detection limit.

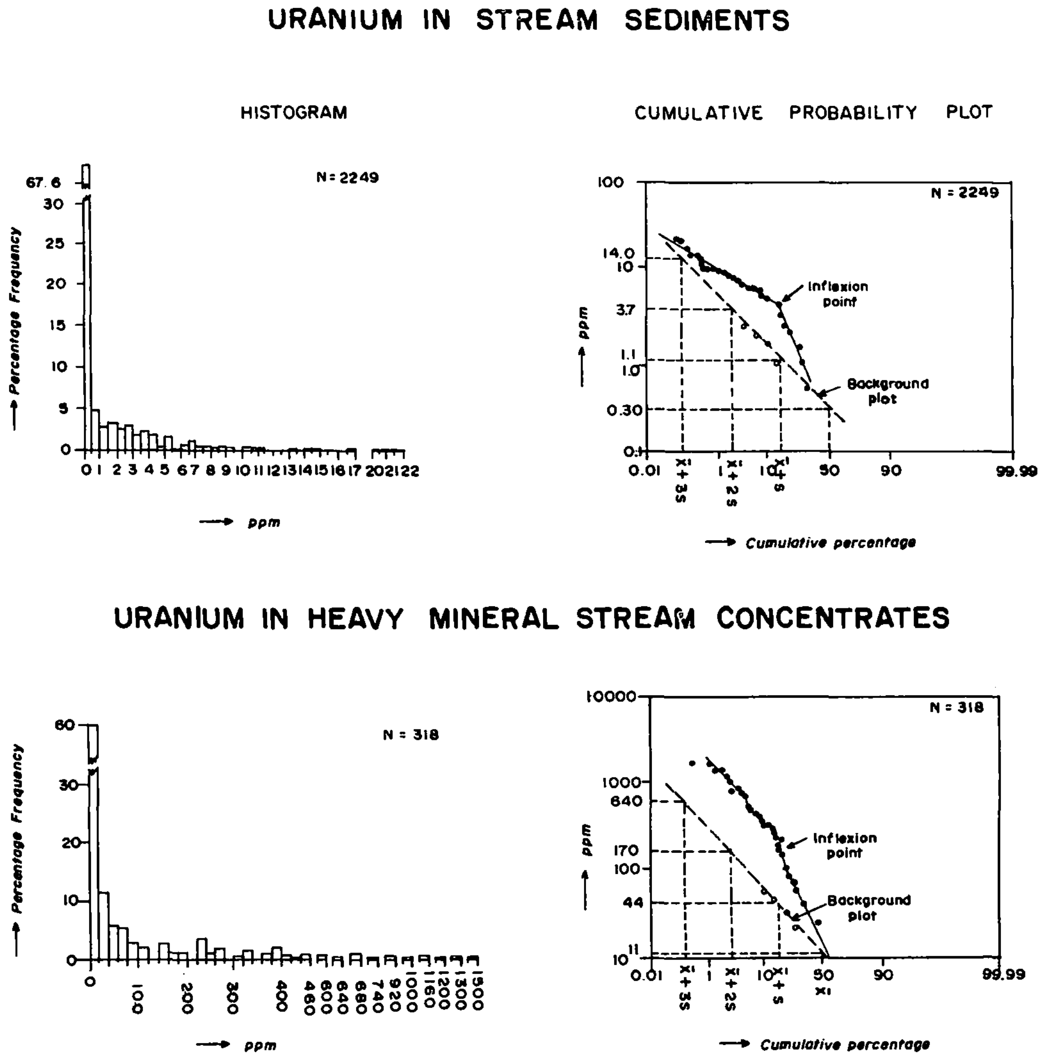

Fig. 4 U content in stream sediments and concentrates, Kelantan

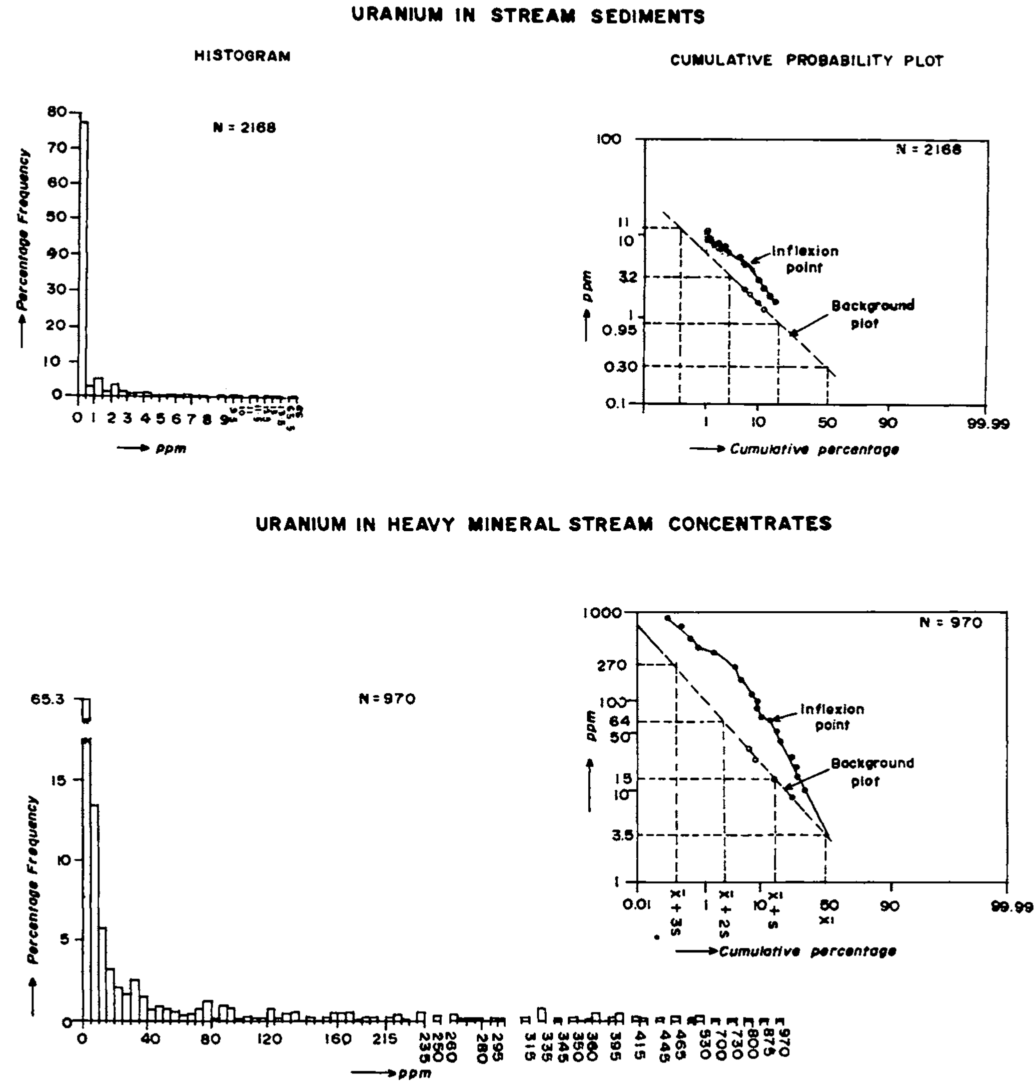

Fig. 5 U content in stream sediments and concentrates, Pahang

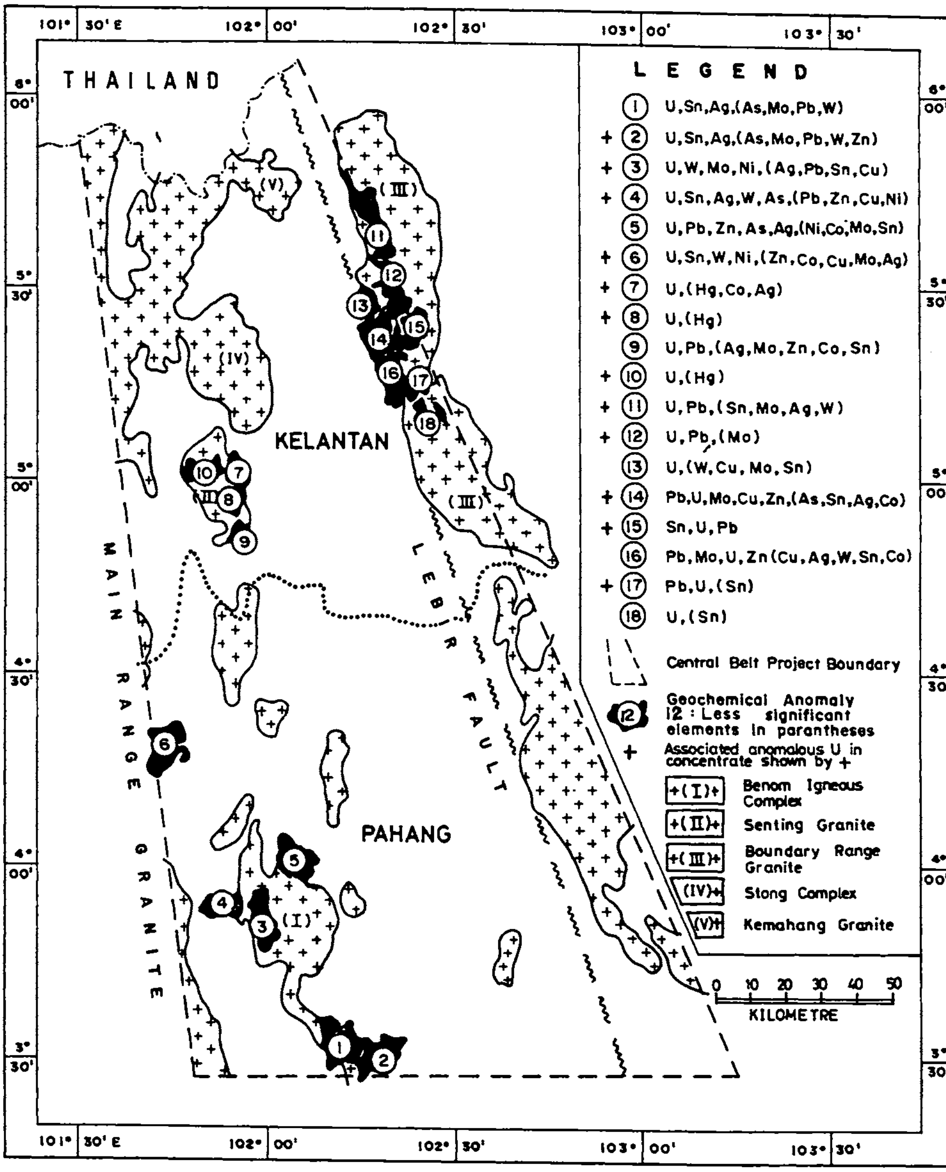

Fig. 6 Stream sediment anomalies with associated uranium highs (Data up to 1978).

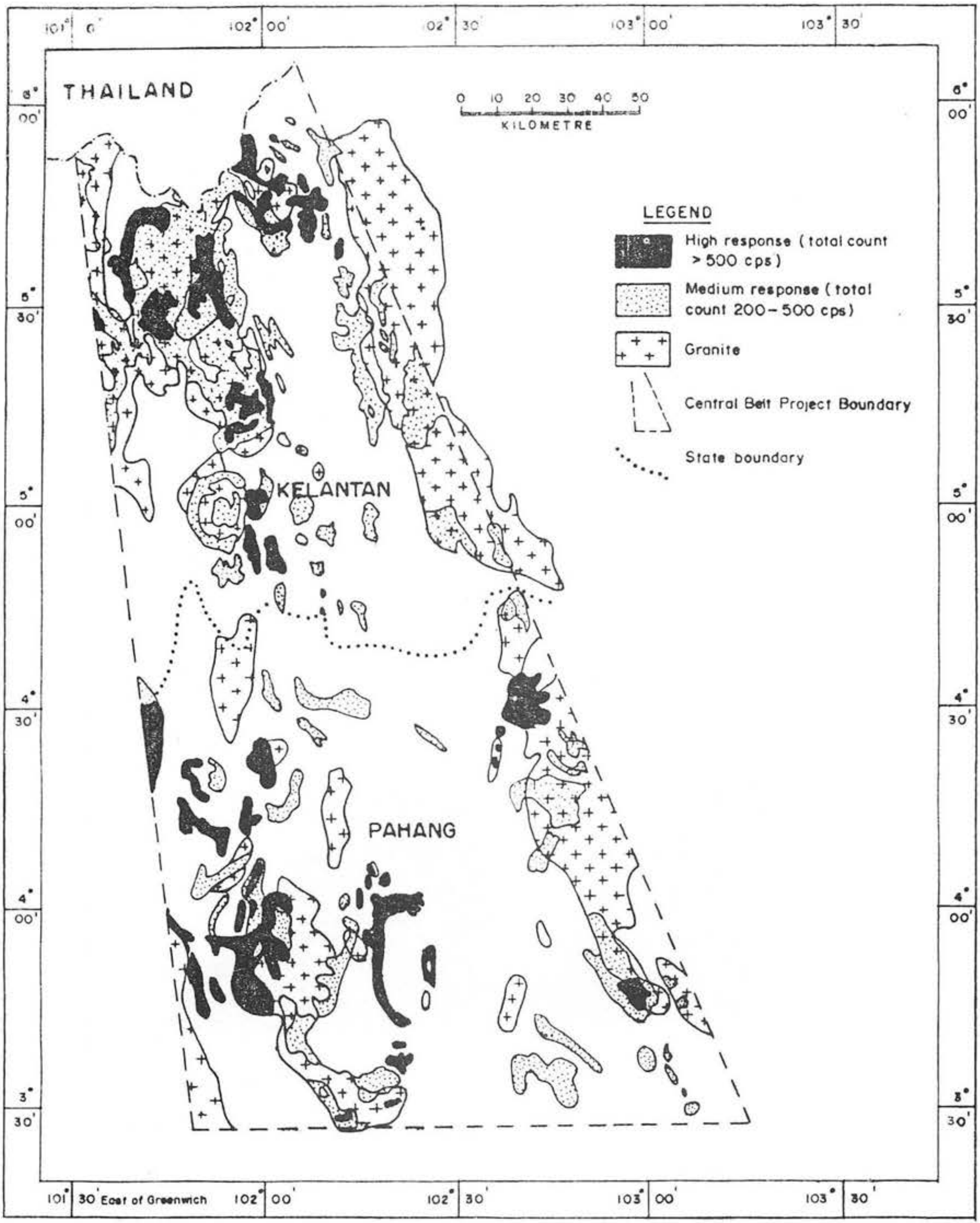

Fig. 7 1980 airborne radiometric survey.

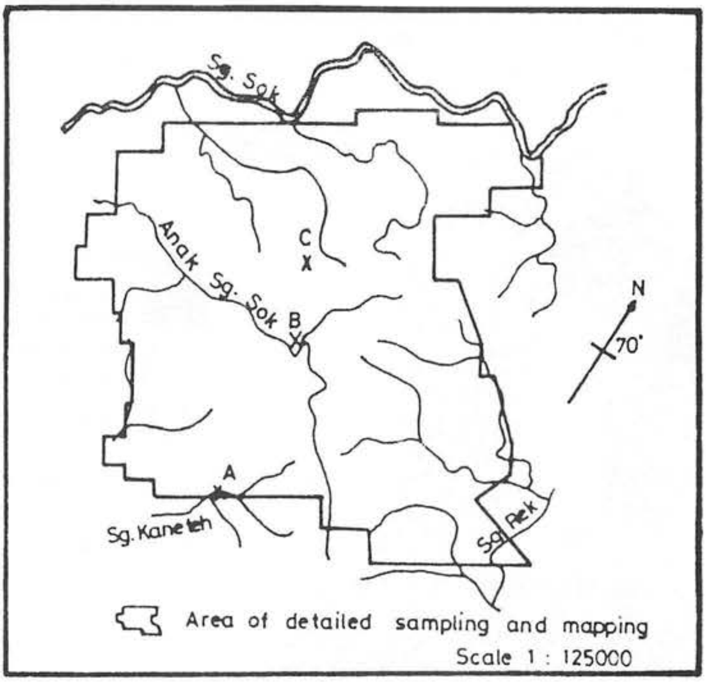

Fig. 8 Radioactive occurrences, Sok prospect, Kelantan.

Plate 1. Printed autoradiographs of radioactive samples from locality A. Uraninite crystals measuring 15-50μm appear as white dots. Other minerals include chlorite, hematite and pyrite. (AMDEL Service Report GS 4333/83, 1983). Actual size. Specimen showed 277 ppm. leacheable U.

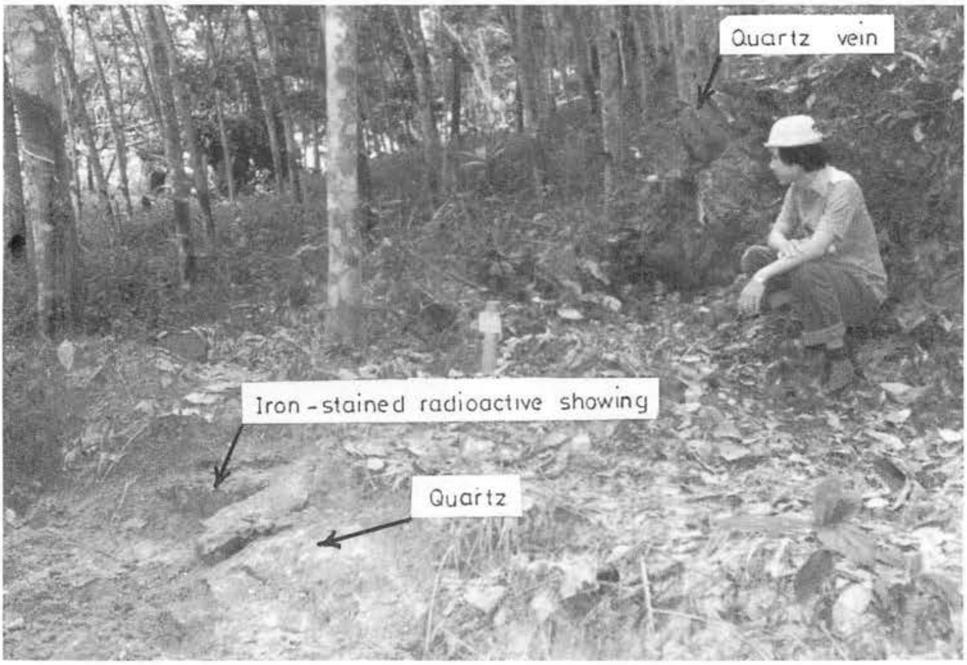

Plate 2. Radioactive quartz vein. Photo taken facing NNE (Locality B). Orientation survey viz., emanometry, track-etch technique, scintillometry and soil sampling undertaken.

Plate 3. Close-up view of iron-stained radioactive showing (Locality B). Total counts range from 700-750 cps. Readings taken with Geometrics GR 101A Scintillometer.

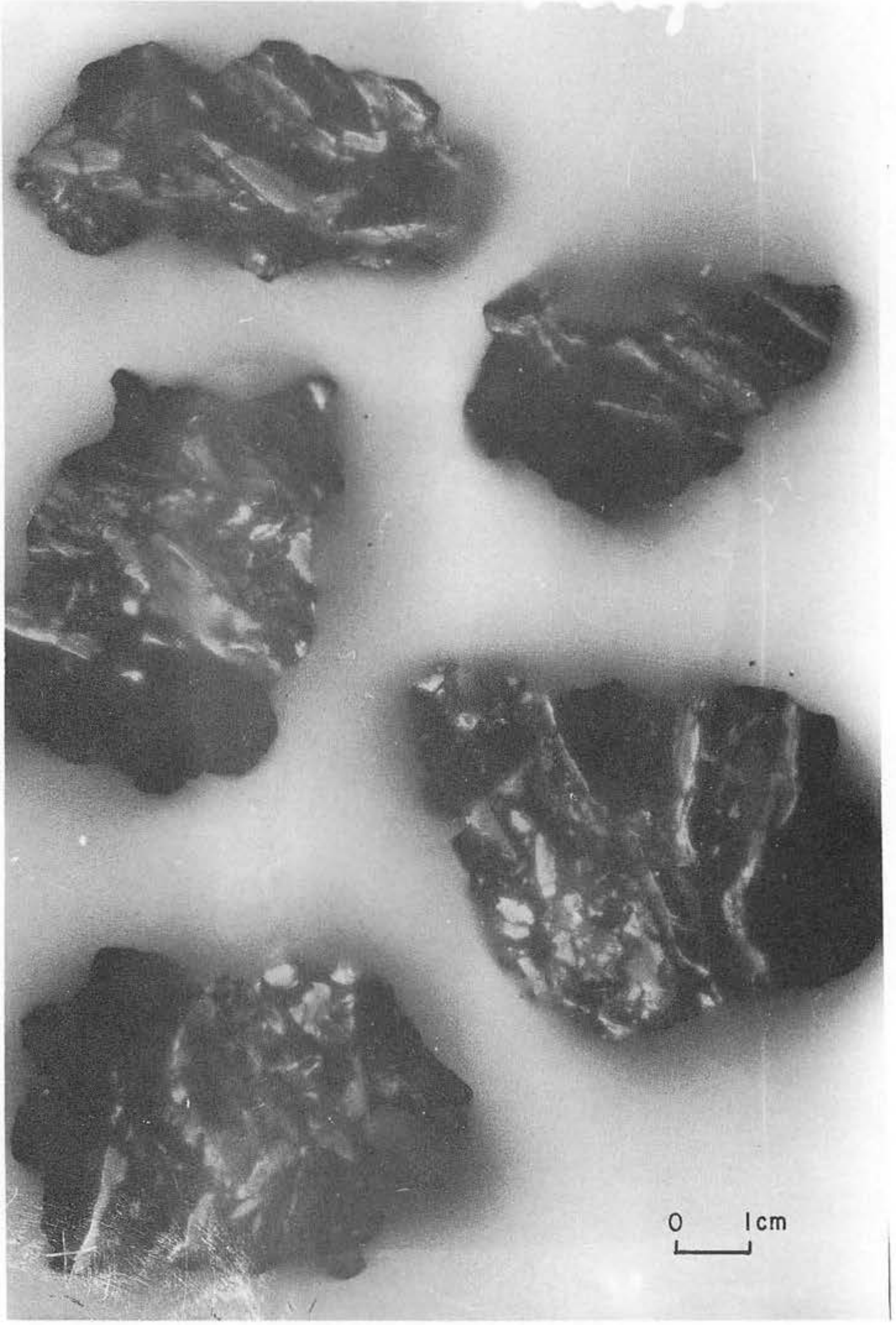

Plate 4. Printed autoradiographs of radioactive samples from locality B. Radioactive centres appear white, consisting of a mixture of uranium-bearing florencite and rhabdophane. (AMDEL Service Report GS 4333/83, 1983). Actual size. Specimen showed 760 ppm leacheable U.

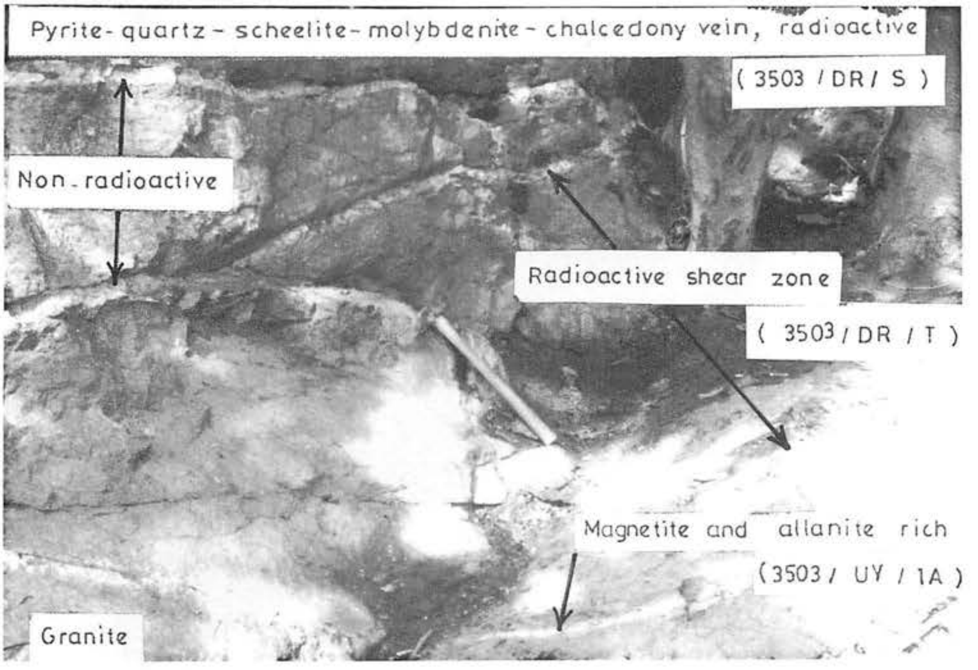

Plate 5. Radioactive vein and shear zone in granite, locality C. Vein gives 360-400 cps; shear zone shows 520-720 cps. Non-radioactive granite shows 200 cps. Background counts are 110 cps. All readings taken with Geometrics GR 101A Scintillometer. Specimens taken for autoradiography are indicated. Shear zone returned 105 ppm leacheable U over 0.65 m.

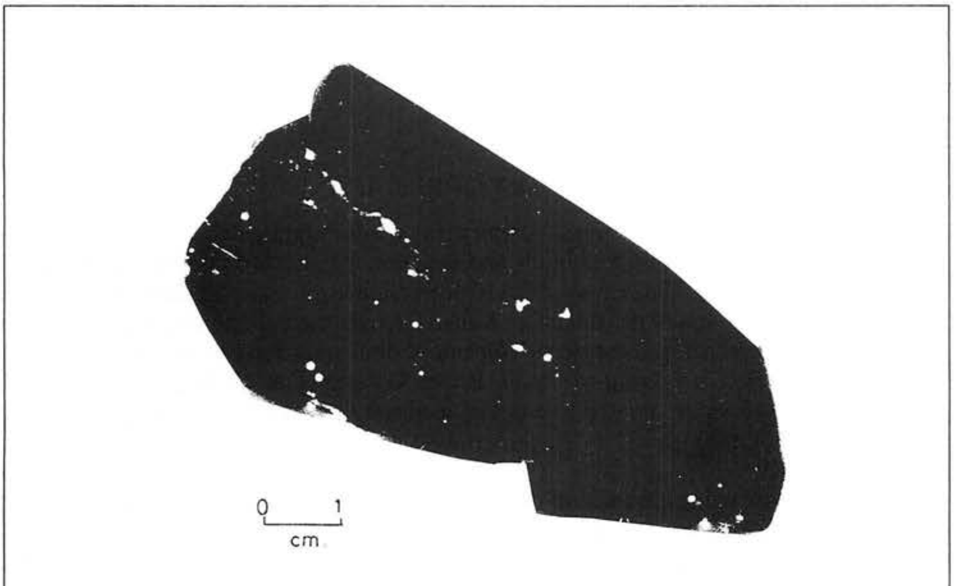

Plate 6. Printed autoradiograph of brecciated magnetite-rich granite 3505/UV/1A, from locality C. Radioactive centres appear as white spots, probably uraninite? Autoradiograph prepared locally at Kota Bharu, 5 days exposure, using ASA 400 ILFORD negative.

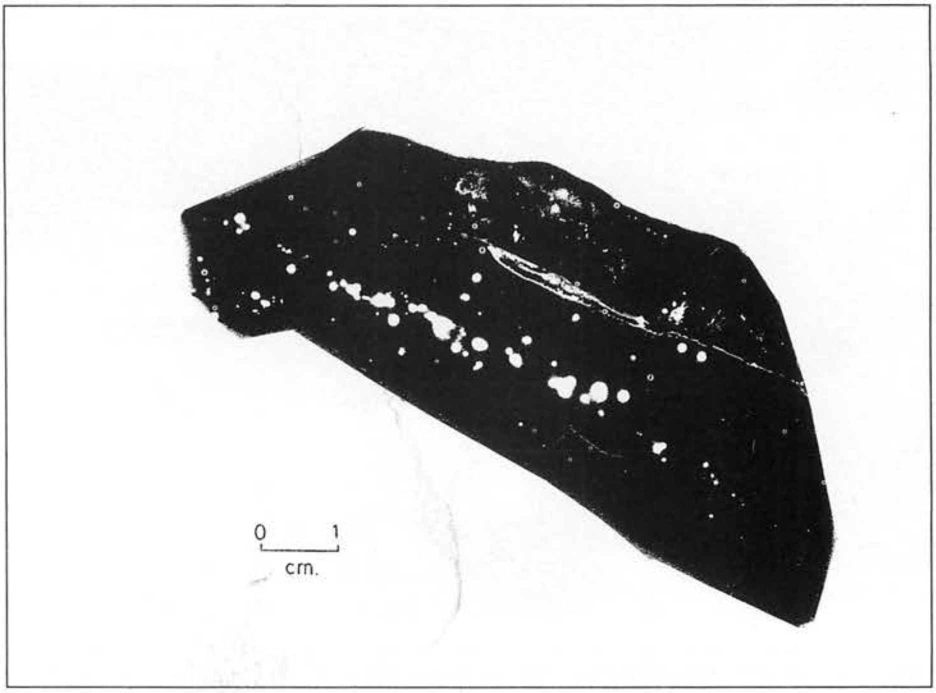

Plate 7. Printed autoradiograph of pyrite-quartz-scheelite-molybdenite-chalcedony vein 3505/DR/S, from locality C. Sample showed 1075 ppm leacheable U. White spots are radioactive centres. Autoradiograph prepared locally at Kota Bharu, 5 days exposure, using ASA 400 ILFORD negative.

SUMMARY OF RESULTS

Multi-element geochemical stream sediment anomalies highlighted by anomalous uranium values exist over certain granitoids and their immediate surrounding country rocks (Chu *et al*, 1982; Lee *et al*, 1982). Anomalies with uranium as the main indicator element have been delineated over parts of the Boundary Range Granite, the Senting Granite, the Benom Igneous Complex including its adjacent volcanic-sedimentary formations, and the Lower Palaeozoic schist belt bordering the Main Range Granite (Fig. 6). Practically all these geochemical anomalies are related to areas of medium to high total airborne radiometric response in excess of 200 cps (Fig. 7).

The most significant region within the limit of geochemical sampling is the Boundary Range Granite. Here eight extensive anomalies with associated uranium highs envelope large tracts of the granitic batholith where the rocks range from 0.3 to 141.0 ppm U and have a mean of 5 ppm U. Of these, Anomaly 14, which has the geochemical attributes of a porphyry system showing a central Mo-Cu core superposed by a Pb-U envelope and fringed by an annulus of Ag, Zn, As, W highs, was followed-up by a stream sediment, soil and rock geochemical survey in 1979 (Chu, 1980). During the course of this survey, some uraninite-bearing

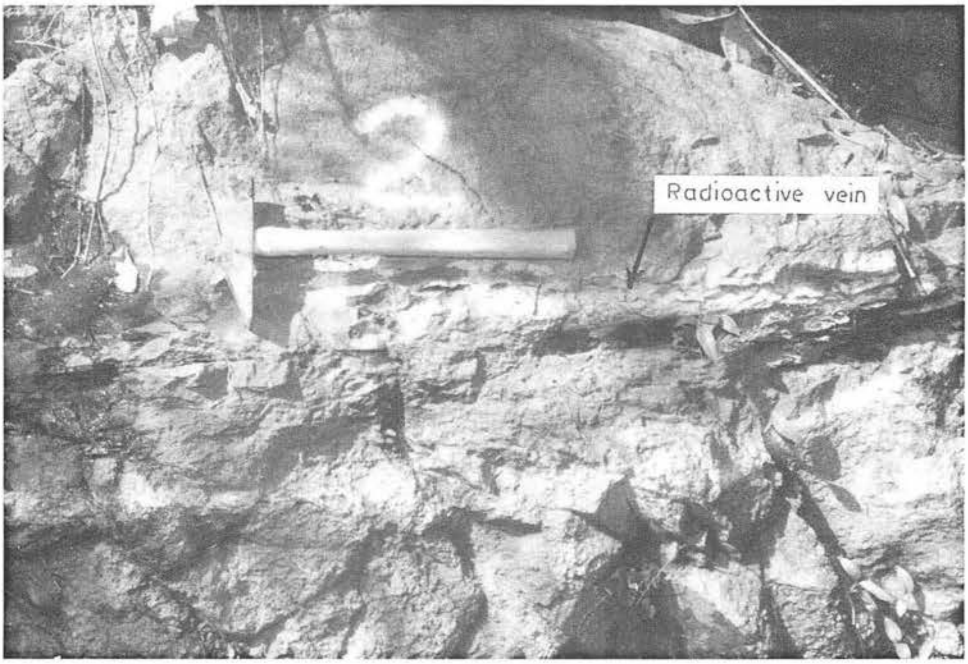

Plate 8. Printed autoradiograph of brecciated granite, specimen 3503/DR/T from locality C. Sample showed 250 ppm leacheable U. Numerous radioactive centres appear as white spots. Autoradiograph prepared locally at Kota Bharu, 5 days exposure, using ASA 400 ILFORD negative.

boulders were encountered (Chu, 1981). Lithologically they are granite and metasediment boulders carrying varying amounts of magnetite and specularite (Fig. 8, locality A; plate 1). Subsequently a radioactive 2m wide iron-stained quartz vein containing uranium-bearing florencite and rhabdophane was found (Fig. 8, locality B; Plates 2-4). An orientation study conducted over this vein showed the effectiveness of soil sampling, emanometry and track-etch techniques (Chu, 1983). Emanometry was found to be more advantageous than the track-etch method for studying soil gas activity in terms of cost and speed, with no loss of information. More recently a radioactive shear zone in granite was discovered (Fig. 8 locality C; Plates 5-10). Channel and chip samples taken from this zone show encouraging U, Mo, Pb values. Samples from this zone have been sent to the Australian Mineral Development Laboratories (AMDEL) for expert study on the nature of the uranium-bearing minerals.

CGG has demarcated a number of Priority 1 and 2 geophysical anomalies over this general area. Inspection of the various spectrometric sub-zones, viewed in conjuction with supplementary geochemical and geological evidence, suggests that those showing a dominant U + Th component, preferably with associated magnetic anomalies, offer the best targets for uranium exploration.

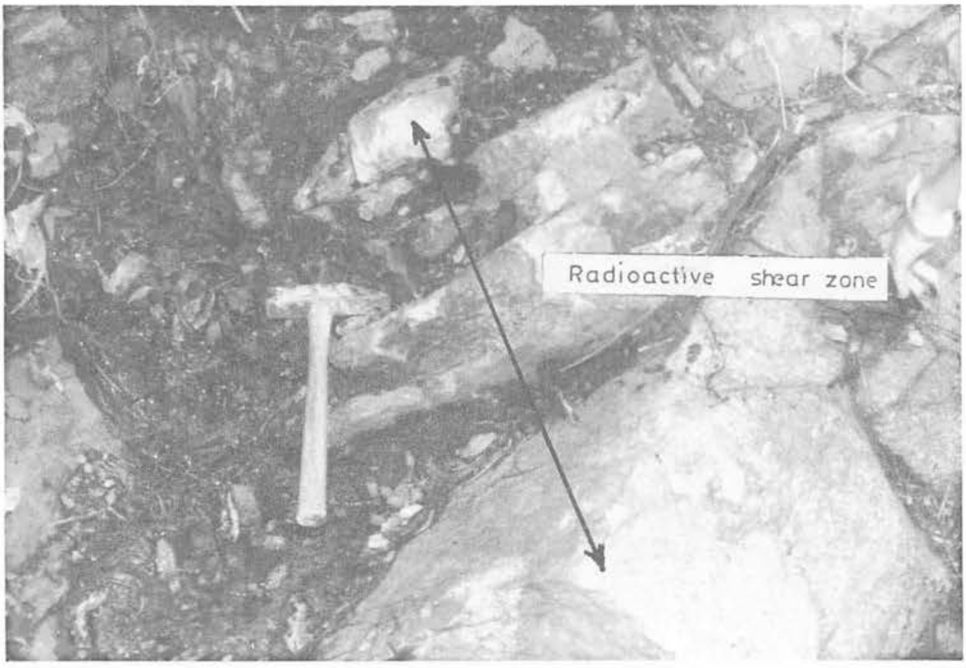

Plate 9. Radioactive shear zone in granite; total count readings range from 600-750 cps. Shear zone showed 308 ppm leacheable U over 0.5 m (Locality C).

The Senting Granite geochemical anomalies are small and discontinous, chiefly because of sampling gaps. CGG has identified two uraniferous subzones over Anomalies 7 and 8. These two geochemicall anomalies have partly been refined through detailed stream sediment, rock and stream water geochemistry, and warrant ground spectrometric traverses, especially within the subzones identified from the airborne data.

On geochemical evidence the western margin of the Benom Igneous Complex represents an important area. Anomaly 3 shows stream sediment values up to 28 ppm U and unfiltered stream water samples of up to 8 ppm U. A recent study using field-filtered, acidified stream waters from the area showed somewhat subdued values, but the anomalies nevertheless still persisted (Chand, 1981). Limited analyses of rocks showed values ranging from 0.3 to 12.9 ppm U, averaging 2.9 ppm U. No uraniferous lithologies or zones have yet been identified but uranothorite and, more recently, thorianite have been noted in the heavy mineral concentrates panned from the area (Teoh, 1981). Airborne results indicate this area as a strongly radioactive and magnetic, Priority 1 zone. CGG has similarly assigned a Priority 1 rating over geochemical Anomalies 1 and 2 at the southern margin of the Complex. This area had also been identified earlier from the 1956-57 airborne scintillation counter survey.

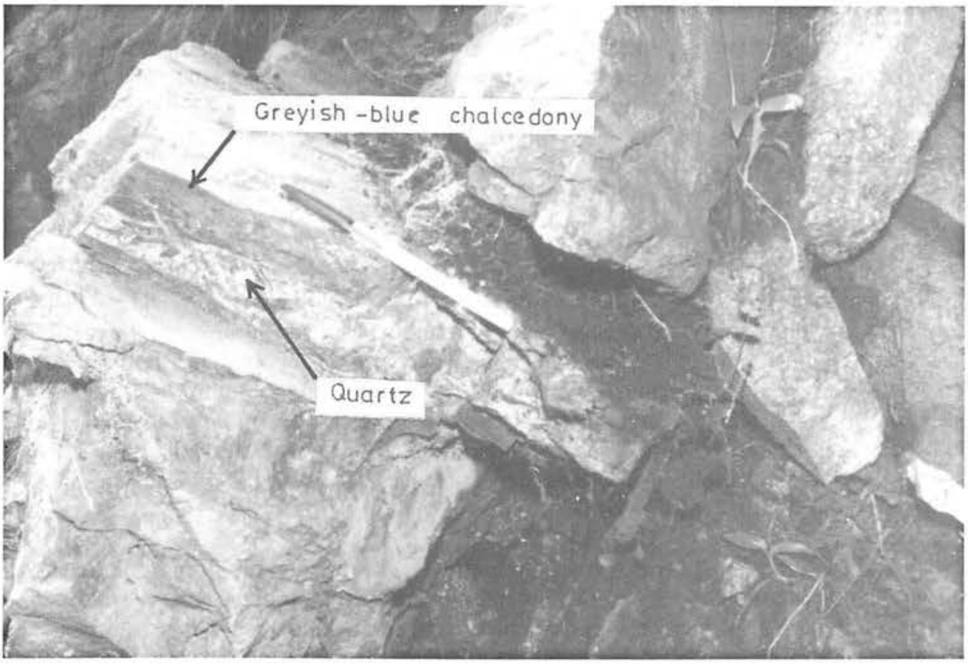

Plate 10. 15 cm wide radioactive brecciated pyrite-quartz-scheelite-molybdenite-chalcedony vein in sheared granite, locality C. Note fragments of greyish-blue chalcedony enclosed in clear quartz. Vein strikes 070°, dip 30° SSE into granite. Total count reading approximately 400 cps. Vein showed 667 ppm. leacheable U.

Radiometric response over the granitoids and their immediate surroundings is strong (Fig. 7). Prominent radioactive zones exist over the Kemahang Granite, Stong Complex and Benom Igneous Complex. Moreover spectrometric analyses indicate the common presence of uraniferous subzones. The Mesozoic continental formations, on the other hand, are not highlighted radiometrically to the same degree. Only a few, small radiometric anomalies occur. They also show a weak geochemical response for uranium, suggesting that contrary to earlier views, their significance as possible hosts for sandstone-type uranium mineralization has been considerably reduced. Nevertheless these formations possess favourable geological characteristics among which are their palaeo-environment, presence of carbonaceous trash, mudstone-siltstone interbeds in poorly sorted arenite, and the presence of acid volcanic intercalations (de Keyser, 1976). Lithological similarities and comparable facies changes with the Mesozoic Khorat Group in nearby Thailand were uranium roll fronts have been recorded, have also been cited as encouraging signs. Besides the volcanic intercalations, the surrounding and underlying granitoids and acid tuffs form potential uranium source rocks. Opinion has been expressed that these continental rocks be evaluated by a combination of reconnaissance drilling and downhole logging, a suggestion that merits some consideration before dismissing these lithologies as having no potential. Probably some of the radioactive subzones should be tested through this technique.

The Tertiary lacustrine basins with their semiconsolidated sand bodies and lignitic seams should also be considered favourable hosts for uranium (Chu *et al*, 1984). Like the Mesozoic continental formations, the underlying and surrounding lithologies include granitoids and acid volcanics, thereby ensuring a potential source of uranium. Unfortunately no geochemical sampling has been undertaken within the basins, which were also not covered by the airborne survey.

CONCLUSIONS

Uranium exploration in Peninsular Malaysia has attained greater dimensions following the implementation of the Central Belt Project by the Geological Survey. The wealth of information obtained through the geochemical sampling phase and the airborne magnetic and spectrometric survey has proved invaluable for the recognition of potential uraniferous areas. Detailed follow-up of one such area over the Boundary Range Granite in Kelantan has successfully indicated the presence of uraniferous lithologies. This finding, together with the known torbernite occurrence in the Main Range Granite and the radiometric and geochemical signatures of the granitoids in general, suggest that the search for granite-hosted uranium mineralization should be accorded priority.

The suggestion to evaluate the Mesozoic continental formations as possible uranium hosts through a combination of wildcat drilling and downhole logging probably warrants some serious contemplation, even though radiometric and geochemical responses are weak. The untested Tertiary basins should probably be similarly drill tested. Meanwhile some of the more radiometrically responsive areas not previously geochemically sampled merit systematic geochemical coverage.

ACKNOWLEDGEMENTS

The writers wish to accord their appreciation to Mr. Santokh Singh, Ag. Director-General Geological Survey Malaysia, for reviewing this report.

The Project staff at Kota Bharu, Kuantan and Ipoh are thanked for assisting in conducting the ground surveys. All geochemical analyses were done at the Ipoh Laboratories where some of the text figures were also drafted. Puan Zalipah and Abdul Wahid Harun typed this manuscript.

REFERENCES

AGOCS, W.B., 1958. *Report of airborne magnetometer and scintillation counter survey of Kedah, Perak, Selangor, Terengganu, Pahang and Johore, Federation of Malaya*. Geological Survey Malaysia Internal Report.

CHAND, F. 1981. *Orientation studies in sampling techniques for uranium*. Geological Survey Malaysia unpublished Ann. Rep.

CHU, L.H., 1980. *Anomaly 3503, Kelantan: Preliminary Report on Geochemistry*. Geol. Surv. Malaysia Internal Report (unpublished).

____, 1981. *The occurrence of radioactive boulders in Kelantan*. Geological Survey Malaysia Internal Report (unpublished).

____, 1983. *An integrated uranium follow-up survey over a radioactive quartz vein, Kelantan*. Geol. Surv. Malaysia Internal Report (unpublished).

CHU, L.H., MUNTANION, H., SIDIK, A., CHAND, F., TROUP, A., 1981. Regional Geochemistry of South Kelantan. *Geol. Surv. Malaysia Geochem. Rep. 1.*

CHU, L.H., CHAND, F., JAAFAR, A., 1984. Favourable geological environments for uranium mineralization, Peninsular Malaysia. *Jour. Geochem. Expl., 20, 205-219.*

DE KEYSER, F., 1976. *Geology and uranium potential of the non-marine Mesozoic Formations in West Malaysia and Sarawak.* Rep. on a joint AGIP/Geol. Surv. Malaysia recce. mission Sept-Oct., 1975 (unpublished).

LEE, A.K., GONZALES, R.A., HUSSEIN, T.F., CHAND, F., TROUP, A., 1982. Regional geochemistry of North Pahang. *Geol. Surv. Malaysia Geochem. Rep. 2.*

ROE, F.W., 1951. The Geology and Mineral Resources of the Fraser's Hill area, Selangor, Perak and Pahang, Fed. of Malaya, with an account of the mineral resources. *Geol. Surv. Malaysia Memoir No. 5.*

SINCLAIR, A.J., 1974. Selection of threshold values in geochemical data using probability graphs. *Jour. Geochem. Expl., 3,* 129-149.

TEOH, L.H., 1981. Thorianite from Bukit Keluang area, Raub, Pahang. *Geological Survey Malaysia Rep. No. MIN/ 2/1981.*

Manuscript received 19th October 1984.