of copper, zinc and partly arsenic. However, the relation between iron and mineralization is not clear because intrusive rocks usually contain a few percent of iron as the original content, and the two samples show higher content than that of ore sample. High values of manganese were also obtained from ore and intrusive rock samples. Some amount of manganese may have been introduced during mineralization since the ore sample shows a much higher manganese value than most intrusive rocks. The behaviour of manganese is very similar to that of copper and zinc, and also near to that of antimony and arsenic. This clearly indicate distinct correlations between copper, zinc and manganese, and between antimony, arsenic and manganese.

From the above described behaviour of metallic elements in rock samples, two distinct associations of metallic elements may be deduced, a Cu-Zn-Mn and Sb-As-Mn assemblage. This is consistent with the Cu-Zn-Fe-Mn and Sb-As-Au associations which are obtained by the factor analysis of the geochemical stream sediments data. The former shows higher contents in intrusive rocks and the latter in limestone and marble. The assemblage of Sb-As-Mn is identical to the mineralization of the Lucky Hill A and B ore deposits, and the Cu-Zn-Mn association is very similar to that of ore deposits at G. Tongga and South of G. Juala which are found in and immediately adjacent to the stock of quartz porphyry.

In the rocks around the ore deposits, the concentration of metallic elements with the same assemblages as that of the ore deposits, suggest not only some dispersion of metallic elements into the host rock, but also that mineralization is clearly related to the intrusive rock in this sampled area.

If this is accepted, geochemical rock sampling may be one of the most efficient method of exploration in the survey area where soil development is lacking, and mining and human activities present serious contamination problems.

2–6–4 *Result of X-ray Diffractive Analysis*

X-ray diffractive analysis was conducted for 16 samples to identify some of the gangue and alteration minerals of stibnite-calcite veins which contained calc-silicate minerals and of altered dike rocks and their limestone wall rock. All samples are from the Lucky Hill mine area.

The localities of the samples and the results of X-ray diffractive analysis are shown in Fig. II–7 and Table II–4.

Of the 10 samples collected from near the contact of quartz porphyry dike and limestone which has been altered to marble, 6 samples of gangue in veins were found to contain quartz, feldspar, calcite, sericite and chlorite, and the other four of marble, only quartz and calcite without alteration minerals. Pyrite was also detected in three samples of the dike rock

Table II—4 Results of X-ray Diffractive Analysis

Ser No.	Sample No.	Coordinates X	Coordinates Y	Rock Name	Macroscopic Feature	Detected Mineral Q	F	Cc	S	Chl	Wo	Py	As	Sb
01	AR067a	91651	5501	Marble	near contact	1	7	5						
02	AR067b	91651	5501	Marble	very near contact	1		5						
03	AR067c	91651	5501	Quartz porphyry	just contact of dyke	4	7	3	4	6		2		
04	AR067d	91651	5501	Quartz porphyry	very near contact	4	9	3	6	7				
05	AR068a	91651	5501	Marble	very near contact	1		5						
06	AR068b	91651	5501	Quartz porphyry	just contact of dyke	4	4	3	5	7		2		
07	AR068c	91651	5501	Quartz porphyry	just contact of dyke	4	7	4	6	7		1		
08	AR0109	91644	5490	Limestone	light gray, re-crystalline	1		5						
09	AR0110	91644	5490	Quartz porphyry	pale green, altered	4	9	3	6	7				
10	AR0112	91644	5485	Quartz porphyry	chilled margin of dyke	4	8	3	4	8				
11	AR0008	91637	5519	Gangue	calcite with dark-grey min.	5		5						
12	AR069b	91655	5497	Gangue	epidote-wollastonite-quartz	4		2			13			
13	AR069c	91655	5497	Gangue	calcite-sarabauite-wollastonite	3		4			11			7
14	AR070b	91637	5444	Gangue	wollastonite-skarn min.	2		3			11			
15	AR0103	91649	5499	Gangue	calcite-quartz-black min.	5		5						
16	AR0128	91636	5444	Gangue	calcite-wollastonite-skarn min.	4		4			8			

Abbreviations:

Q : Quartz F : Feldspar Cc: Calcite S : Sericite Chl: Chlorite

Wo: Wollastonite Py: Pyrite As: Arsenopyrite Sb: Sarabauite

Remark: Numeral shows number of peaks in X-ray Chart at its contact with marble. Wollastonite, garnet, epidote and other alteration and skarn minerals are absent in these samples, although rare garnet and epidote were recognized in thin section of one sample, (AR0068).

These results show that although limestone was recrystallized, alteration associated with the intrusion of dikes is very weak and only the dikes have undergone alteration such as silicification, sericitization and chloritization. They also indicate that dikes were intruded under a relatively low-temperature environment.

On the other hand, the six samples taken from the Lucky Hill mine and of the G. Krian ore deposits show the existence of quartz, calcite and wollastonite. Sarabauite, grossularite, epidote and other minerals were not detected in any samples although hand-specimens contain some of these minerals. This suggest that alteration and skarnization is very localized.

2–7 Geological Structure

2–7–1 Bedding Fabric Analysis

Bedding fabric analysis as proposed by Sugiyama (1981), is a statistical method using stereographic projection of bedding data for the interpretation of the geological structure and tectonic history of an area. The resulting stereographic plot is called a "bedding fabric diagram". This method applied to the Bau area was found to be especially useful for the understanding of its faulting and folding history.

Construction of Bedding Fabric Diagram

For the construction of bedding fabric diagram, the Wulff's net is preferred as it shows better concentration of points than the Schmidt's net. A simplified method for contouring stereographic projected data was devised by Sugiyama and involves the following basic steps:

i) Plotting of bedding attitudes on a Wulff's net (Fig. II–8);

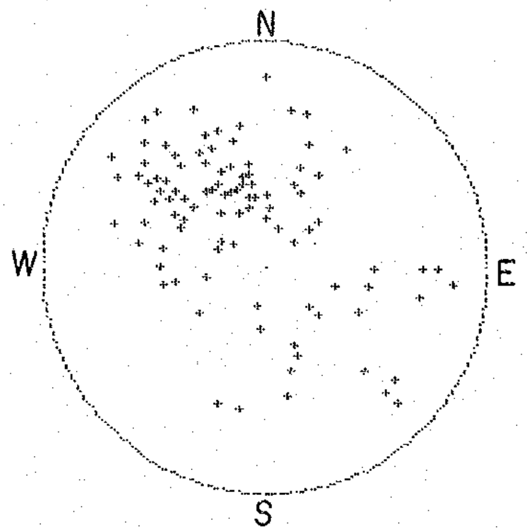
ii) Transferring pole points onto a net with 5° or 10° grids (Fig. II–8);

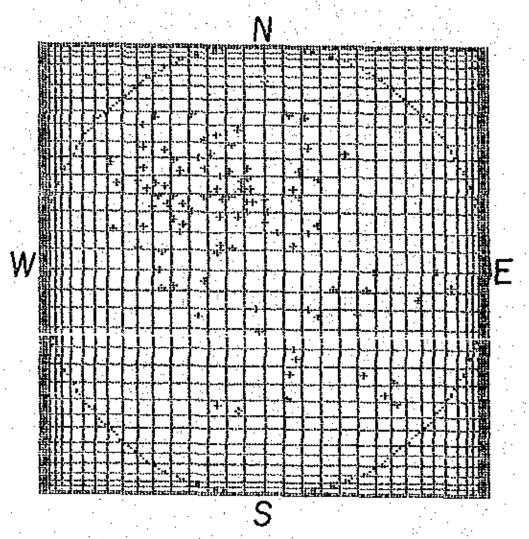
iii) Counting of the total number of points within each rectangular grid and its neighbouring 4 rectangular grids;

iv) Contouring of the points based on the total numbers of points plotted at the centre of each rectangular grid.

Interpretation of Bedding Fabric Diagrams

Based on the geology and geographic distribution of the various rock formations, the project area was divided into 6 domains, the Bau, Siniawan, Seropak, Tebang, Serikin and Skebang domains (Fig. II–9). A bedding fabric diagram was drawn for the Pedawan Formation occurring in each domain using field data of bedding attitudes (Fig. II–11). Separate





The upper diagram is stereographic projection of bedding attitudes on the lower hemisphere. The lower diagram shows a 5 grid net use for point counting.

Fig. Ⅱ−8 Example of Stereographic Projection

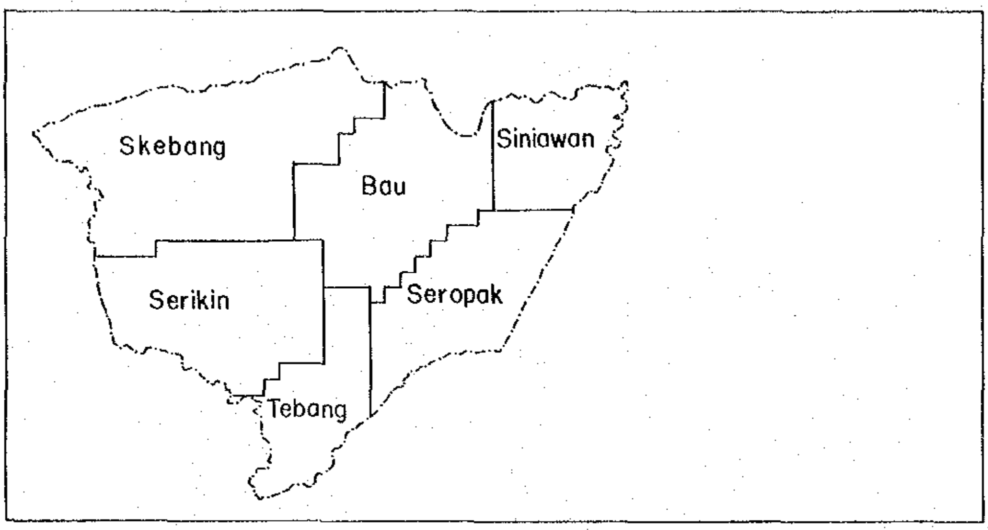


Fig. Ⅱ—9 Location Map of Domains

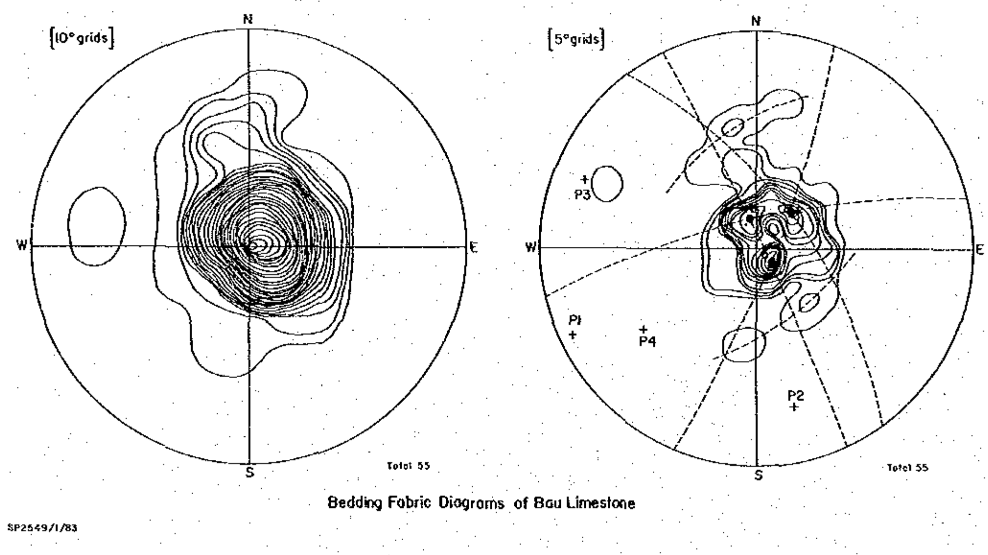


Fig. Ⅱ—10 Bedding Fabring Fabric Diagrams of Bau Limestone

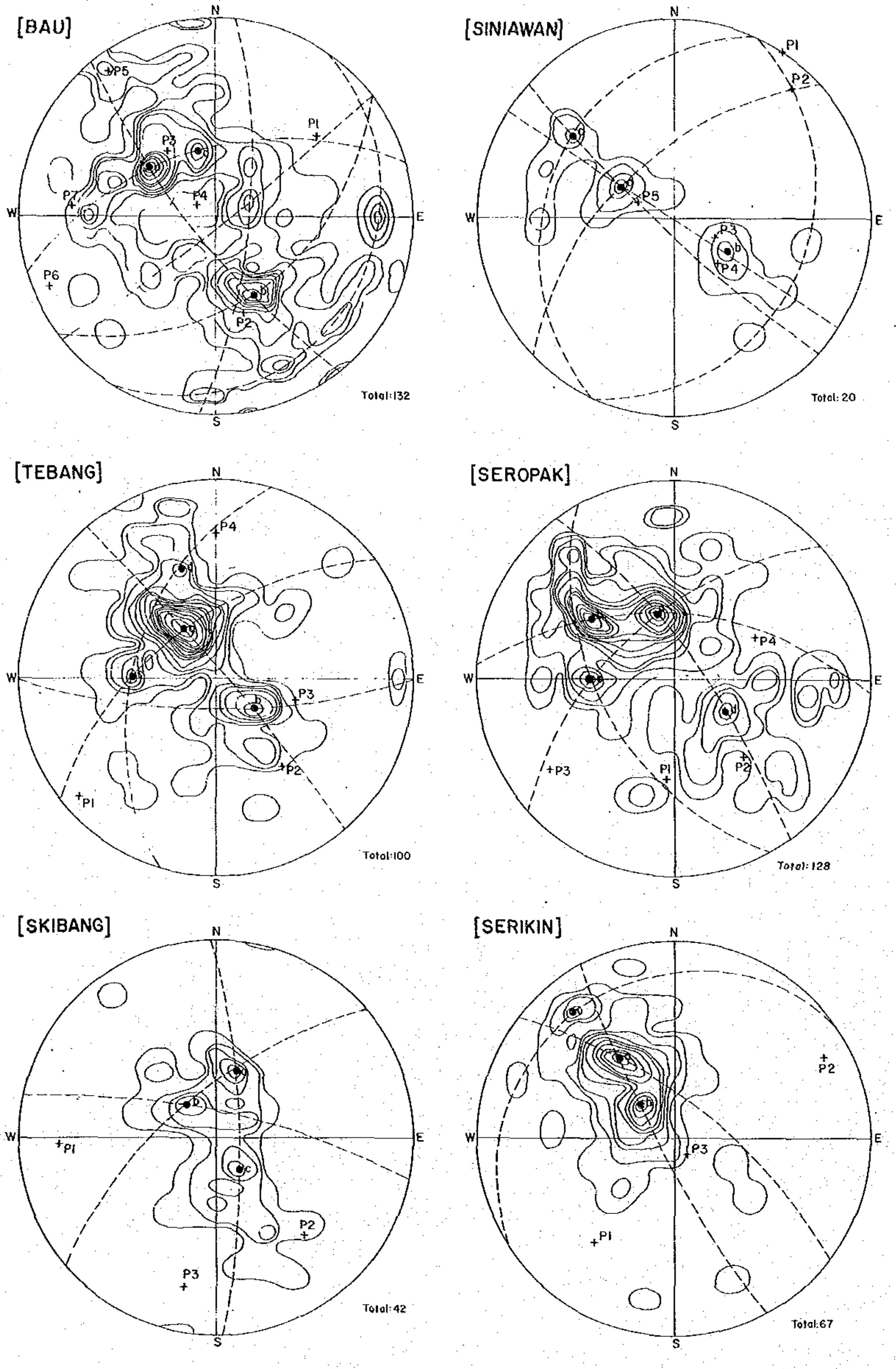


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Fig. II −11 Bedding Fabric Diagrams of Pedawan Formation

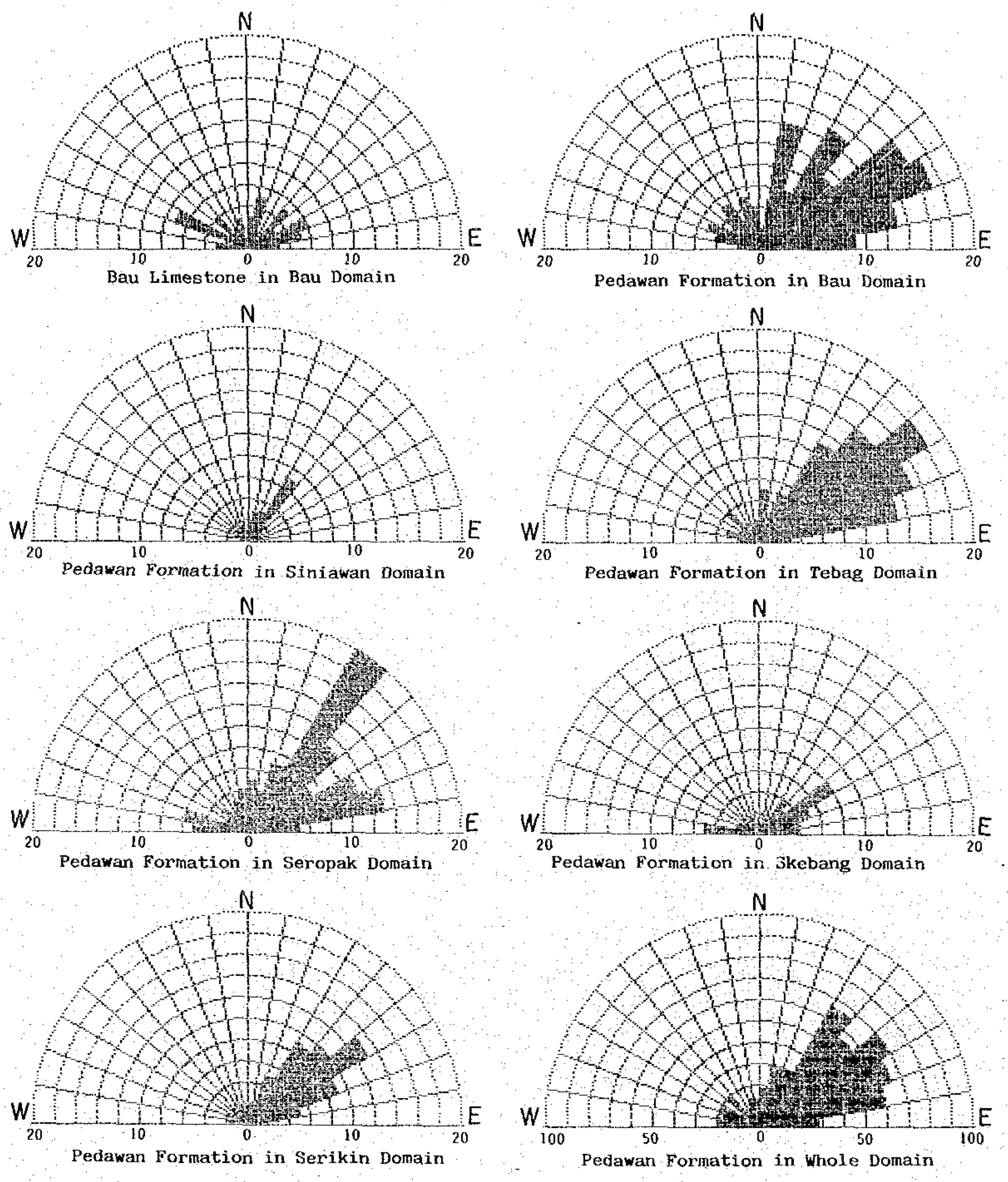

Fig. Ⅱ—12 Bedding Strike Frequencies in the Bau Limestone and Pedawan Formation

Table Ⅱ—5 Result of Bedding Fabric Analysis

Domain	Formation	No. of points	Major Concentration	Great Circle		Remarks
				Pole	Faulted/Fold	
BAU	Bau Limestone	55	a: N41E, 10NW b: N78E, 16SE c: N46W, 26SW	P1: S64W, 4SW P2: S14E, 15SE P3: N68W, 10NW P4: S53W, 25SW	Faulted Faulted/Fold Faulted/Fold Fold	connecting a to b connecting b to c connecting a to c elongation of c
	Pedawan	132	a: N36E, 34SE b: N66E, 48NW c: N76E, 37SE	P1: N52E, 25NE P2: S16E, 36SE P3: N38W, 46NW P4: N59W, 88NW P5: N37W, 5NW P6: S66W, 5SW P7: N86W, 19NW	Faulted Faulted/Fold Fold Fold Fold Faulted Fold	connecting a to b connecting a to c elongation of bb elongation of contour elongation of contour connecting b to c elongation of contour
SINIAWAN	Pedawan	20	a: N33E, 34SE b: N33E, 34NW c: N39E, 66SE	P1: N34E, Horizon P2: N42E, 7NE P3: S66E, 66SE P4: S44E, 55SE P5: N66W, 68NW	Faulted Faulted Fold Fold Faulted/Fold	connecting a to b connecting a to c elongation of c elongation of a arrangement of contour
TEBANG	Pedawan	100	a: N58E, 27SE b: N40E, 26NW c: N-S, 45E d: N72E, 60SE	P1: S50W, 5SW P2: S43E, 33SE P3: S74E, 45SE P4: N, 17N	Faulted/Fold Faulted/Fold Faulted Fold	elongation of a, connecting a to b elongation of a, connecting a to b connecting c to d elongation of b
SEROPAK	Pedawan	128	a: N76E, 38SE b: N37E, 53SE c: N-S, 45E d: N32E, 34NW	P1: S4W, 35SW P2: S43E, 35SE P3: S54W, 15SW P4: N62E, 40NE	Faulted/Fold Faulted Faulted Faulted/Fold	connecting a to b, elongation of contour connecting a to c connecting a to d connecting a to others, elongation of contour
SKEBANG	Pedawan	42	a: N76W, 38SW b: N48E, 24SE c: N59E, 22NW	P1: S88W, 12SW P2: S50E, 24SE P3: S12W, 15SW	Faulted/Fold Faulted Fold	connecting a to c, elongation of contour connecting a to b elongation of b
SERIKIN	Pedawan	67	a: N56E, 50SE b: N44E, 26SE c: N52E, 78SE	P1: N62E, 8NE P2: S37W, 22SW P3: S36E, 78SE	Fold Faulted Fold	elongation of a connecting a to b elongation of c

bedding fabric diagrams were also made for the Bau Limestone and rose diagrams of the bedding strikes of the Pedawan Formation constructed for all of the 6 domains (Figs. II–10 and 12).

Structural characteristics of each domain which may be interpreted from the diagrams are shown in Table II–5.

i) Bau. The Bau Limestone in this domain appears to form a dome according to the 10° grid diagram (Fig. II–10, left). The same data on a 5° grid diagram (Fig. II–10, right), however, shows three close concentrations of gentle beddings which may be interpreted as a gentle domal type of folding with slight faulting. The Pedawan Formation has steeper dips and is folded and highly faulted. Three sets of folds may be inferred, a set with NE axial trends, a NNW to NW set and an E set. The NE folds plunge towards the NE (P1) and their crests are hinged and cut by strike faults. The NNW to NW trending folds are open and cut by NE faults. They plunge mainly towards the NW (P3, P4, P5) with a large group plunging moderately towards the SE (P2). The E trending set plunges gently towards the W (P7).

There are at least 2 sets of faults in the area, a NE and NW to NNW set.

ii) Siniawan. The Pedawan Formation in this domain strikes NE and is folded and faulted. 2 sets of folds may be inferred, a NE set with nearly horizontal plunge towards the NE (P1, P2) and a NW to NNW set plunging mainly towards the SE (P3, P4, P5). The folds are cut by NE trending faults.

iii) Seropak. The Pedawan Formation in this domain strikes generally NE and ENE with moderate to steep dips towards the south. The dominant folds are NE trending, plunging towards both the SW and NE (P3, P4), and SE trending plunging towards the SE (P2). A north trending set plunging towards the south may also be inferred (P1). All the 3 sets of folds in the area are cut and hinged by NE and NW trending faults.

iv) Tebang. The Pedawan Formation in this domain also strikes generally NE with moderate dips towards the south. Folds are similarly to those in the Seropak domain with dominantly NE and NW axial trends, plunging towards the SW and SE respectively (P1, P2). Strike faults cut the crests of the faults.

v) Serikin. The Pedawan Formation in this domain strikes generally NE and dips moderately to steeply towards south. The dominant set of folds has NE axial trends (P1) plunging towards the SW and is cut by NE strike faults. NW folds may also be inferred.

vi) Skebang. The Pedawan Formation in this domain generally strikes east with gentle to moderate dips towards north and south. A dominant east trending fold set plunging towards the east may be inferred (P1) but this may not be a general case for the area as the data available is not evenly distributed over the area.

The structural characteristics of the Bau area resulting from the bedding fabric analysis discussed, may be summarized as follows :

i) The Bau Limestone in general, dips very gently in comparison to the overlying Pedawan Formation.

ii) The extensive Pedawan Formation in the area underwent complex folding and faulting.

iii) The dominant folds of the Pedawan Formation have NE and NW axial trends.

iv) The Bau domain in which most of the known old mine workings are found, most probably represents the area where a major NE trending anticline interferes with a major NW trending anticline.

2–7–2 *Faults*

The project area, particularly the limestone hill area, are traversed by many faults which may be classified into 4 groups based on their trends, apparent movements and lengths :

i) WNW to W trending faults

ii) NE to E trending faults

iii) NNE trending faults

iv) NW to N trending faults

WNW to W Trending Faults

This group of faults which are mainly inferred from airphotos, are confined to in and around the Jagoi grandiorite. The longest of this group bordering the northern margin of the grandiorite may be traced from the Indonesian border to Pangkalan Jagoi. The faults are probably cut by NW faults.

NE to E Trending Faults

These are strike faults developed in the Pedawan Formation. Because the Pedawan is poorly exposed, such faults are not commonly observed in the field but in all likelihood are more intensively developed than indicated. In the Tebang area, these faults appear to have provided the structural control for the emplacement of the Tertiary intrusives. The faults are mostly steeply dipping to vertical and are obviously cut by NW to N faults. Most are reverse faults as may be observed in an outcrop at the upper reaches of S. Ma-an, a tributary of S. Sta'at where 2 reverse faults dipping 30° and 35° toward the south and southeast are exposed. In S. Sekam, a tributary of S. Pedan-un, a reverse fault dipping 35° to 40° to the SSE were encountered. Some probably reverse, parallel faults steeply dipping to the NNE were also observed at the foot of the G. Undan range.

NNE Trending Faults

These faults are confined to the limestone hill area around Bau town and cut obliquely the so-called "Bau Anticline". They form several long parallel faults among which is the Tai Parit Fault where some well known mine workings such as the Tai Parit, Saburan and Tai Ton are located. The NNE faults appear to play an important role as channels for mineralization but not for the intrusion of dikes. This may indicate that the widths of these faults (shear) whilst suitable for channelling ore solution, is not so for acidic magma. Some NNE faults continue as ENE to E trending faults probably as a result of a change of rock type from limestone to shale and sandstone.

NW to N Trending Faults

These generally, steeply dipping faults are widely distributed in the project area and are the youngest being not cut by other faults. In the limestone area, they are intruded into by Tertiary dikes which may indicate that the original widths (tensional) were suitable for magma emplacement.

2–7–3 Folds

The project area is characterized by the large scale "Bau Anticline" and numerous small scale folds which developed only in the Pedawan Formation. The ENE Bau anticline largely governs the present distribution of the various rock units in the area.

Its crestal parts composed predominantly of the Bau Limestone and pre-Upper Jurassic rocks are distributed over 2 main areas along the axis of the anticline, the Jagoi granodiorite area and the Limestone hill area. The uneven distribution of these rocks along the axis, suggests a later superimposed folding of the axis. This corroborates the results of bedding fabric analysis discussed earlier, from which was inferred that there is a set of NW trending folds in addition to a NE to ENE set which is represented mainly by the Bau Anticline. Folds however, are not clearly recognisable in the Bau Limestone and may be explained probably by the competency of limestone which makes it more amenable to faulting rather than folding.

The Pedawan Formation on the other hand, developed many small scale folds with NE to ENE axial trends parallel to the Bau Anticline. These folds are most likely congruent folds which may have slipped and formed over the underlying Bau Limestone. The actual relationship however, has not been observed in the field.

2–7–4 Trend of Tertiary Intrusives

The shapes of the Tertiary stocks in the areas of the Bau and Siniawan domains are distinctly different in plan view from those in the Tebang area. Whereas those forming G. Juala, G. Ropih, G. Bekajang, G. Serambu and G. Sirenggok in the north show generally circular shapes, those forming G. Tra-an, G. Ngian, G. Duyan, Bt. Tebang, G. Badud, G. Api, Bt. Buan Bidi and G. Orat in the south, are elliptical in shape. The difference is inferred to be a result of intrusions at the intersections of NW and NNE faults in the former area and along ENE strike faults in the latter area. The elongation trends of the stocks in the south are also clearly consistent with the general strike trend of the Pedawan Formation (Fig. II–13).

The regional NNE alignment of the Tertiary stocks cannot be related to any tectonic line other than the NNE faults in the limestone area. Results of the bedding fabric analysis and interpretation of landsat imageries over the area also do not indicate any major structural lineament coincident with the NNE alignment. It is therefore suggested that this trend is probably controlled by a deeper tectonic line such as a major boundary between buried basement rocks or a major fracture zone in these rocks.

As indicated previously, the trend of Tertiary dikes are similar to those of the faults, being controlled mainly by them.

2–7–5 Stress Field

To restore the paleo-stress field which existed in Late Cretaceous times when most of the main structural features were produced, the following would be important aspects to be considered :

i) The ENE trending Bau Anticline;

ii) The small-scale folds of the Pedawan Formation with axial trends parallel to that of the Bau Anticline;

iii) The observation that most of the NE to E faults are reverse faults;

iv) The indication that some of the faults of (iii) were produced as a result of a folding episode;

v) The observation that NW to N trending faults especially in the limestone hill area show no displacement and are mostly intruded into by Tertiary dikes.

When considered in the light of the above, it may be inferred that the project area during Late Cretaceous time was subjected to a compression stress field with its principal stress axis directed from the NNW and SSE. This produced the Bau Anticline and the small-scale congruent

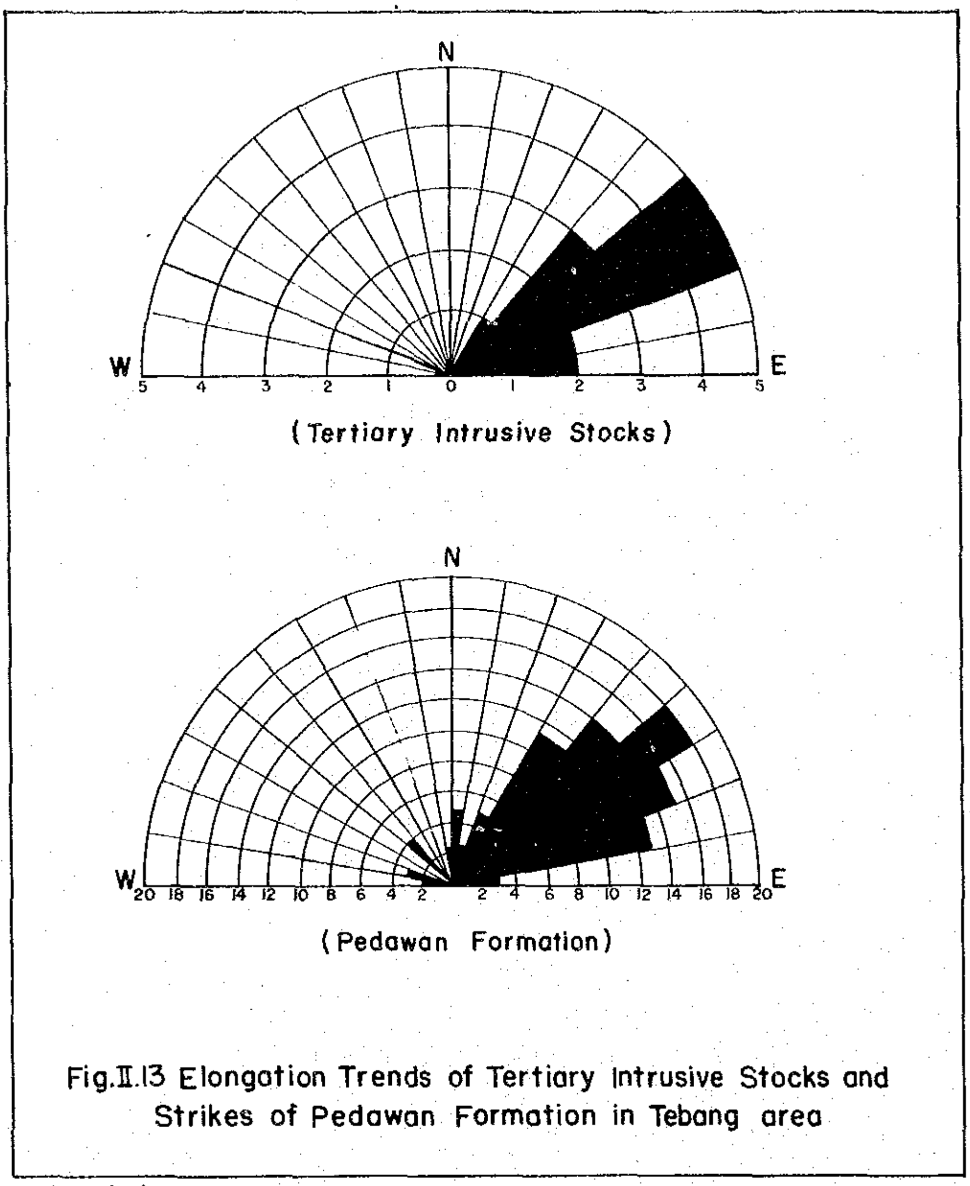

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Fig. II—13 Elongation Trends of Tertiary Intrusive Stocks and Strikes of the Pedawan Formation in the Tebang Area folds of the Pedawan Limestone. Tight NE to E faults and tensional NW faults with little displacement were also produced under the same stress field.

2–7–6 Conclusions

From the foregoing discussions, the main structural features of the project area may be summarized as follows :

i) The ENE Bau Anticline largely governs the present distribution of the various rock units in the area. This anticline was produced under a compression stress field with its principal stress axes directed from the NNW and SSE ;

ii) The same stress field also produced many small-scale congruent folds in the Pedawan Formation ;

iii) There is also a set of folds with NW axial trends ;

iv) 4 sets of faults may be distinguished in the area, a WNW to W, NE to E, NNE and a NW to N set. The ENE to E faults largely controlled the elongated shapes of the Tertiary stocks in the south. In the limestone area near Bau town, Jambusan and Bt. Pangga, the general circular shapes of the stocks indicate intrusions at the intersections of NW and NNE faults. The NNE faults in the limestone hill area apparently acted as suitable channels for mineralizing solutions whereas the NW faults, the youngest set, being more open (tensional), were intruded into by Tertiary dikes. ENE to E faults are strike faults parallel to the general strike trend of the Pedawan Formation. They are mainly reverse faults.

v) The regional NNE alignment of the Tertiary stocks cannot be related to any major tectonic line. It is suggested that this trend may be controlled by a tectonic line such as a major boundary between buried basement rocks or a major fracture zone in these rocks.

2–8 Geological History

The oldest rocks in the project area is almost certainly the Jagoi granodiorite. This intrusion in pre-Late Triassic times was followed by uplift and subsequent erosion. After a period of peneplanation and slight subsidence, deposition of estuarine to shallow marine sediments in the adjacent Penrissen and Kuap areas took place. There is however, no evidence of this event in the Bau area. The deposition was accompanied by widespread volcanism in Late Triassic in the region to the east. In the Bau area, this volcanic activity is represented by only a small occurrence of andesite in the upper reaches of Ulu S. Siniawan.

After uplift and erosion, sedimentation recommended in Late Jurassic with the deposition initially of sandstone in small basins. Continued subsidence gave excess to the sea resulting in the development of limestone reefs and an extensive carbonate shelf. Limestone deposition (the Bau Limestone) was probably brought to an end by further subsidence and the subsequent influx of sediments in Early Cretaceous. Deposition of these sediments of mainly shale and sandstone of the Pedawan Formation continued till Late Cretaceous when volcanism took place and gave rise to the thick beds of tuff and tuffaceous near the top of the Pedawan Formation. Volcanism was accompanied shortly by gentle NW folding and uplift.

The Bau area was again subjected to intense compression from NW and SE directions probably at the end of late Cretaceous time. This resulted in strong folding and faulting. The major Bau Anticline, the small-scale folds in the Pedawan Formation and most of the faults in the area were developed.

Large synclinal troughs formed subsequently, became the sedimentary basins for the deposition of the Kayan Sandstone. By Miocene time, the major topography of the area had been formed. At about this time, intrusion of stocks, dikes and sills and extrusion of minor volcanics took place accompanied by mineralization especially near the intersection of west of the Bau Anticline and the NNE alignment of the intrusive stocks.

Erosion of the area since the Miocene continued to the present day.

CHAPTER 3. ORE DEPOSITS

3–1 General Statement

Geological and geochemical surveys, as well as compilation of existing data confirm and disclose the existence of numerous ore deposits including old mine workings and mineralized zones in the Phase I survey area (Fig. II–14).

The ore deposits occurring in the area, are considered to be of the epithermal vein-type, related genetically to the igneous activity of Miocene time. They can be divided into three groups, namely gold-antimony, gold-bearing copper-lead-zinc and mercury deposits based on the assemblage of the main metallic minerals.

The gold-antimony ore deposits are restricted to occur in the Bau Limestone, exposed mainly from Bau to Krokong. It is concentrated particularly in the area between the north-northeast trending alignment of Tertiary intrusives and the Tai Parit Fault and in the area just west of the fault. This area forms a zone approximately 10 km in the NE–SW and 2.5 km in NW–SE directions. On the eastern side of the Tertiary intrusive alignment, only a few ore deposits are known near Jambusan and north of it. In addition, most of the gold-antimony ore deposits occurring in the limestone flats show a distinct tendency to concentrate near the contact with the overlying Pedawan Formation. However, no deposits have been found in that formation.

A few gold-bearing copper-lead-zinc ore deposits are found in a quartz porphyry stock and the limestone immediately adjacent to that stock, which intruded into the approximate centre of the gold-antimony ore deposit zone. From the viewpoint of zonal arrangement of metallic ore deposits, this seems to suggest that the base-metal ore deposits form the centre of mineralization in the limestone area.

Two known mercury ore deposits show a geological environment quite different from those discussed. The deposits were formed in brecciated shale and sandstone of the Pedawan Formation, close to intrusive stocks.

The characteristic features of ore deposits distributed in the survey area are described and discussed in detail in the following sections. The overall results of chemical analysis for ore samples are shown in Table II–6.

3–2 Description of Ore Deposits

During the Phase I survey, some ore deposits were mapped and investigated in detail. Their occurrences, scale and nature were clarified. Unfortunately, most of the ore deposits

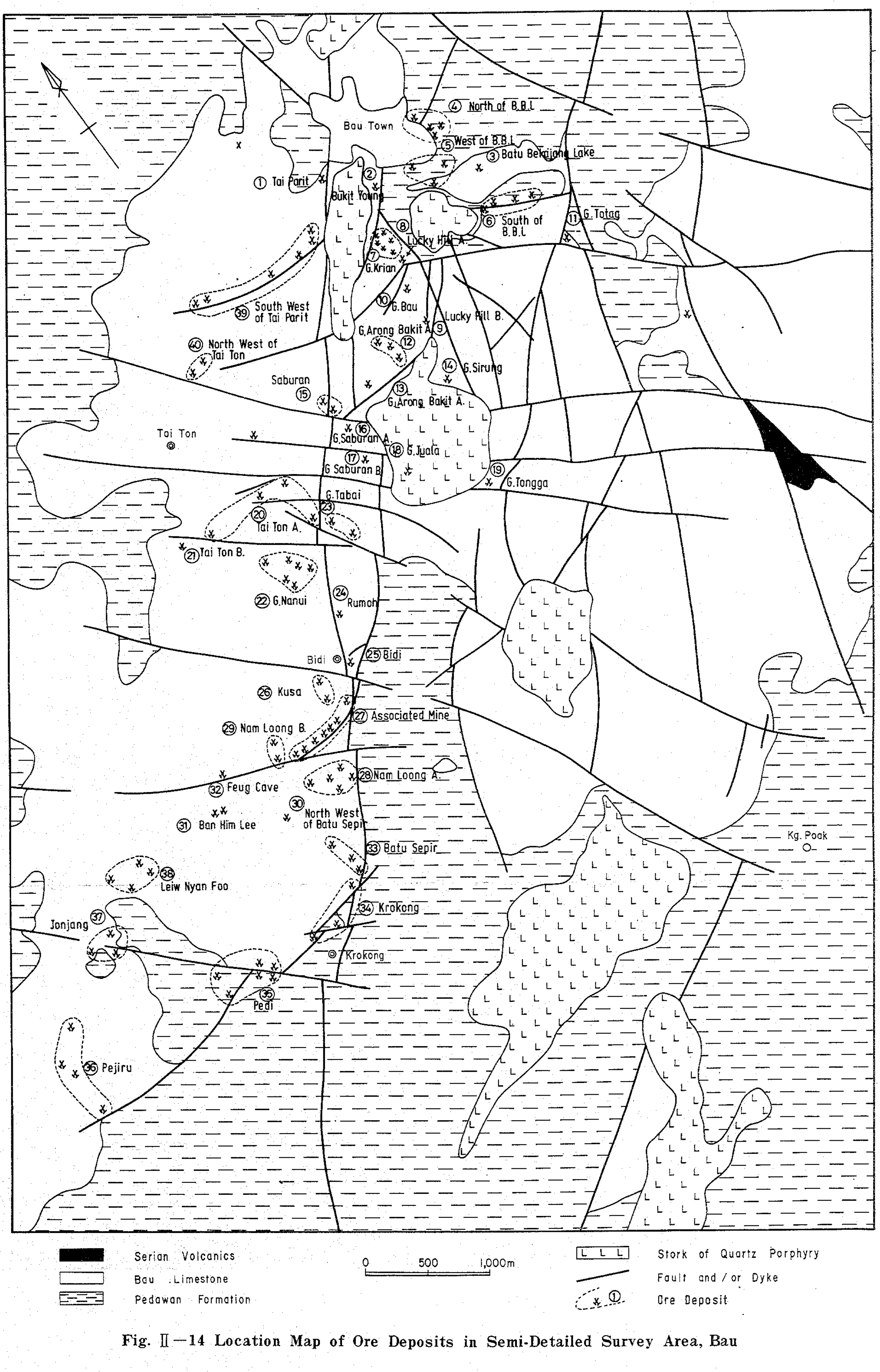


Fig. Ⅱ—14 Location Map of Ore Deposits in Semi-Detailed Survey Area, Bau

Table Ⅱ−6 Results of Chemical Analysis of Ore Samples

Area	Ser. No.	Sample No.	Coordinates X	Coordinates Y	Sample Locality	Macroscopic Feature	Au g/t	Ag g/t	Cu %	Pb %	Zn %	Sb %	As %	Hg ppm
Semi-detailed Area	001	AR0007	91637	5519	G. Krian	zb-ga-calcite vein	2.3	52.3	0.02	0.20	3.54	0.14	NA	NA
	002	AR0008	91637	5519		py-sb-calcite vein	24.0	17.2	tr.	0.16	0.07	0.11	NA	NA
	003	AR0021	91143	5322	Kg. Boring	brecciated, with sb-py-calcite veinlets	2.1	8.1	0.02	0.14	0.05	0.23	NA	NA
	004	AR032a	91590	5310	G. Tongga	galena and sphalerite rich ore	7.0	268.0	1.54	5.39	4.25	0.46	NA	NA
	005	AR032c	91590	5310		pyrite-arsenic rich ore	3.3	129.0	0.64	2.62	1.20	0.26	14.28	NA
	006	AR032d	91590	5310		py-zb-calcite ore	20.0	84.3	0.24	4.05	7.90	tr.	NA	NA
	007	AR0043	91572	5110	(boulder at G. Ropih)	vein quartz with py-sb	1.3	9.8	0.02	0.45	0.60	0.52	NA	NA
	008	*AR0049*	*91390*	*5250*	Kusa	*channel sample*	tr.	tr.	tr.	*0.01*	tr	tr.	NA	NA
	009	AR0050	91390	5250		channel sample	0.7	tr.	tr.	0.01	tr.	0.02	NA	NA
	010	AR0051	91390	5250		channel sample	tr.	tr.	tr.	0.02	tr.	0.03	NA	NA
	011	AR0052	91390	5250		channel sample	tr.	tr.	tr.	0.02	tr.	tr.	NA	NA
	012	AR0053	91400	5265		stocked ore (crushed)	9.0	18.0	tr.	0.01	0.03	1.69	11.15	19.3
	013	AR054d	91400	5265		stibnite and realgar rich ore	20.0	237.0	0.18	0.03	0.01	13.10	17.89	NA
	014	AR054e	91400	5265		stibnite and arsenic ore	24.0	272.0	0.08	0.01	0.02	2.10	7.48	NA
	015	AR054f	91400	5265		realgar rich calcite vein	74.4	211.0	tr.	0.04	0.01	0.53	46.44	NA
	016	AR054g	91400	5265		banded black mineral and calcite ore	0.2	26.1	0.01	0.01	tr.	1.26	1.38	14.2
	017	AR054h	91400	5265		brecciated, black limestone with calcite	6.0	14.7	tr.	0.02	0.01	1.22	NA	NA
	018	AR058a	91322	5221	Nam Loong	light brown-coloured clay ore	0.2	tr.	tr.	0.01	0.01	tr.	NA	NA
	019	AR058b	91322	5221		vein calcite in clay ore	4.2	16.2	tr.	0.03	0.01	0.17	NA	NA
	020	AR059c	91328	5233		clay ore	65.2	43.8	tr.	tr.	0.01	5.71	NA	NA
	021	AR059d	91328	5233		clay ore	2.4	tr.	0.01	0.01	0.04	tr.	NA	NA
	022	AR061a	91397	5225	Associated Mine	sb-quartz ore	69.6	29.1	0.01	0.03	0.01	1.36	1.91	NA
	023	AR061b	91397	5225		sb-arsenic ore	20.4	89.8	tr.	1.09	0.10	1.78	NA	NA
	024	AR062a	91435	5291	Rumoh	clay ore	6.0	124.0	0.03	0.25	0.06	0.01	NA	NA
	025	AR063b	91435	5291		*black banded vein calcite*	*5.5*	*tr.*	*tr.*	*0.01*	*0.02*	*0.14*	*NA*	NA
	026	AR065a	91651	5501	Lucky Hill (A)	channel sample	6.0	35.2	0.01	tr.	0.04	53.92	NA	NA
	027	AR065c	91651	5501		channel sample	14.1	150.0	tr.	tr.	0.01	36.02	2.03	NA
	028	AR069a	91655	5497		fine-grained sb-epidote ore	7.6	21.7	0.01	0.03	0.01	4.61	1.70	NA
	029	AR069d	91655	5497		sarabauite and stibnite ore	3.6	8.1	tr.	tr.	0.01	11.90	2.81	NA
	030	AR070a	91637	5444	Lucky Hill (B)	massive stibnite ore	15.3	148.0	0.02	tr.	0.05	15.38	1.65	NA
	031	AR070b	91637	5444		sb-wollastonite-calcite ore	5.1	17.6	tr.	tr.	0.02	14.02	NA	NA
	032	AR083a	91410	5415	Tai Ton (A)	sb-realgar-calcite vein	17.5	tr.	tr.	tr.	0.01	0.07	10.32	NA
	033	AR083b	91410	5415		black mineral-calcite vein	14.9	tr.	tr.	0.05	tr.	0.14	NA	NA
	034	AR0084	91410	5415		stibnite rich, arsenic ore	8.2	1.6	tr.	tr.	0.01	1.01	NA	NA
	035	AR0086	91361	5409	Tai Ton (B)	black calcite vein	1.1	tr.	tr.	tr.	0.01	tr.	NA	NA
	036	AR0087	91361	5409		brown clay ore	5.7	7.0	0.03	0.02	0.10	0.04	NA	NA
	037	AR0089	91361	5409		clay ore	13.8	19.0	0.03	0.67	0.11	0.20	NA	NA
	038	AR0090	91361	5409		channel sample	8.4	tr.	tr.	tr.	tr.	tr.	NA	NA
	039	AR0091	91361	5409		channel sample	1.4	tr.	tr.	0.01	tr.	tr.	NA	NA
	040	AR0092	91361	5409		channel sample	1.1	tr.	tr.	0.01	tr.	tr.	NA	NA
	041	AR0093	91361	5409		channel sample	1.8	tr.	tr.	0.01	tr.	0.01	NA	NA
	042	AR0094	91523	5447	Saburan	channel sample	9.7	tr.	tr.	0.01	tr.	tr.	NA	NA
	043	AR0098	91526	5428		py-aspy in black vein calcite	77.6	8.1	tr.	0.02	tr.	tr.	1.53	17.3
	044	AR0100	91527	5427		py-aspy in black limestone	5.9	tr.	tr.	0.02	tr.	0.04	1.04	48.0
	045	AR0101	91527	5427		red-coloured ore	1.6	tr.	tr.	0.05	0.01	0.04	NA	NA
	046	AR0103	91649	5499	Lucky Hill (A)	sb-py-calcite vein	4.2	27.5	tr.	0.26	0.06	0.36	0.37	NA
	047	BR0003	91727	5492	South of Bt. Bekajang Lake	py-sb-aspy-calcite vein	33.2	85.0	0.03	0.65	0.90	0.33	3.98	NA
	048	BR0007	91266	5213	Ban Him Lee	fibrous stibnite in brecciated l.s.	8.9	3.3	tr.	0.01	0.01	0.04	5.43	NA
	049	BR0008	91031	5119	Pejiru	py-calcite-quartz vein	3.2	3.2	tr.	0.04	tr.	0.12	NA	NA
	050	BR0009	91034	5111		quartz, calcite and pyrite ore	7.6	tr.	tr.	0.01	0.02	0.04	NA	NA
	051	BR0017	91483	5326	G. Tabai	black calcite ore	1.1	tr.	tr.	0.03	0.03	0.01	NA	NA
	052	BR0020	91485	5337		py-calcite-quartz vein	11.7	37.6	0.03	0.72	0.84	0.07	NA	NA
Reconnaisance Area	*053*	*AR0075*	*91780*	*5765*	G. Sirrenggok	py rich ore in sandstone	*0.2*	6.5	*0.02*	*0.02*	*1.90*	tr.	*NA*	NA
	054	AR0078	92015	5680	boulder (near Jambusan)	py rich ore in conglomerate	0.2	tr.	tr.	tr.	tr.	tr.	NA	NA
	055	JR0011	91700	4427	Tegora	gray, muddy rock with cinnaber	tr.	tr.	0.01	tr.	tr.	0.06	0.78	23100
	056	SR0061	91090	4265	Gadin	py-realgar in brecciated zone	0.2	tr.	tr.	tr.	0.01	0.51	1.62	NA
	057	SR0075	92775	5665	SW of Bt. Skunyit (boulder)	sb-patch in gangue	0.4	1.6	tr.	tr.	tr.	8.49	NA	NA

Abbreviations :

sb : stibnite, py : pyrite, zb : zineblende, ga : galena, aspy : arsenopyrite and old mine workings have been flooded and concealed by thick vegetation and alluvium, and it was not possible to examine the details of the deposits. Most known ore deposits have been studied and reported by Wilford (1955), Wolfenden (1965), Pimm (1967) and other geologists and mining companies.

In this section, the main ore deposits and mine workings investigated during Phase I, are described. Descriptions of other known deposits are summarized in Tables A–6 and A–7. These descriptions are based mainly the above-mentioned previous reports and other relevant published and unpublished data of the Geological Survey of Malaysia, Sarawak.

3–2–2 *Ore Deposits in Semi-detailed Survey Area*

(1) Lucky Hill A Ore Deposit

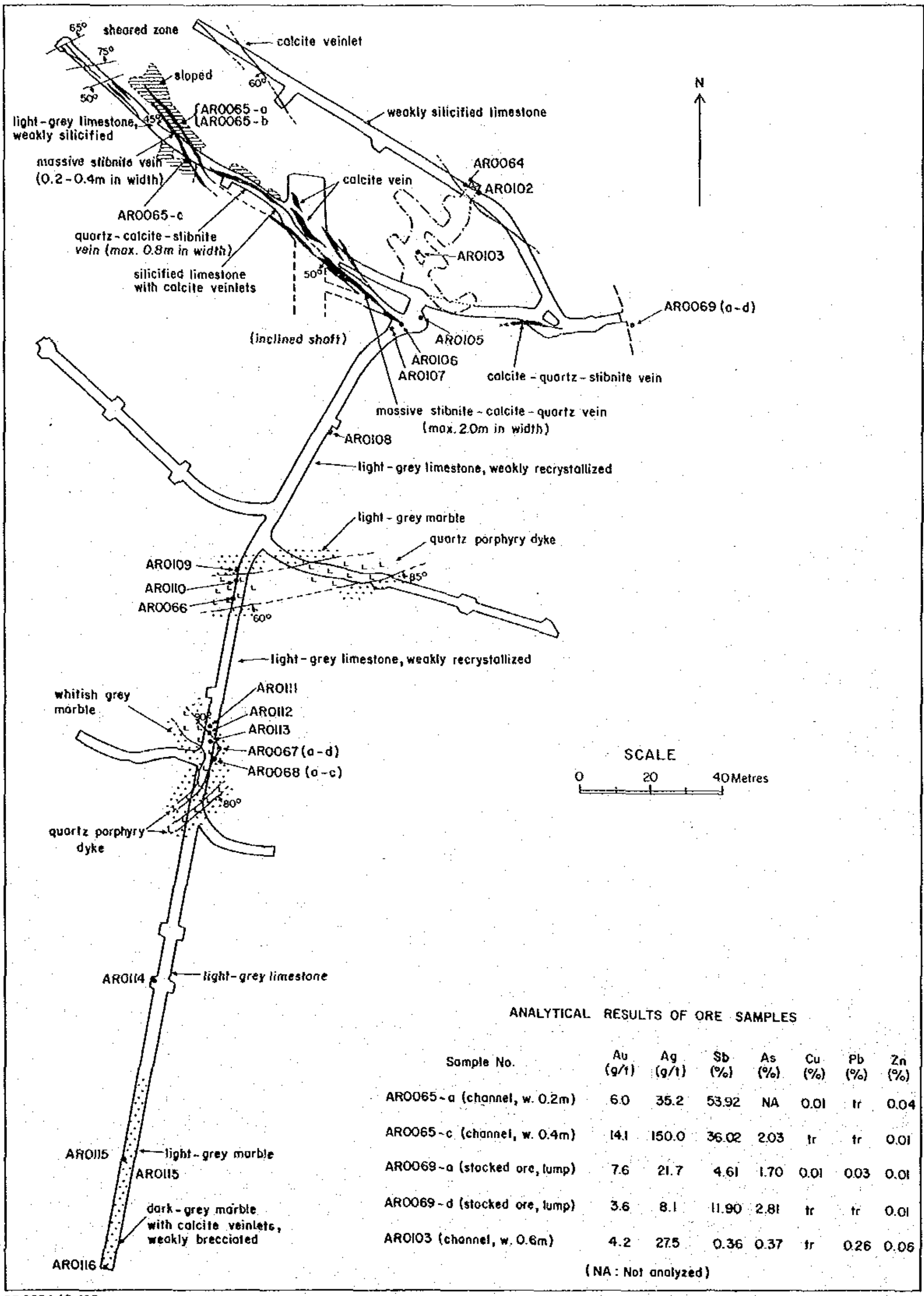
The mine, located about 1.2 km south of Bau Town, was formerly operated during the 1960's by the Kwei Fah Mining Company with a production of about 130 t of 40% Sb ore. The property was later taken over by the Lucky Hill Mining Sdn. Bhd. which produced about 5,000 t of 60–68% Sb ore concentrates until it ceased operation in 1982.

The geology of the mine area consists of massive limestone and marble of the Bau Limestone intruded by small quartz porphyry dykes. The limestone is in fault contact with shale and sandstone of the Pedawan Formation near the entrance of the main level adit. Dykes of quartz porphyry are found in the cross-cut adit towards the south. They have been subjected to alteration and very weak metallic mineralization.

As shown in Fig. II–15 the ore deposit at the mine occures only in limestone and its extent is approximately 150 m in strike and 110 m in dip. The deposit may be considered to be of the vein and lenticular replacement types on the basis of the mode of occurrence and mineral assemblage.

The vein-type antimony ore body consists of fracture-filling quartz-calcite veins trending NW–SE to WNW–ESE along fractured or shattered zone in massive limestone. These veins are usually small and normally less than 50 cm in widths and a few tens of meters in strike extent. Stibnite occurs as massive aggregates of fine-grained crystals associated with pyrite, arsenopyrite and a little amount of gold and silver in the quartz-calcite veins. Three channel samples (AR0065-a, AR0065-c, AR0103) collected from the face of the mined areas near the main-level, contain about 0.3–54% Sb, 4–14% g/t Au and 27–150 g/t Ag.

The replacement-type ore body occurs as elongated lenses extending in the NW–SE direction to about 20 m in length, 2–3 m in width, with rapid swelling and pinching both laterally and vertically. Besides minerals similar to that of the vein-type deposit, the ore is



ANALYTICAL RESULTS OF ORE SAMPLES

Sample No.	Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
AR0065-a (channel, w. 0.2m)	6.0	35.2	53.92	NA	0.01	tr	0.04
AR0065-c (channel, w. 0.4m)	14.1	150.0	36.02	2.03	tr	tr	0.01
AR0069-a (stocked ore, lump)	7.6	21.7	4.61	1.70	0.01	0.03	0.01
AR0069-d (stocked ore, lump)	3.6	8.1	11.90	2.81	tr	tr	0.01
AR0103 (channel, w. 0.6m)	4.2	27.5	0.36	0.37	tr	0.26	0.06

(NA : Not analyzed)

Fig. II—15 Geology of Lucky Hill Mine A

also characterized by abundant calc-silicate minerals such as wollastonite, grossularite, vesuvianite and epidote, and sarabauite. Analytical results of two samples (AR0069-a, AR0069-d) from dump ore at the entrance of the main level show 3.6–7.6 g/t Au, 4.61–11.90% Sb and 1.70–2.81% As.

One massive stibnite ore (AR0065-b) and three stibnite-calcsilicate ore samples (AR0069-a, AR0069-d-1, AR0069-d-2) were studied under the microscope. The section of AR0065-b contains abundant stibnite associated with minor amount of arsenopyrite. Stibnite occurs as large crystals showing the lamellar texture of polysynthetic twins and as fine granular mass. Arsenopyrite occurs as fine-grained, euhedral, rhombic crystals in the interstitial spaces and along the rims of the stibnite crystals. Stibnite in sample AR0069-a, occurs as fine-grained (average 0.01 mm in diameter) interstitial, anhedral crystals associated with fine-grained sarabauite in banded gangue minerals. Three minute grains of native gold, very likely electrum, are recognized in the gangue minerals. The sections AR0069-d-1 and AR0069-d-2 consist mostly of various sizes of stibnite crystals. Fine-grained stibnite forms a banded and/or colloform texture with jamesonite. A white unknown mineral in the gangue shows a feathery to fibrous texture. A small amount of sarabauite is also present in the sulphide-rich zone.

The structural control of ore mineralization is evident in that the formation of ore bodies is restricted to the NW–SE trending fractures.

Slight silicification and numerous small calcite veinlets are also observed in the limestone near to the ore bodies.

(2) Lucky Hill B Ore Deposit

This ore deposit is situated 500 m south of Lucky Hill A, and has been prospected by means of inclined and horizontal tunnels and intensive drilling by the Lucky Hill Mining Sdn. Bhd.

The deposit occurs as a replacement-type, lenticular ore body along a fracture that strikes N20° ~ 30°W, and dips 35° NE in dark-grey argillaceous marble, but is of a smaller scale than that of Lucky Hill A. It consists mainly of quartz, calcite, stibnite and wollastonite and subordinate pyrite, arsenopyrite, gold, grossularite and epidote. This occurrence and the features are very similar to those of the Lucky Hill A.

Physical control of mineralization of this deposit, however, is obviously different in that the deposit has replaced only argillaceous limestone along fractures. In light-grey pure limestone, only small calcite veinlets are found.

Two lump ore samples (AR0070-a, AR0070-b) taken from the ore dump at the entrance of the inclined shaft, were assayed as follows:

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
AR0070-a	Stibnite-rich ore	15.3	148.0	15.38	1.65	0.02	tr.	0.05
AR0070-b	Stibnite-calcite-wallastonite-ore	5.1	17.6	14.02	NA	tr.	tr.	0.02

(NA : not analyzed)

Three polished sections, two of AR0070-a and one of AR0070-b, were examined under the microscope. All section contain large and fine-grained acicular crystals of stibnite. The large crystals of stibnite are usually prismatic. Some show a lamellar texture caused by pressure. Fine-grained stibnite occurs among the gangue minerals as aggregates, disseminations or in narrow zones of needle-or feather-shaped crystals. Some fine-grained stibnite crystals are also seen along the cleavages of gangue minerals and also form a feathery texture. One sample shows minor aggregates of fine-grained pyrite, but otherwise metallic minerals, other than stibnite are not observed in any of the sections.

Alteration of the host rock is not distinct, but argillaceous marble possibly underwent slight silicification near the ore body.

(3) Saburan Ore Deposit

The ore deposit is located at the northern flank of G. Saburan, about 2 km southwest of Bau Town. During the early part of the mining operation, auriferous clay ore was extracted. Since 1947, primary ore has also been mined by the Saburan Gold Mining Company. The operation ceased in the 1970's.

The ore deposit is composed of numerous smaller ore bodies formed within a disturbed and fractured zone, adjacent to the Tai Parit Fault as shown in Fig. II–16. The mine area consists predominantly of dark-grey, argillaceous limestone and subordinate light-grey pure limestone with a thin layer of calcareous sandstone. These rocks have been intruded in places by a number of small quartz porphyry dykes.

Within the area approximately 250 m in the N–S direction and 150 m in the E–W direction, numerous ore bodies are concentrated along the Tai Parit Fault and immediately adjacent to it towards the southeast. The ore bodies are composed of mineralized quartz-calcite vein filling fractures trending mainly N10° E and N60° E, or formed along bedding planes of the argillaceous limestone. An ore vein containing gold, in argillaceous limestone is locally observed in the southern part of the area. The size of the body is less than 50 m in length with a maximum width of 3 m. The vein consists predominantly of calcite and quartz with minor amounts of pyrite, arsenic minerals and gold. At the northwestern part of the Tai Parit Fault, veins with coarse-grained calcite crystals and minor arsenic minerals are abundant, but in the southeast region of the fault the veins contain more arsenic minerals, such as native arsenic, realgar,

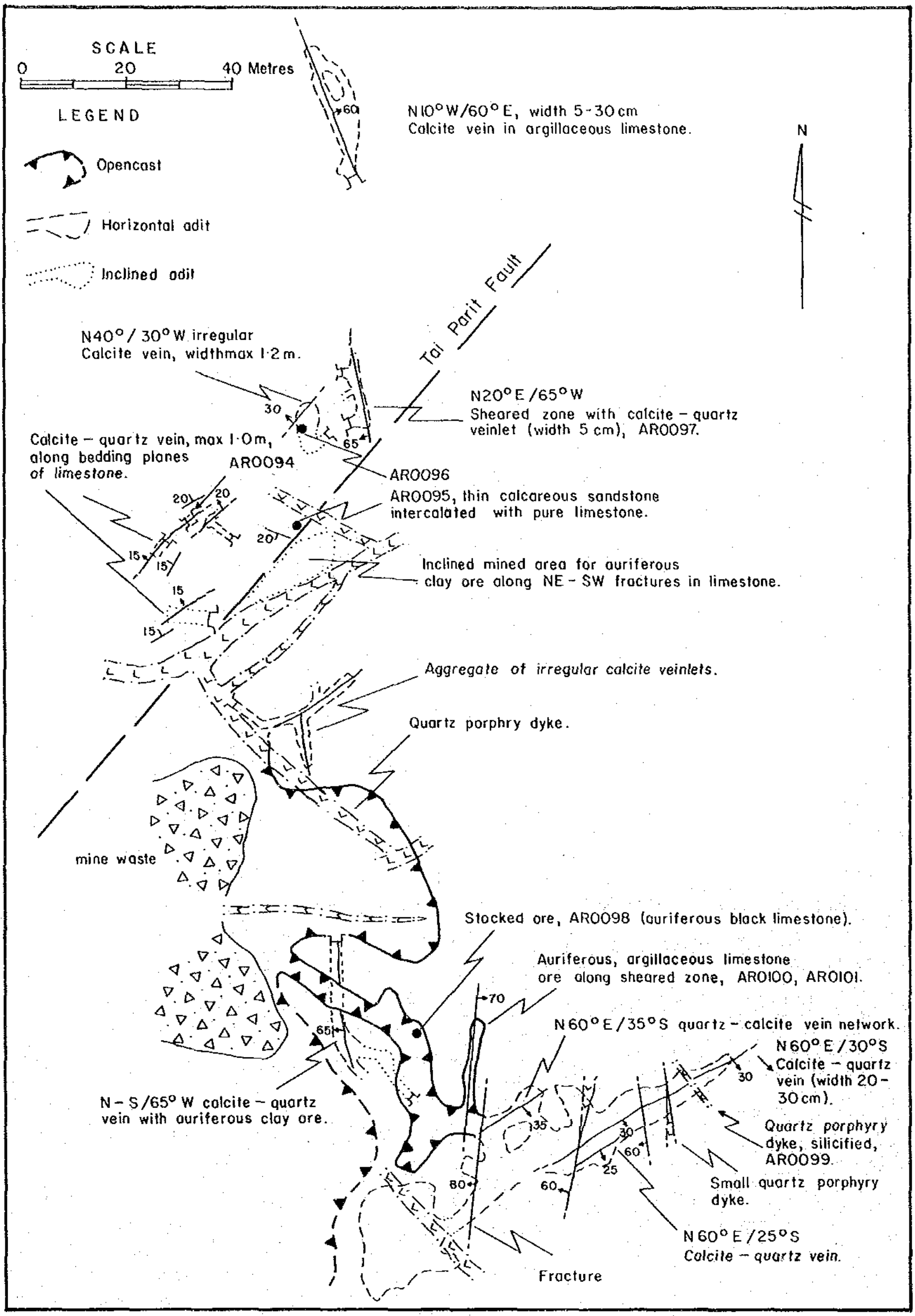


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Fig. II—16 Geology of Saburan Mine

arsenopyrite and some orpiment. Minor amounts of stibnite are also present in these veins.

Auriferous, argillaceous, limestone ores are observed near arsenical veins, and these are considered to be a small-scale, local dissemination of gold and arsenic minerals, formed in fractured or shattered argillaceous limestone. One sample of this ore assayed 77.6 g/t of gold and 1.53% arsenic.

The mineralization at this ore deposit is obviously controlled by fractures trending in the NNW–SSE to NNE–SSW and ENE–WSW directions. The former is parallel to the Tai Parit Fault. Some veins occurring along bedding planes are emplaced in only argillaceous limestone. This is a distinct lithological control of mineralization.

Alteration of the host rocks is generally slight; rare silicification, argillization and very local sericitization are recognizable immediately adjacent to the ore bodies.

Between 1949 and 1964, the mine recorded a production of about 109 kg of gold from 14,000 tons of crude ore. This indicated an average gold content of higher than 8 g/t. It was also reported that some samples of quartz-calcite ore and arsenical ores contain 9–50 g/t and a maximum of 48 g/t of gold respectively.

During the Phase I survey, one channel sample and three samples were analyzed, and the metal contents are as follows :

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Hg (ppm)	Cu (%)	Pb (%)	Zn (%)
AR0094	Calcite-quartz vein (channel sample)	9.7	tr.	tr.	NA	NA	tr.	0.01	tr.
AR0098	Auriferous argillaceous limestone	77.6	8.1	tr	1.53	17.3	tr	0.02	tr.
AR0100	Calcite-clay ore	5.9	tr.	0.04	1.04	48.0	tr.	0.02	tr.
AR0101	Pinkish calcite ore	1.6	tr.	0.04	NA	NA	tr.	0.05	0.01

(NA : not analyzed)

Polished section of sample AR0098 contains arsenopyrite, pyrite, marcasite and rare stibnite. Arsenopyrite occurs as euhedral crystals (0.05~0.2 mm long, 0.02~0.04 mm wide) and forms three thin veinlets in the host rock. Between the arsenopyrite veinlets, very thin veinlets consisting of pyrite and marcasite are present. Some pyrite and marcasite are sparsely disseminated in the rock. Rare stibnite are sporadically found. In spite of the high gold content, gold grains could not be seen in this section.

(4) G. Tongga Ore Deposit

A lenticular ore body containing abundant galena and sphalerite is located 1.5 km south of the Lucky Hill B ore deposit. This deposit was prospected by the Malayan Miners Limited in 1962. At present, the working is abandoned and no detailed reports are available. However, part of the adit which is 25 m long in the N50° E direction and a little amount of stocked ore near the entrance of the adit can still be seen.

According to previous data, the ore deposit consists of a quartz-calcite vein filling fracture in marble. The vein contains abundant galena, sphalerite, chalcopyrite, pyrite and arsenopyrite. One sample of ore collected by the Geological Survey of Malaysia, Sarawak, assayed 3.1 g/t Atu, 136.8 g/t Ag, 0.26% Cu, 10.4% Pb, 3.2% Zn, 0.07% Sb, 1.96% As and 42.2% Fe.

During the Phase I survey, three kinds of ore samples were taken from the stock pile for chemical analysis and microscopic study. The analytical results are as follows:

		Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)	As (%)
AR0032-a	Galena, sphalerite rich ore	7.0	268.0	1.54	5.39	4.25	0.46	NA
AR0032-c	Pyrite, arsenopyrite rich ore	3.3	129.0	0.64	2.62	1.20	0.26	14.28
AR0032-d	Galena, sphalerite with calcite ore	20.0	84.3	0.24	4.05	7.90	tr.	NA

(NA : not analyzed)

Two polished sections (AR0032-a and AR0032-c) were studied under the microscope. The section AR0032-a contains large crystals of arsenopyrite, galena and pyrite, and fine-grained sphalerite and chalcopyrite. Arsenopyrite occurs as large, isolated, rhombic-euhedral crystals and occasionally as aggregates. Most crystals show a distinct zonal structure. Galena is usually present as large crystals, the maximum diameter being 2 mm, and closely co-exists with pyrite and arsenopyrite, and rare bournonite and boulangerite. The rims of the crystals of galena is often replaced by very fine-grained, indistinguishable secondary minerals, presumed to be limonite. A small amount of sphalerite containing chalcopyrite dots formed by exolution occurs in pyrite as isolated grains, 0.3~0.8 mm in diameter. The sample contains high silver, although no silver minerals were recognized in the section. The section AR0032-c shows *almost the same mineral assemblage as section* AR0032-a, *and contains much more bournonite.*

(5) Tai Ton A Ore Deposit

The four flooded opencasts of Tai Ton A are situated within an area of 800 m by 500 m, about 1 km, SSE of Tai Ton village. These workings were operated by the Tai Ton Gold Mining Syndicate during the period 1931 to 1954.

At present there are no outcrops of the ore deposit and only a little stocked ore remains near the old mining shed. This ore suggests that the ore deposit consists of a quartz-calcite vein containing stibnite and abundant arsenic minerals.

Three ore samples (AR0083-a, AR0083-b, AR0084) were analyzed and two (AR0083-a, AR0084) were also microscopically examined. The analytical results are as follows:

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
AR0083-a	Arsenical calcite-quartz ore	17.5	tr.	0.07	10.32	tr.	tr.	0.01
AR0083-b	Native arsenic-calcite ore	14.9	tr.	0.14	NA	tr.	0.05	tr.
AR0084	Stibnite-native arsenic ore	8.2	1.6	1.01	NA	tr.	tr.	0.01

(NA: not analyzed)

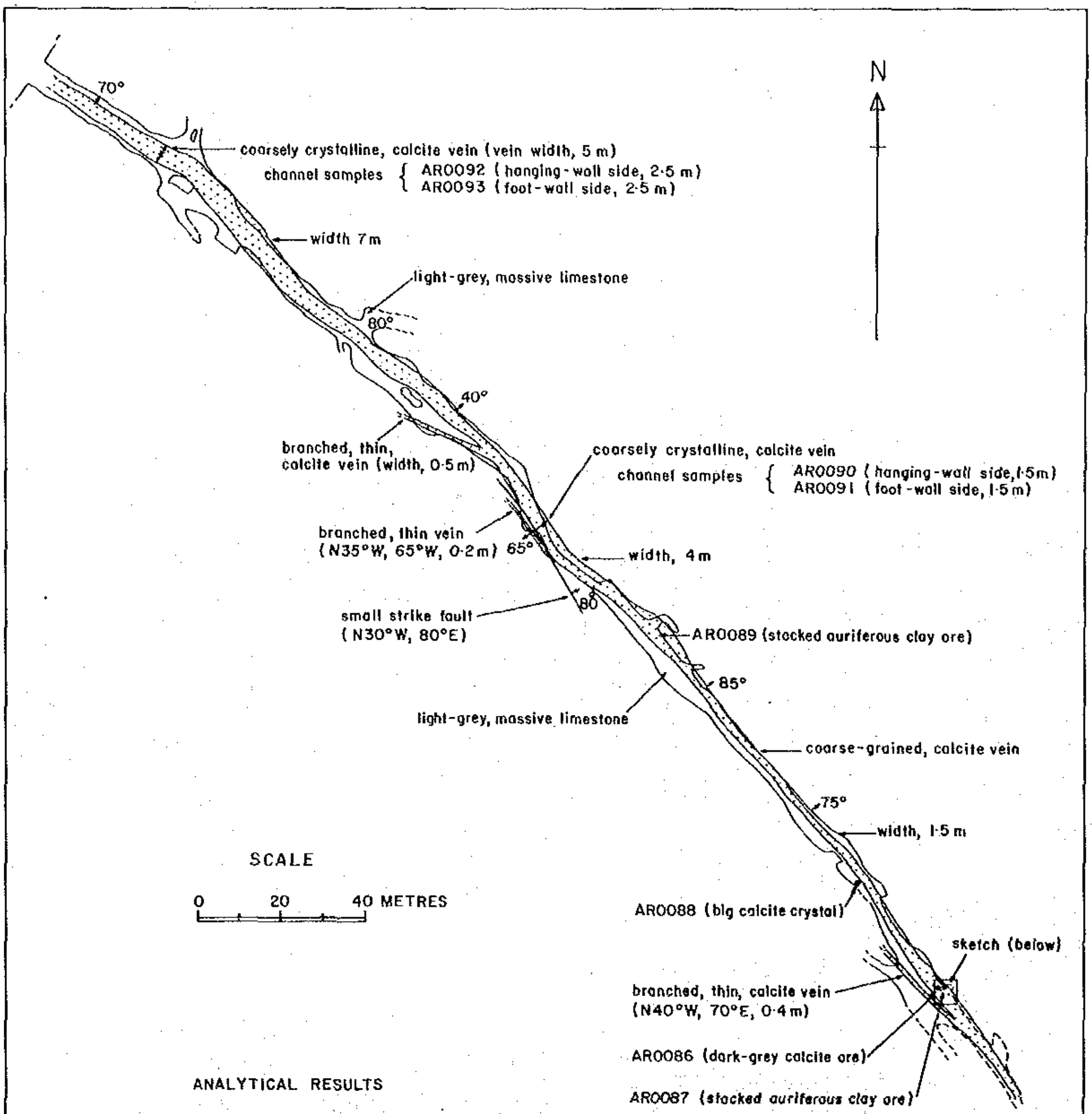
The polished section AR0083-a contains considerable native arsenic, and minor amounts of stibnite, pyrite, marcasite and chalcopyrite in a gangue of quartz and calcite. Abundant fine-grained spheres of native arsenic are present mainly in the quartz. The other metallic minerals occur as very fine-grained crystals in quartz and some calcite. The section AR0084 contains large stibnite crystals having a maximum length of 2 mm and fine-grained spherical native arsenic.

(6) Tai Ton B Ore Deposit

The ore deposit, worked by the Tai Ton Gold Mining Syndicate, is situated at the northern end of G. Palat Kolong, 800 m south of Tai Ton village. It has been traced for about 350 m by underground working along a joint which strikes N45°W and dips 40~85° NE, in massive limestone (Fig. II–17).

The vein is composed predominantly of coarsely crystalline calcite and subordinate fine-grained auriferous quartz filling interstices between calcite crystals. Microscopically, sulphide and arsenic minerals are very rare, and only rare stibnite, pyrite and a black mineral which is possibly oxidised native arsenic are occasionally recognized in the quartz-rich zone.

The formation of the vein has been obviously controlled by the fracture parallel to the



ANALYTICAL RESULTS

	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn (%)	Sb (%)
AR0086	1·1	tr	tr	tr	0·01	tr
AR0087	5·7	7·0	0·03	0·02	0·10	0·04
AR0089	13·8	19·0	0·03	0·67	0·11	0·20
AR0090	8·4	tr	tr	tr	tr	tr
AR0091	1·4	tr	tr	0·01	tr	tr
AR0092	1·1	tr	tr	0·01	tr	tr
AR0093	1·8	tr	tr	0·01	tr	0·01

SKETCH OF SITE OF SAMPLES AR0086 AND AR0087

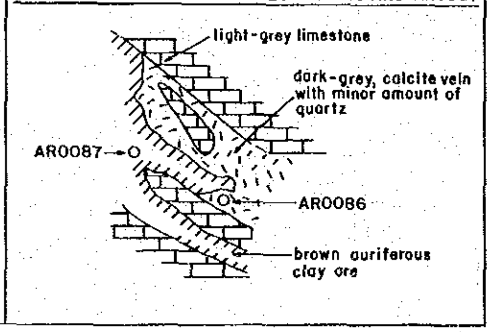


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Fig. Ⅱ—17 Geology of Tai Ton B Ore Deposit

NW–SE trending fault which extends along the foot of G. Palat Kolong and G. Jabul, and controlled the formation of the Tai Ton A ore deposit.

The limestone host rock underwent rare silicification immediately adjacent to the vein where many thin, small calcite veinlets are observed filling joints and small fractures, mostly parallel to the vein.

According to past reports, the gold ore mined out in 1960 contains an average of 7 g/t of gold. However, the channel samples (AR0090 ~ AR0093) taken from two places contain an average of only 3 g/t of gold and two auriferous clay ores show 5.7 and 13.8 g/t of gold. At present, auriferous clay ore is intermittently extracted on a small scale. Gold of this ore is presumed to have been derived and concentrated from weathering of the primary quartz-calcite vein.

(7) Rumoh Ore Deposit

The large Rumoh ore deposit comprising many smaller ore bodies, is formed in massive limestone, 300 m northwest of Bidi and has been worked by the Rumoh Gold Mining Company during the period 1949 to the late 1970's. The underground workings of the company are scattered within an area of 250 m in the NNE–SSW and 80 m in the NNW–ESE directions.

The ore deposit is composed of numerous irregular, lenticular quartz-calcite veins, occurring along two sets of fractures striking N40°E and N5°E in limestone, immediately adjacent to the Tai Parit Fault. This occurrence seems to suggest that the fault plays a prominent role as a conduit for ascending ore solution which forms ore bodies in subsidiary fractures caused by the fault movement. This concept may also partly explain the occurrence of the Saburan ore deposit.

Deep and steeply dipping underground workings at the mine prevented detailed investigation at present but ore dumps near the workings indicate that the ore deposit is very similar to that of Tai Ton B.

Auriferous clay ore (AR0062-a) and banded quartz-calcite ore (AR0063-b) with a black mineral assayed as follows:

	Au (g/t)	Ag (g/t)	Sb (%)	Cu (%)	Pb (%)	Zn (%)
AR0062-a	6.0	124.0	0.01	0.03	0.25	0.06
AR0063-b	5.5	tr.	0.14	tr.	0.01	0.02

The polished section of AR0063-b contains bundles and radial aggregates of an unknown acicular, prismatic mineral, 0.01 ~ 0.1 mm long and 0.002 mm wide in quartz-calcite. This mineral may be derived from the oxidation of pyrite and marcasite. Secondary manganese minerals, possibly manganese dioxide, are also observed.

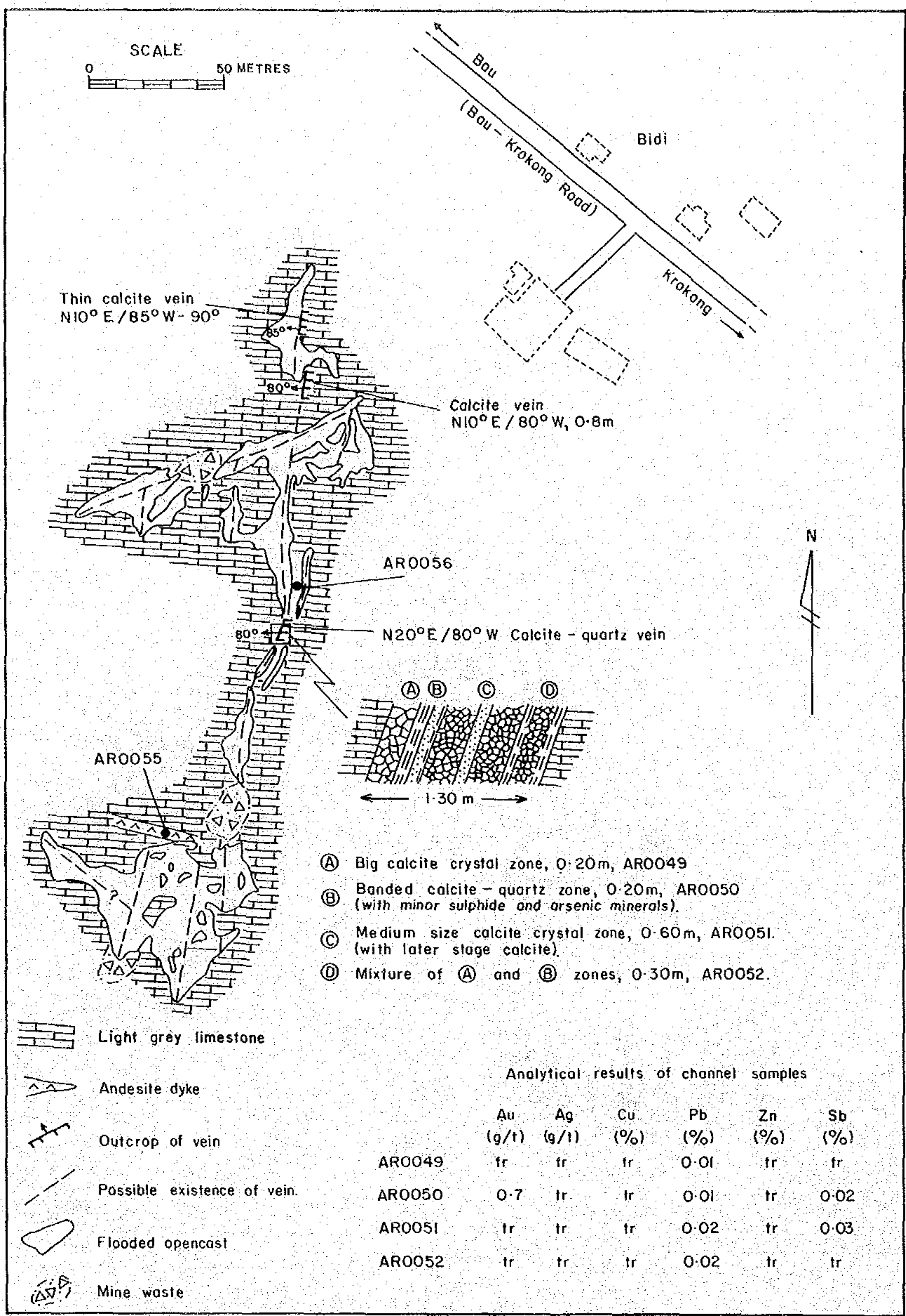
(8) Kusa Ore Deposit

This deposit is located at Bidi and worked by opencast by the Kusa Mining Sdn. Bhd. in the 1970's. The workings are now flooded. A few outcrops of veins which were not mined because of the low grade of gold and antimony, can still be observed.

The deposit is a typical vein-type mineralization consisting of two prominent sets of veins, a NNE–SSW and a ENE–WSW set, and a subordinate NW–SE set. The deposit can be discontinously traced for approximately 300 m in the NNE–SSW direction and 130 m in the WNW–ESE direction, as shown in Fig. II–18. Each vein occurs along a joint fracture in light-grey massive limestone and consists predominantly of calcite and quartz with abundant stibnite and arsenic minerals. Gold content of the arsenical ore is high. The vein outcrop at the centre of mineralized zone is composed mainly of dark-grey and light-grey to pinkish-grey, coarsely crystallized calcite with a little amount of quartz, in which rare amounts of arsenic minerals and stibnite are sporadically observed. The analytical results of four channel samples (AR0049~AR0052) show no valuable metallic elements. However, three ore samples (AR0054-d to AR0054-f) rich in sulphide and arsenic minerals, taken from the stocked ore, assayed 20.0 ~ 74.4 g/t gold, 211.0 ~ 272.0 g/t silver, 0.52 ~ 13.10% antimony and 7.48 ~ 46.44% arsenic.

Four polished sections of samples with high gold content and three of samples with fine-grained stibnite, arsenic minerals and a large amount of gangue were microscopically examined. Abundant isolated and/or linked aggregates of fine-to coarse-grained, native arsenic crystals are contained in the first four sections. Minor large, anhedral crystals of stibnite are scattered in places in arsenic and rare gangue minerals. Native arsenic often shows zonal, concentric shells and a banded texture. Two of the four sections contain sarabauite which appears as a dark-grey, rough surface, granular crystals and shows a characteristic ruby-red internal reflection. Gold grains were found in two sections (AR0054-f-1 and f-2). They are light cream or faintly yellow in colour and are probably electrum occurring in massive native arsenic as granular, angular and occasionally, irregularly rounded, fine grains with a maximum diameter of 7μ. This suggests that gold is closely related to the concentration of arsenic in the veins. In spite of the high content of silver, no silver minerals were recognized in any sections. Clarification of origin of the silver content requires more detailed microscopic study, although a part of the silver present may be derived from electrum.

The other three sections contain medium-to coarse-grained crystals of stibnite and native arsenic in a complex mixture of quartz and calcite. Very fine-grained pyrite, arsenopyrite and rare amounts of minute sarabauite are sporadically present near native arsenic lodged in the



Analytical results of channel samples

	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)
AR0049	tr	tr	tr	0·01	tr	tr
AR0050	0·7	tr	tr	0·01	tr	0·02
AR0051	tr	tr	tr	0·02	tr	0·03
AR0052	tr	tr	tr	0·02	tr	tr

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Fig. Ⅱ—18 Geology of Kusa Mine

gangue minerals. In the section AR0054-h-1, a medium-grained unknown mineral was observed. It shows reflection, pleochroism and anisotropism weaker than stibnite.

(9) Nam Loong B Ore Deposit

Nam Loong Mine is located 1.5 km to the south-southwest of Bidi. The mine started operation in the area in the middle of the 1900's. The underground workings were carried out along weathered quartz-calcite veins which occurred as fracture-fillings in the limestone hill. The main ore type mined was auriferous clay accumulated along the fractures. Primary ore of slightly weathered quartz-calcite vein was also worked from walls, roof and floor of the cave workings.

Below the northern entrance of the underground workings, quartzose gold ore was located by drilling which was carried out by the Geological Survey of Malaysia, Sarawak in 1966. The ore deposit was encountered at a depth of 6.6 ~ 12 m from the surface.

The mine area consists of the Bau limestone which forms a steep-cliff hill and limestone flats. The limestone is massive with faults and joints. At the limestone hill there are cave openings resulting from the weathering of quartz-calcite veins along joint fractures.

A quartz-calcite vein in one of the underground workings (Fig. II–19) measures 1 ~ 3 m in width and extends 7 m in the dip direction and 100 m in strike direction. The mineralizing solution probably rose upward along the joint fracture and crystallized to form the quartz-calcite vein which partly replaced the limestone along the fracture. Gold is associated with minor amounts of stibnite in the quartz-calcite vein.

During the Phase I survey, one calcite vein and three clay samples were collected from the underground workings and analyzed. The results are shown below:

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Hg (ppm)	Cu (%)	Pb (%)	Zn (%)
AR0058-a	Light brown-coloured clay	0.2	tr.	tr.	NA	NA	tr.	0.01	0.01
AR0058-b	Calcite vein in clay ore	4.2	16.2	0.17	NA	NA	tr.	0.03	0.01
AR0059-a	Auriferous clay ore	65.2	43.8	5.71	NA	NA	tr.	tr.	0.01
AR0059-b	Auriferous clay ore	2.4	tr.	tr.	NA	NA	0.01	0.01	0.04

(NA: not analysed)

The main structural controls in the area are probably faults and joints. Mineralization occurs mainly as fissure filling of these faults and joints.

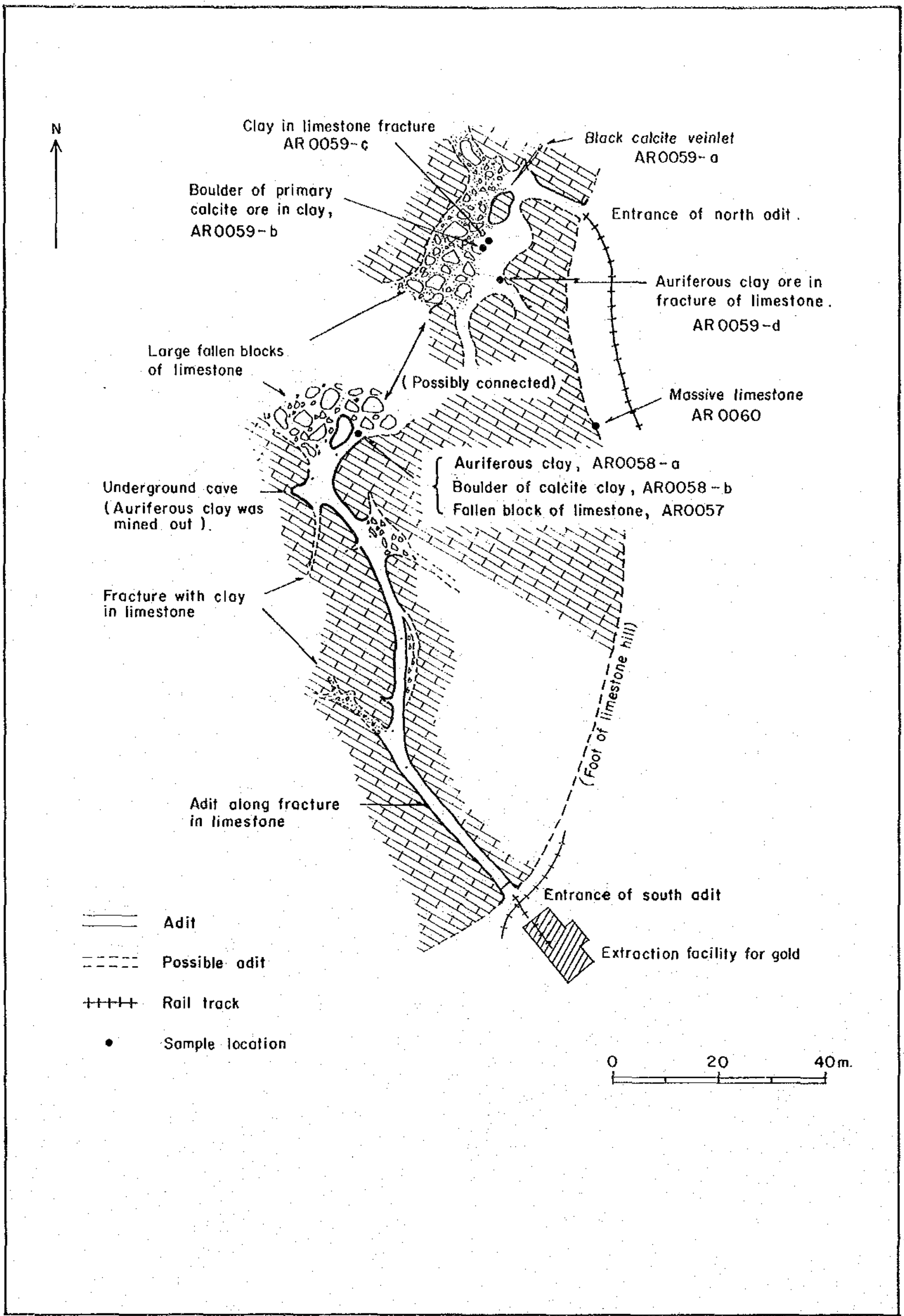

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Fig. Ⅱ—19 Geology of Nam Loong Mine B

(10) Other Ore Deposits and Indications of Mineralization

Of the other ore deposits and possible mineralized sites in the semi-detailed survey area, some were partially investigated in the field and by chemical analysis and microscopic study.

i) Batu Bekajang Lake Ore Deposit

In the southern to southwestern vicinity of the Batu Bekajang Lake, four flooded mine workings are distributed along the fault contact between the Bau Limestone and the Pedawan Formation. The deposits at the workings were reported to be highly weathered auriferous, quartz-calcite veins. During the Phase I survey, a small stibnite-bearing quartz-calcite vein, only 2 cm in width, was found in dark-grey limestone at the second working from southwest, and it assayed 33.2 g/t Au, 85.0 g/t Ag, 0.33% Sb and 3.98% As. The occurrence and nature of this vein seem to be similar to that of the Kusa ore deposit.

ii) Krian Ore Deposit

The deposit consisting of eleven small lenticular, quartz-calcite veins, that strike mainly in the NNE–SSW and NW–SE directions, are exposed in a steep-sided limestone-marble hill about 1 km south of Bau town. These had been prospected by means of adits and mined out. During this survey, field observations were undertaken in three of the workings, in which auriferous clay and primary, barren calcite-quartz veins were present. Two samples of primary ore containing galena and sphalerite (AR0007), and stibnite (AR0008) were collected from the ore dump for chemical analysis and microscopic study. Analytical results show that these samples contain 2.3~24.0 g/t gold, 17.2~52.3 g/t silver and 3.54% zinc (AR0007).

The polished section AR0007, is composed mainly of sphalerite and pyrite with minor amounts of galena, chalcopyrite and a sulfosalt, possibly boulangerite. Sphalerite is present as isolated and/or aggregates of large crystals in a gangue of quartz and calcite. Large crystals of pyrite and minute inclusions of chalcopyrite were also observed. Galena occurs irregularly shaped along cracks or cleavages of the sphalerite and is accompanied by greyish white, very fine-grained, tabular crystals of a sulfosalt mineral which was determined as boulangerite. Stibnite and arsenic minerals are absent in this section.

The section AR0008 is poor in ore minerals. A few stibnite and pyrite crystals are observed in the gangue. Some stibnite crystals enclose fine sphalerite crystals and form a eutectic texture. Arsenopyrite, pyrite and marcasite are present in the gangue as sparse disseminations of very fine-grained crystals.

The occurrences described above indicate the existence of two kinds of mineral assemblages, a sphalerite-pyrite-galena and a stibnite-arsenopyrite-pyrite assemblage. Gold is richer in the latter.

iii) G. Tabai Ore Deposit

Several old mine workings and outcrops of lenticular quartz-calcite veins are found along NNE–SSW trending joints in limestone on the northeastern side of G. Tabai and southeastern side of G. Tai Ton. These veins contain stibnite, pyrite and a little sphalerite. One calcite-rich ore sample (BR0017) and one pyrite-bearing, quartz-calcite ore sample (BR0020) from veins, 20 cm and 40 cm in width, respectively were analyzed. BR0020 shows a content of 11.7 g/t Au, 37.6 g/t Ag, 0.72% Pb and 0.84% Zn. These results appear to indicate that the mineral assemblage of the vein is similar to some of those of the Krian ore deposit.

iv) Associated Mine Ore Deposit

More than ten flooded small opencasts are found aligned in the ENE–WSW to E–W direction along a fault in limestone flats, approximately 500 m south of Bidi and can be traced for about 700 m. No outcrop of the ore body is observable in and around these workings. However, some boulders of primary ore were found at the northeastern end of the alignment. The primary ore consists of calcite-quartz vein containing stibnite and arsenic minerals. Two ore samples (AR0061-a, AR0061-b) show the following analytical results:

		Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)	As (%)
AR0061-a	Stibnite-quartz vein	69.6	29.1	0.01	0.03	0.01	1.36	1.91
AR0061-b	Stibnite-arsenic ore	20.4	89.8	tr.	1.09	0.10	1.78	NA

(NA: not analyzed)

Both the samples were also microscopically studied. The section AR0061-a consists of a native arsenic-rich band next to a stibnite-predominant band.

The section AR0061-b is composed mainly of spherulitic native arsenic. The interstices between arsenic crystals are filled by quartz with minor amounts of pyrite, arsenopyrite and boulangerite. Boulangerite occurs in the interstices of quartz crystals as fibrous aggregates and irregular, anhedral crystals, in which fine-grained pyrite and arsenopyrite are included. Gold and silver minerals could not be recognized in both the sections. The mineral assemblage and analytical results are almost the same as that of the Kusa ore deposit.

v) Mineralization at G. Ropih

G. Ropih located about 1.3 km south of the G. Tongga copper-lead-zinc ore deposit, is composed of a stock of highly silicified quartz porphyry. In places network of thin quartz veinlets is common and occasionally, disseminations of pyrite and molybdenite observed. Existence of a small mine working for gold, was reported at the northern flank of G. Ropih.

Many bouldery floats consisting of vuggy quartz vein associated with pyrite and stibnite were fou l in a stream draining southwards at the southeastern foot of G. Ropih. Some cobbles consi of massive pyrite were also found. One boulder of vuggy vein quartz containing pyrite and bnite ssayed as follows:

	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)
Ak 3	1.3	9.8	0.02	0.45	0.60	0.52

Microscopic observa on disclose the occurrence of fine-grained pyrite and arsenopyrite in quartz.

These results in themselves are not encouraging. However, the interesting results of field observations and the existence of numurous boulders of pyrite-quartz vein and some cobbles of massive pyrite sugg t a high p ential for copper lead-zinc mineralization similar to the G. Tongga ore deposit and/or disseminated type copper mineralization

3–2–2 Ore Deposits in Reconnaissance Survey Area

(1) Tegora Mercury Deposit

The Tegora mercury deposit is located 11 km south of Bau town. The area was worked by the Borneo Company from 1868 to 1909. During the period, 1942 to 1945, the area was again mined by the Japanese. During its operation the mine extracted both primary and eluvial ore occurring in silicified black shale and sandstone he total production from 1868 to 1899 was about 363 kg of Hg. The main rock types in the area are sandstone and shale of the Pedawan Formation striking northeast and dipping 80°~90° south. The area is intruded by a dyke of acidic rock.

The deposit is a chimney-like pocket occurring in silicified bl k shale and sandstone and is controlled by steep fissures with northeast strike and northwest   southeast dip. The ore shoot trends towards N30°E to N60°E. The principal ore mineral is cinnabar, with pyrite and a small quantity of realgar. The cinnabar occurs mainly as coatings on the surface of fractures of the silicified sandstone and shale breccia.

During the Phase I survey, one ore sample was collected. The sample was analyzed and studied under the microscope. The results of the analysis are as follows:

		Hg (%)	Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
JR0011	Grey shale with cinnabar	2.31	tr.	tr.	0.06	0.78	0.01	tr.	tr.

The polished section of JR0011 contains enhedral crystals of pyrite and irregular, anhedral cinnabar filling interstices of quartz grains. The sample has undergone weak oxidation and some of the pyrite have been altered to limonite.

The mineralization in this area is clearly associated with the NE trending shale and sandstone breccia zone with the ore occurring as fissure fillings within this brecciated zone.

(2) Gading Mercury Deposit

The Gading mercury deposit is about 14 km to the south-southwest of Bau Town. The area was worked together with the Tegora deposit. The ore from Gading was transported to Tegora for smelting. By the early 1900s, most of the deposit had already been mined. During the period, 1942~1945, the area was again reworked for mercury by the Japanese.

The geology of the area is similar to that of Tegora with shale and sandstone as the main rock types. The area is intruded by a quartz prophyry stock.

The ore deposit occurs in the sheared zone with a northeast strike and a dip towards 70° south, and extends about 50 m along the strike direction. Low grade placer deposits occurred along S. Nusu S. Ma-ong and S. Balom to the south of the Gading Mine. The main ore minerals are cinnabar with some realgar and pyrite. The main gangue mineral is quartz.

During the Phase I survey, one ore sample was collected, analysed and studied under the microscope. The results of the analysis are as follows:

		Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)	As (%)
SR0061	Pyrite-realgar in brecciated zone	0.2	tr.	tr.	tr.	0.01	0.51	1.62

From microscopic observation, the sample, SR0061, consists mainly of pyrite and cinnabar, with subordinate kermesite and native arsenic. Pyrite occurs as euhedral crystals. Spherical aggregates of colloform pyrite, framboidal pyrite and aggregates of long tabular pyrite crystals are also observed. Cinnabar occurs as anhedral crystals in the interstices between the crystals of gangue minerals. Kermesite and native arsenic are usually associated with cinnabar.

The mineralization in the area is structurally controlled by fault and joint fissures.

(3) Other Indication of Mineralization

An outcrop of sandstone with pyrite-dissemination was recognized at the southern foot of G. Sirenggok, about 1 km northwest of Bau town. The sequence at the outcrop consists mainly of well-bedded shale intercalated with thin sandstone layers of the Pedawan Formation. Only one sandstone layer, about 20 to 30 cm thick, contains abundant disseminations of fine- to coarse-grained pyrite. The analytical result of a sample assayed as follows:

	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)
AR0075	0.2	6.5	0.02	0.02	1.90	tr.

This result is not encouraging, but the sample contains mackinawite which is usually indicative of a high temperature environment. Mackinawite occurs in some chalcopyrite dots in sphalerite. The existence of this mineral suggest that the disseminations of pyrite is caused by mineralization different from that of the gold-antimony mineralization.

3–2–3 Microscopic Observation of Ore Samples

Twenty-nine polished sections were observed under the microscope during the Phase I survey, and the results are as summarized in Table II–7. Based on the principal mineral assemblage, the results show that the mineralization in the survey area can be divided into three groups, namely (1) gold-stibnite-native arsenic group; (2) galena-sphalerite-chalcopyrite-pyrite-arsenopyrite group; and (3) cinnabar-pyrite-stibnite (kermesite) group. This grouping of mineralization is supported by the results of field observations.

3–3 General Features of Ore Deposits and Genetical Consideration of Ore Formation

The general features of the known ore deposits in the project area can be summarized as follows:

1. The known ore deposits occur mainly in the area from Bau to Krokong, around Bt. Pangga and Jambusan, and in the Gading and Tegora mine areas. No significant ore deposits are known in the western and southeastern parts of the Bau area, and around the Jagoi granodiorite mass.
2. Most of the ore deposits are formed along the crest of the Bau Anticline and the NNE trending alignment of Tertiary intrusives. Numerous ore deposits are localized at the intersection of these two prominent major structures around the Bau town area.
3. Most ore deposits are of the epithermal, fissure-filling vein type. Some however, occur also in closely fractured or shattered zones in limestone. These are lenticular in shape and were formed by the local replacement of the host rock. Economic contact metasomatic and disseminated ore deposits to-date have not been recognized in the area.
4. On the basis of the metals mined and mineral assemblages, the ore deposits can be roughly divided into gold-antimony deposits, gold-bearing copper-lead-zinc deposits, and mercury deposits. The main ore minerals of each group are as follows:

i) Gold-antimony ore deposits

Gold, stibnite, native arsenic, pyrite and arsenopyrite are common. Subordinate minerals are sphalerite, galena, chalcopyrite, marcasite and some sulfosalt minerals. Gangue minerals are quartz and calcite with calc-silicate minerals in some ore bodies.

Table II—7 Results of Polished Section Examination

Area	Sample No.	Sample Locality	Py	Mc	Cp	Ga	Sph	Asp	As	Sb	Sarab	Gold	Cinn	Bourn	Boula	James	Mack	Kerm	2nd min.	Remarks
Semi-detailed Area	AR0007	G. Krian	+++	–	+	+	++++	–	–	–	–	–	–	–	+	–	–	–	–	
	8		+	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	
	32-a	G. Tongga	++++	+	+	+++	+	+++	–	–	–	–	–	+	+	–	–	–	+	Lm, Cc, Cv, Bo
	32-c		++++	+	+	++	+	++++	–	–	–	–	–	+	–	–	–	–	–	
	43	G. Ropih (boulder)	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	
	54-d	Kusa	–	–	–	–	–	+	–	+	++	–	–	–	–	–	–	–	–	
	54-e		+	+	–	–	–	–	+++	+	–	–	–	–	–	–	–	–	–	
	54-f-1		–	–	–	–	–	–	+++	+	+	+	–	–	–	–	–	–	–	
	54-f-2		+	+	–	–	–	–	++++	++	–	+	–	–	–	–	–	–	–	
	54-g		+	–	–	–	–	+	++	++	–	–	–	–	–	–	–	–	–	
	54-h-1		+	–	–	–	–	+	++	++	+	–	–	–	–	–	–	–	–	
	54-h-2		–	–	–	–	–	–	++	++	–	–	–	–	–	–	–	–	–	
	61-a	Associated mine	+	–	–	–	–	–	++++	+++	–	–	–	–	–	–	–	–	–	
	61-b		++	–	–	–	–	+	++++	–	–	–	–	–	++	–	–	–	–	
	63-b	Rumoh	++	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	Mn-oxide, Lm
	65-b	Lucky Hill A	+	–	–	–	–	++	–	++++	–	–	–	–	–	–	–	–	–	
	69-a		–	–	–	–	–	–	–	++++	++	+	–	–	–	–	–	–	–	
	69-d-1		–	–	–	–	–	–	–	++++	+	–	–	–	–	+++	–	–	–	Unknown min
	69-d-2		–	–	–	–	–	–	–	++	+	–	–	–	–	++++	–	–	–	Unknown min
	70-a-1	Lucky Hill B	+	–	–	–	–	–	–	++++	–	–	–	–	–	–	–	–	–	
	70-a-2		–	–	–	–	–	–	–	++++	–	–	–	–	–	–	–	–	–	
	70-b		–	–	–	–	–	–	–	++++	–	–	–	–	–	–	–	–	–	
	83-a	Tai Ton A	+	–	+	–	–	+	++++	+	–	–	–	–	–	–	–	–	–	
	84		–	–	–	–	–	–	++++	++	–	–	–	–	–	–	–	–	–	
	98	Saburan	++	++	–	–	–	++	–	+	–	–	–	–	–	–	–	–	–	
Reconnaissance Area	AR-0075	G. Sirrenggok	++++	–	+	–	+++	–	–	–	–	–	–	–	–	–	+	–	–	
	JR-0011	Tegora	+++	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	++	Lm
	SR-0061	Gading	++++	–	–	–	–	–	+	–	–	–	+	–	–	–	–	++	–	
	75	G. Serambu (boulder)	–	–	–	–	–	–	–	+++	–	–	–	–	–	–	–	–	+	

Py : pyrite
Mc : marcasite
Cp : chalcopyrite
Ga : galena
Sph : sphalerite

Asp : arsenopyrite
As : arsenic
Sb : stibnite
Sarab : sarabauite
Cinn : Cinnabar

Bourn : bournonite
Boula : boulangerite
James : jamesonite
Mack : mackinawite
Kerm : kermesite

2nd. min: secondary mineral
Lm : limonite
Cc : chalcocite
Cv : covellite
Bo : bornite

++++ : abundant
+++ : common
++ : some
\+ : little-rare
– : none

ii) Gold-bearing copper-lead-zinc ore deposits

Ore minerals are mainly galena, sphalerite, chalcopyrite, pyrite and arsenopyrite with minor amounts of stibnite, gold and sulfosalt minerals. Quartz and calcite are common gangue minerals. Calc-silicate minerals are absent.

iii) Mercury ore deposits

Cinnabar, native arsenic, arsenopyrite and occasionally, native mercury are common with gangue minerals, such as calcite, barite, flourite and talc.

5. Most of gold-antimony ore deposits occur in limestone along fractures and joints trending NNE to NE and WNW to NW. These fractures and joints are consistent with the direction of faults and dykes developed throughout the limestone area. Thus it can be said that the most favourable sites for ore deposits are fractured zones adjacent to faults and dykes in limestone. Gold-bearing copper-lead-zinc ore deposits occur along fractures and/or joints in the Tertiary intrusive stocks and in limestone immediately adjacent to the stocks. They occupy approximately the centre around which gold-antimony ore deposits are distributed. Mercury ore deposits occupy the brecciated or highly sheared zone in shale and sandstone of the Pedawan Formation near small intrusive stocks.

6. The scale of ore deposits is generally small, mostly several ten of meters in strike length and down dip, and a few meters in width, although a few larger deposits such as the Tai Parit ore deposit which was recorded to have produced more than 2 million tonnes of crude ore (about 15 tonnes of gold), and a vein at the Tai Ton B deposit having a strike length of more than 350 m, are also known.

7. Alteration of the host rock caused by gold-antimony mineralization is usually very weak and sparse. Only slight silicification and local sericitization are recognized near veins. In the case of copper-lead-zinc mineralization, the intrusive host rock has undergone intense hydrothermal alteration such as silicification, sericitization and occasionally, argillization and pyritization. Mercury ore deposits are accompanied by silicification, pyritization and argillization.

8. The Cu, Zn, Sb and As contents of the Tertiary intrusives as shown by analytical results of rock samples from around the Lucky Hill (A) ore deposit, are relatively higher than those of limestone and marble.

The observations discussed above leave little doubt that the ore deposits in the area are closely related to the Tertiary intrusives which may also be the source of the mineralization.

3–4 Preliminary Assessment of Old Mine Waste and Tailings

Mining activities were carried out in the Bau Mining District since early 19th Century.

Mining operations reached their peak in the 1900's during which time the Borneo Company operated two central gold treatment plants, one at Bau and the other at Bidi. The Bau treatment plant treated ore from the Tai Parit mine, Batu Bekajang mine and other nearby mines. The Bidi treatment plant treated ore from mines in the Tai Ton, Bidi and Krokong areas. Tailings from these two plants were dumped in the low-lying areas around the plants and in disused opencast workings, as in the case of Bidi. After 1912, the Bau treatment plant treated part of the tailing dump located at 0.33 km south of Bau, just east of the Bukit Young Mine. During the early part of its operation, Bukit Young Mine also treated some of the tailings of this dump. Part of the tailing dump at Bidi was treated by Associated Mine sometime during the middle of the 20th Century. In all the three cases only very small proportions of the tailing dumps were treated.

Small tailing dumps are also found at Saburan, Tai Ton, Boring and Krokong (Fig. II–20). The tailing dumps from other smaller mines are probably much too small to be of any significance.

The samples of the tailings from Saburan, Tai Ton, Bidi and Krokong were collected by Anglo-Oriental (Malaya) Limited sometime in the early 1950's and were analysed by the Malayan Geological Survey for gold. The results are given in the table below (Wilford, 1955).

Area	Gold Content (g. per tons)
Saburan	5.43
Tai Ton	0.31
Bidi	0.93
Krokong	0.78

The tailing dump at Bidi which is estimated to be around 1 million tons was investigated by the Department of Mines, Federation of Malaya and samples were collected by banka-drilling. The results of the analyses of the samples are given in the table below (Harris, 1958).

		Gold Content (g. per tons)
Drill hole No. 1	0~5.18 m	1.86
Drill hole No. 2	0~7.92 m	1.24
Drill hole No. 3	0~17.37 m	2.02
Drill hole No. 4	0~1.2 m	1.55

During the present investigation, samples of the tailings at the old Bau airstrip and at the southwest end of Tai Parit lake were collected using a hand auger and the samples were analysed for gold by the Geological Survey Malaysia, Sarawak (Fig. II–21).

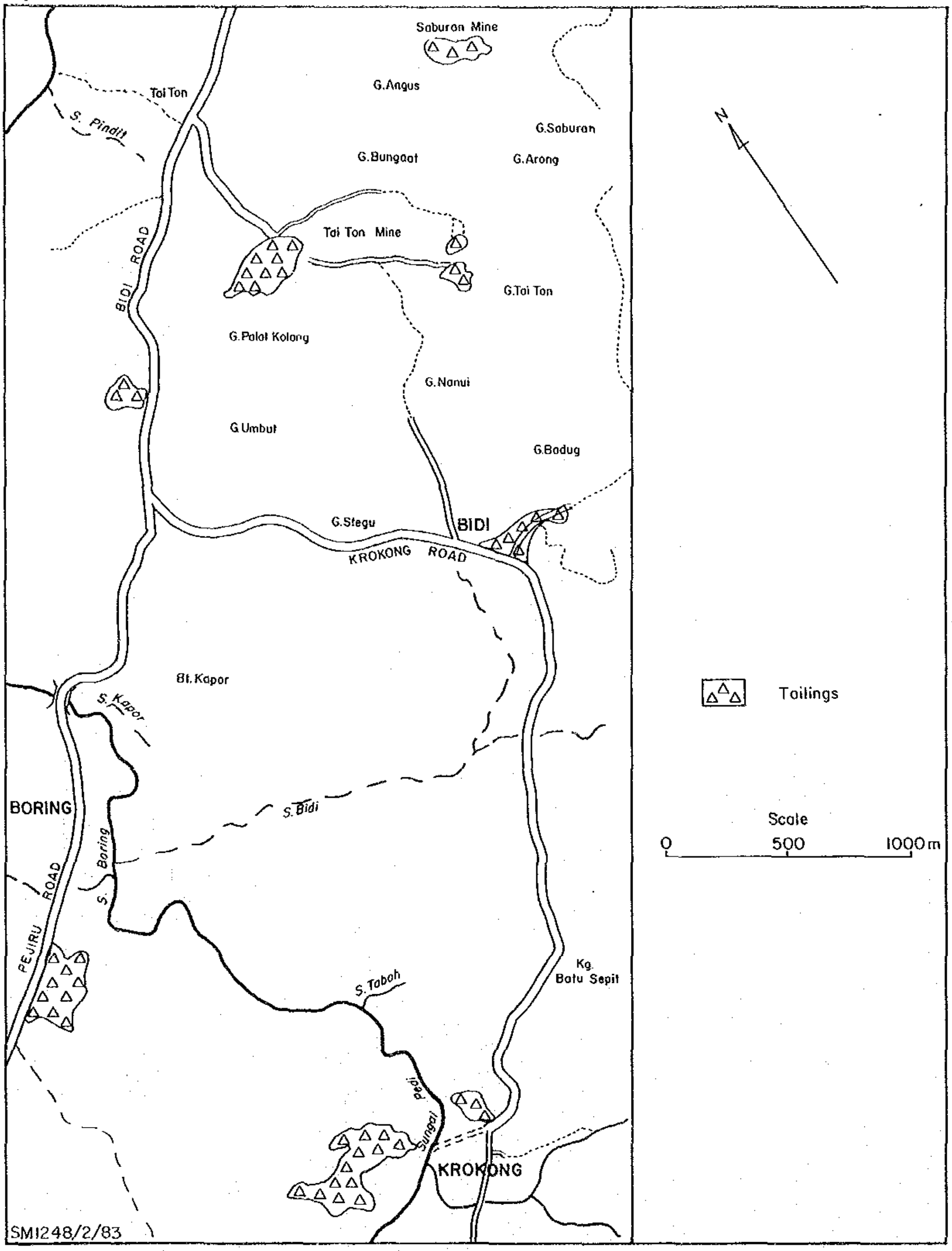

Fig. II—20 Location Map of Mine Tailing Dumps Along Bau-Krokong and Bau-Pejiru Roads

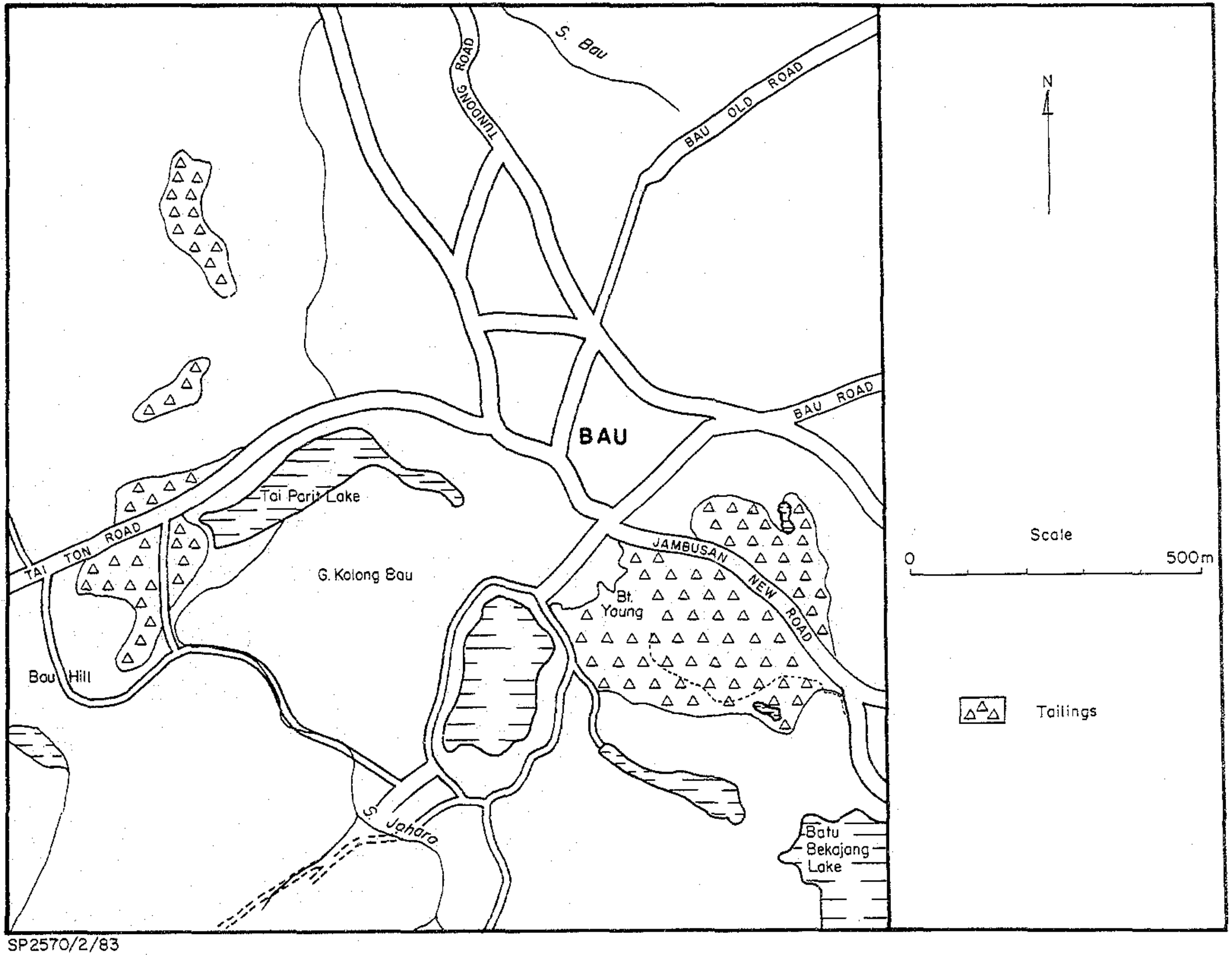

Fig. II—21 Location Map of Mine Tailing Dumps, Bau Town

Old Bau Airstrip

23 auger holes were sunk in the area, ideally each until the bottom of the tailing dump was intersected or as deep as conditions permitted (Fig. II–22). The thickness of the dump varies from 0.2 m to 4 m (Fig. II–23). Representative samples were taken from each auger hole and analysed for Au, Ag and As. The average Au content for samples from each hole was calculated and by block averaging, the overall average grade and tonnage of the tailing dump estimated.

Average Au grade of Tailing Dump = 2.01 g/t

Total Reserve of Tailing Dump = 261,160 t

(s.g. of tailings = 1.6)

Southwest End of Tai Parit Lake

The mine dump at the southwest end of the Tai Parit lake consists of a mixture of tailings, waste overburden and limestone blocks. 15 auger holes were sunk in the same manner as described above (Figs. II–24 & 25). The thickness of the dump varies from 0.4 m to 3.7 m. The average Au grade of the dump computed from the analysed samples of representative auger hole samples, is 0.77 g/t. As this value is too low to merit further consideration, no reserves estimation was made.

Based on the investigations described, the averaged Au grades of the tailing dumps in the Bau Mining District vary between 1.24 to 2.02 g/t except for that at Saburan which probably averages around 5.0 g/t of gold. The total reserve of the tailings is estimated to be not less than 2,000,000 t.

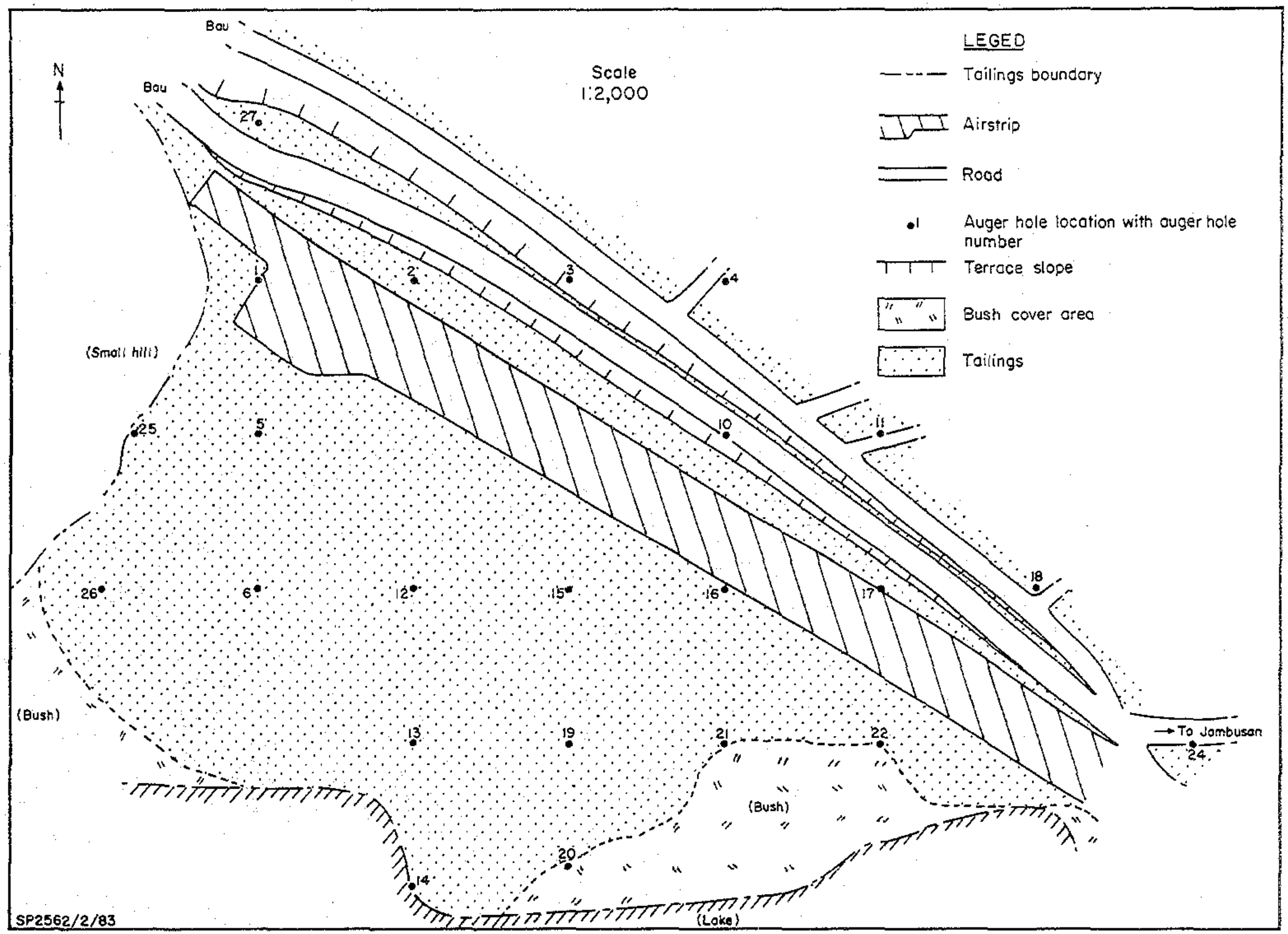

Fig. II —22 Distribution of Mine Tailings, Old Bau Airstrip

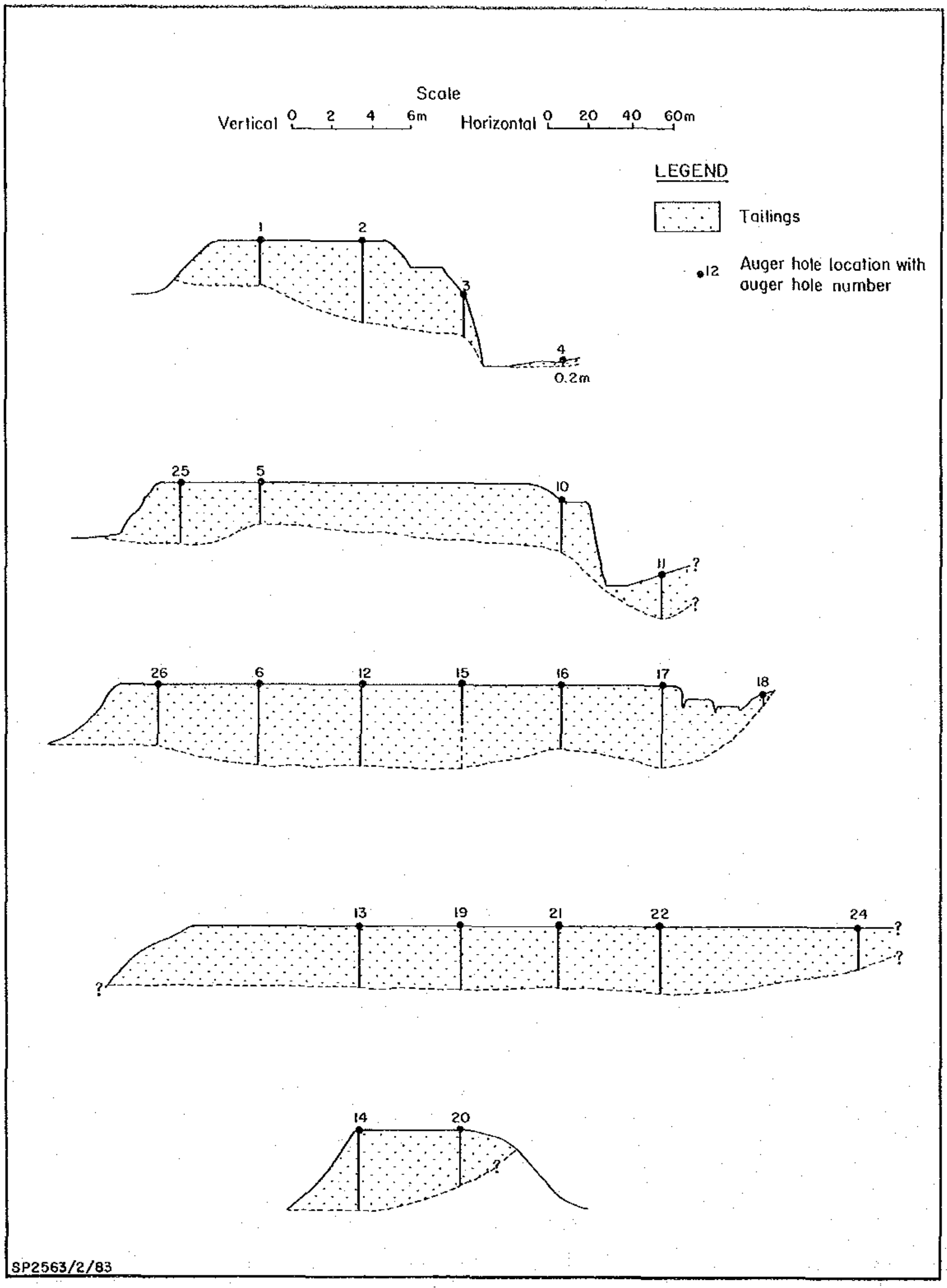

Fig. Ⅱ—23 Section of Mine Tailing Dump, Old Bau Airstrip

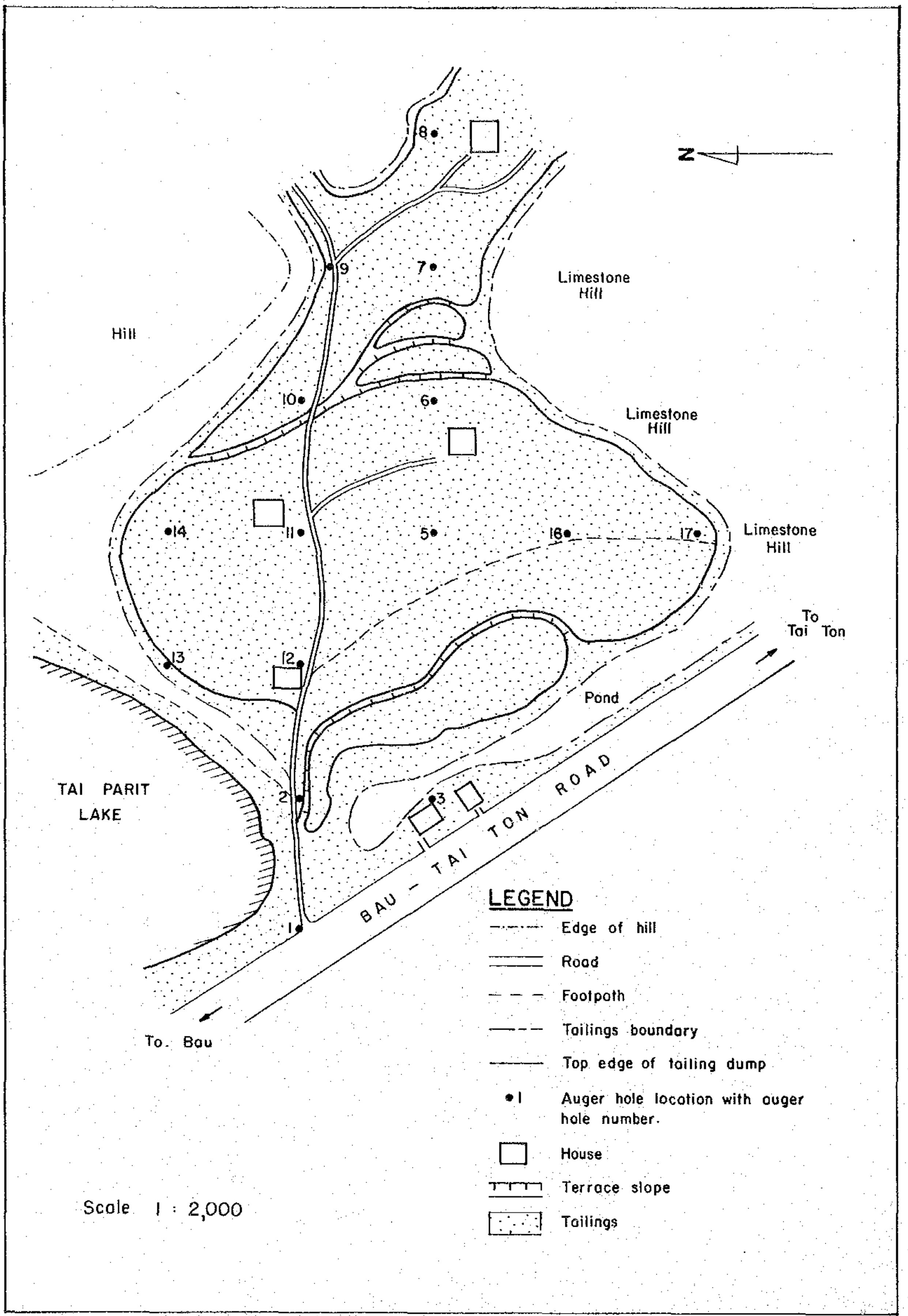

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Fig. II—24 Distribution of Mine Tailings, Southwest End of Tai Parit Lake

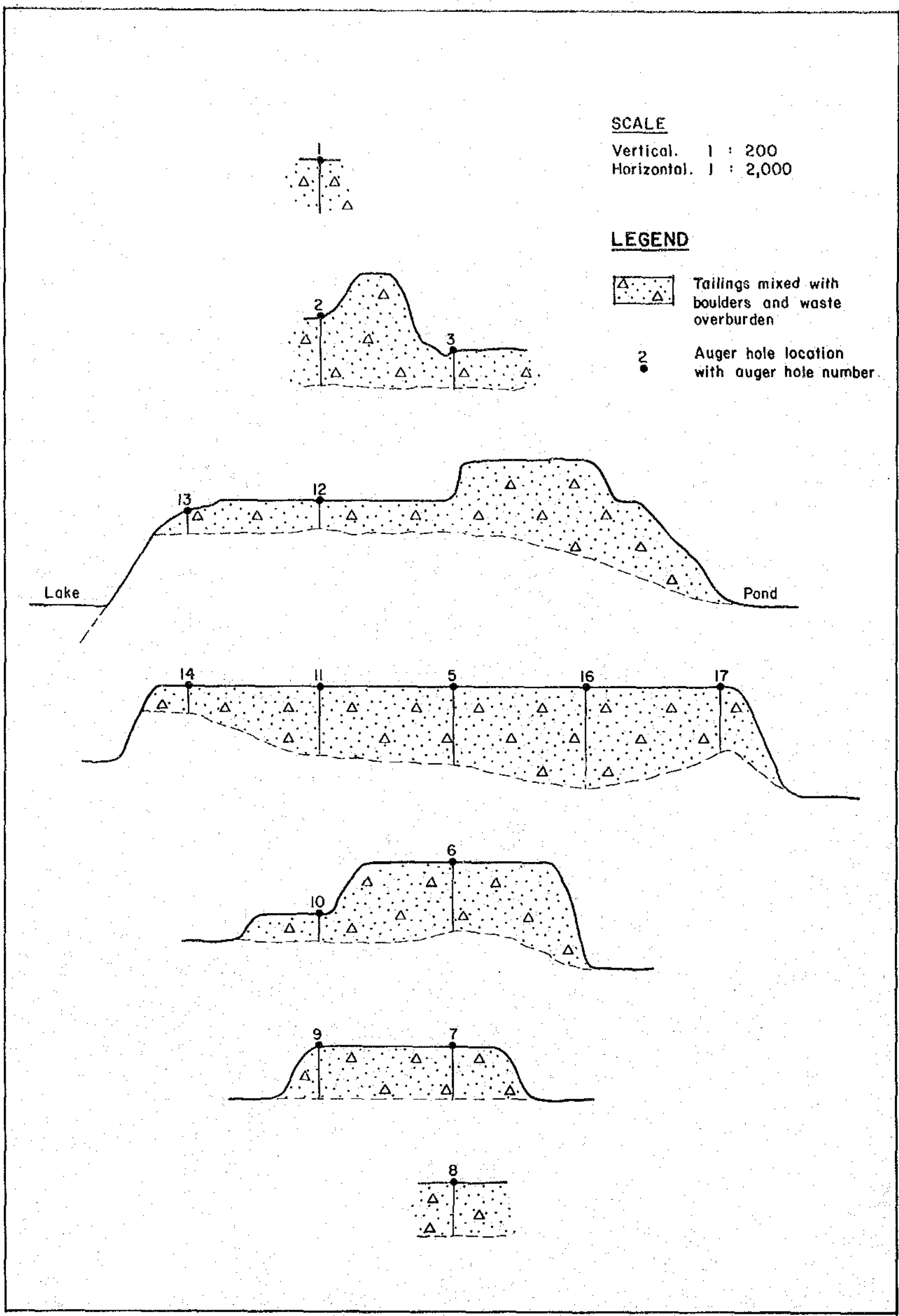

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Fig. II—25 Sections of the Tailing Dump, Southwest End of Tai Parit Lake

PART Ⅲ GEOCHEMICAL SURVEY

CHAPTER 1. GENERAL REMARKS

Geochemical survey by means of stream sediment and panned concentrate sampling constitutes a major part of Phase I of the Collaborative Mineral Exploration Project. Though the joint survey between the staff of the Geological Survey of Malaysia, Sarawak and the Japanese aid team commenced only in August 1982, collection of geochemical samples was started independently by the Geological Survey of Malaysia as early as March, 1982. By October, 1982, the whole project area of 540 km^2 was covered with a total collection of 663 stream sediment and 454 panned concentrate samples. The field routes traversed were also geologically mapped and rock samples were also collected.

The stream sediment samples were analysed for 14 elements: Au, Sb, As, W, Ag, Cu, Pb, Zn, Mo, Fe, Mn, Hg, Ba and U. Panned concentrate samples were counted for gold grains and treated simply by plotting the number of gold grains detected in the samples on a drainage map of the area. Statistical methods including a simple graphic method of deriving meaningful statistical level and multivariate analysis techniques were applied to treat and interpret the analytical results of stream sediment samples.

CHAPTER 2. GEOCHEMICAL SURVEY - STREAM SEDIMENT SAMPLING

Reconnaissance geochemical survey of the project area of 540 km^2 by sampling of active stream sediments was commenced independently in March, 1982 by the staff of the Geological Survey of Malaysia, Sarawak. Sampling was continued jointly with the Japanese aid team in August 1982 and by October 1982, the whole project area was covered with a total collection of 663 stream sediment samples. Rock and panned concentrate sampling, and geological mapping of the routes traversed were also undertaken at the same time.

The stream sediments samples were analysed for 14 elements: Au, Ag, Sb, Cu, Pb, Zn, Fe, Mn, As, Mo and Hg in the laboratory of the Geological Survey of Malaysia, Sarawak and W, Ba and U in the laboratory of Chemex Labs Ltd., Vancouver, Canada. The analytical data are interpreted and discussed in following sections.

In the heavily prospected Bau area, especially in the vicinity of Bau town, contamination of samples primarily by mining activities chiefly of the 'dig and burro' type cannot be avoided. An inventory of all known old workings and field observations at all sampling sites are relied upon in the interpretation of geochemical data.

2–1 Field Procedure

The total collection of 663 stream sediment samples results in a sampling density of 1.2 samples per km^2. Except for those from the limestone area around Bau Town, all other samples sites were preselected on a 1:50,000 scale, topographic map of the project area. In the former area, selection of sample sites was only possible in the field as drainage is not shown on the topographic map or is uncertain. Most samples were collected from first and second order streams though some were also from third and fourth order streams. At each site, a minimum of about 20 g of wet sieved, stream sediment sample of –80 mesh was collected in a plastic bag. All relevant information including among others, the sample number, geographic co-ordinates, elevation, rock type, vegetation and possible source of contamination was recorded on a standard field coding form.

2–2 Laboratory Procedure

Stream sediment samples were air-dried prior to analysis. About 5 g of each sample was sent to Chemex Labs Pye, Ltd., Vancouver, Canada for the analysis of Ba, W and U. The rest of the samples were analysed for Au, Ag, Sb, Cu, Pb, Zn, Fe, Mn, As, Mo and Hg in the laboratory of the Geological Survey of Malaysia, Sarawak. Mo, W, Sb, and As were analysed by calorimetric methods, U fluorimetrically, Au, Ag, Cu, Pb, Zn, Fe, Mn and Ba by atomic absorption and Hg by the Jerome Gold Film Mercury Detector, Model 301. The Atomic Absorption Spectrophotometer used in the Sarawak laboratory is the Perkin-Elmer 2380 and that by Chemex Labs, Ltd. is the Techtron AA5. Details of analytical procedures used and their detection limits are given in Appendix A–1 and A–2.

2–3 Data Treatment

2–3–1 Simple Statistical Analysis

The analytical results for all 14 elements and samples were tabulated (Table A–8). By inspection, any obvious highly anomalous values for each element were ignored in the determination of the arithmetic class intervals for histogram construction. The general rule of $\sqrt{N}$, where N is the number of data, was used as a guide to the number of classes to be used is the calculation. For censored distributions in which more than 50% of each data set is below the analytical detection limit, however, class intervals were dictated by the detection limit. Class limits are determined generally by dividing the range of values of each data set by the number of classes. The above calculations, class frequencies, the reverse cumulative frequencies, and histogram plots were undertaken with the help of a mini desk-top computer. Cumulative probability plots using log-probability paper were manually done. In drawing the best fitting line for the background population, points around the 50 percentile are given greater importance as they represent classes with greater proportions of the population.

Distributions of most elements show bimodel populations. In such cases, partitioning as described by Sinclair (1974) was used to separate the anomalous from the background population. The mean of the background ($\bar{X}$), mean plus one standard deviation ($\bar{X}$ + S), mean plus two standard deviations ($\bar{X}$ + 2S) and mean plus three standard deviations ($\bar{X}$ + 3S) were then directly read off from the cumulative-probability plot. Censored distributions for Au, Mo and Sb were similarly treated by assuming that the data below the detection limit forms part of the detected background population. The statistical parameters for the various elements derived are shown in Table III–1. For Au, the statistical levels $\bar{X}$ + S and $\bar{X}$ are not extrapolated as they fall well below the detection limit.

The analytical results for each element were subsequently plotted on a 1:100,000 scale drainage map using symbols to correspond to values of less than $\bar{X}$ + S, equal or greater than $\bar{X}$ + S, equal or greater than $\bar{X}$ + 2S and equal or greater than $\bar{X}$ + 3S. The exact values for all samples with values of equal or greater than $\bar{X}$ + 3S are also shown on the map. In the cases of Au and Sb, for which the $\bar{X}$ + S values fall below their detection limits, all values below

Table Ⅲ—1 **Statistical Parameters of Metal Contents in Stream Sediments**

Element	Statistical Parameters			
	$\overline{X}$	$\overline{X}$ + S	$\overline{X}$ + 2S	$\overline{X}$ + 3S
Au	—	—	0.04 ppm*	4.4 ppm
Sb	0.06 ppm*	0.39 ppm*	2.6 ppm	19.0 ppm
As	5.7 ppm	15 ppm	40 ppm	105 ppm
Ag	0.37 ppm	0.68 ppm	1.2 ppm	2.3 ppm
Cu	9.3 ppm	16 ppm	28 ppm	48 ppm
Pb	9.5 ppm	18 ppm	35 ppm	66 ppm
Zn	38 ppm	75 ppm	142 ppm	280 ppm
Mo	0.38 ppm	0.8 ppm	1.75 ppm	3.75 ppm
W	0.8 ppm	2 ppm	4 ppm	9 ppm
Fe	1.8 %	3.5 %	6.6 %	13 %
Mn	100 ppm	260 ppm	500 ppm	1000 ppm
U	0.6 ppm	1.1 ppm	1.8 ppm	3.1 ppm
Ba	100 ppm	200 ppm	340 ppm	600 ppm
Hg	38 ppb	87 ppb	210 ppb	500 ppb

Statistical parameters are derived from cumulative probability plots

$\overline{X}$ = mean, S = standard deviation

* value extrapolated below analytical detection limit

the detection limits are indicated by same symbol.

2–3–2 Multivariate Analysis

Several mathematical methods are applicable for the interpretation of multivariate geochemical data. Two of these methods namely, cluster analysis and factor analysis were applied to the analytical results of all the stream sediment samples obtained during the geochemical survey of the project area.

Cluster Analysis

Cluster analysis is the most fundamental method which is frequently used to classify variables or samples in their order of magnitude of similarity. There exists several ways of performing cluster analysis based on different approaches used in grouping the variables of the multivariate data set. The method of agglomerative hierarchical cluster analysis was employed in this exercise to classify the 14 elements analysed for all the stream sediments. All calculations were performed by computer which involved the various steps as outlined in Fig. III–1. In the construction of the dendrogram, various processes of calculation can be used. For the stream sediment analytical data, all six calculations shown in the Fig. III–1 were tried.

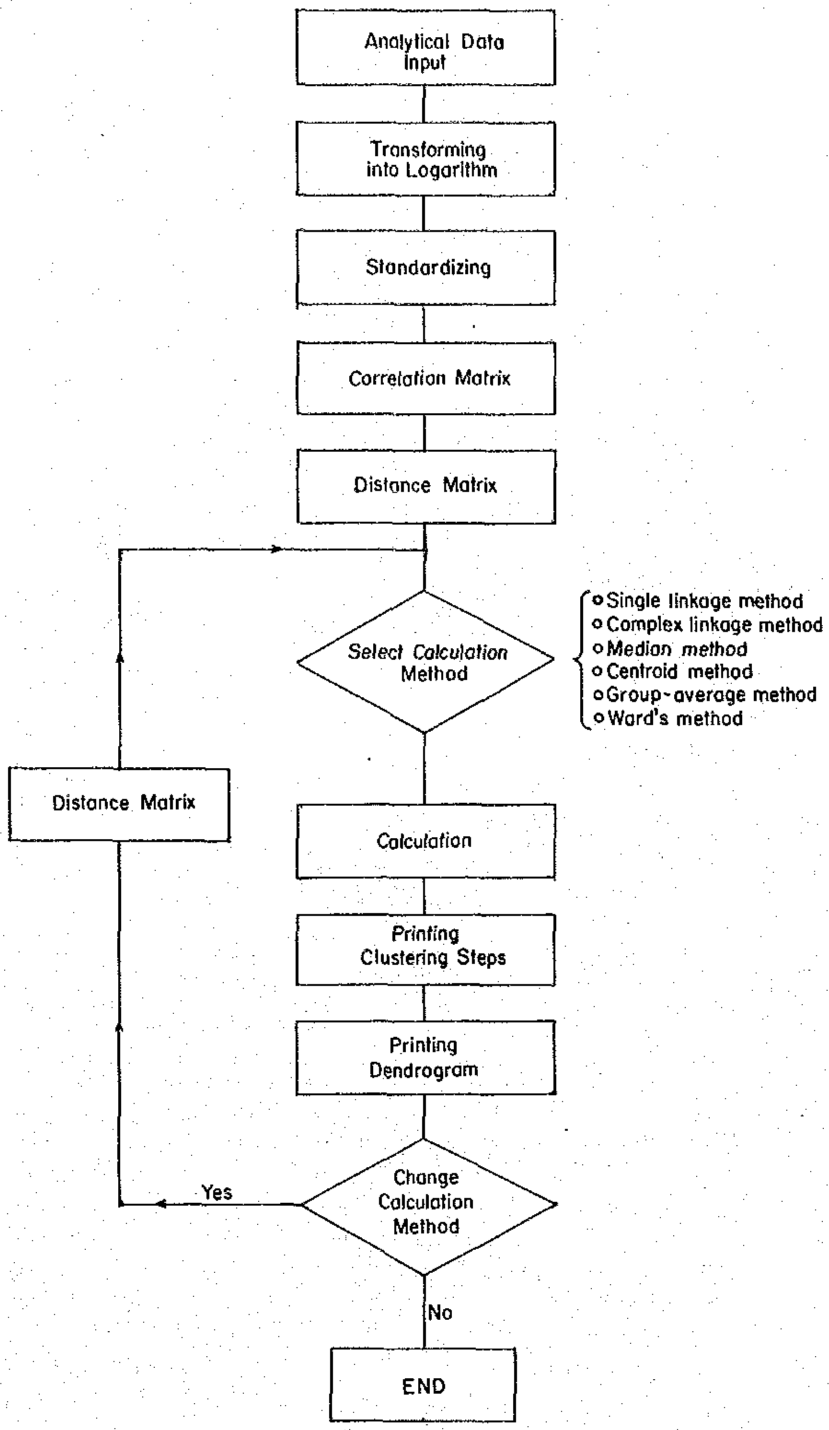
Factor Analysis

Factor analysis was used to interpret possible relationships among the 14 elements of the stream sediment samples analysed. The technique basically involved establishing a smaller number of provisional variables called factors from a large number of variables. By quantitfying the degree of association each sample has to a factor, that is giving it a factor score, it is possible to describe spatially, the relationship of the samples to each factor. Each factor in the case of geochemical values probably represent a type of mineralization in which various elements are closely associated. For the computer treatment of the stream sediment data, the R-mode technique of factor analysis which is outlined in Fig. III–2 was used.

2–4 Distributions of Elements

The distributions of the 14 elements analysed are displayed on 1:100,000 scale drainage maps of the project area. The values are denoted by symbols to correspond to the various statistical levels derived as discussed earlier. The actual values of all highly anomalous samples equal or greater than $\overline{X} + 3S$ are also indicated on the maps.

Contamination of geochemical stream sediment samples as a result of intensive prospecting and mining activities around the Bau town area presents a serious problem in the evaluation of the true importance of anomalous values obtained in this area. There is little doubt that



Agglomerative Hierarchical Cluster Analysis

Fig. Ⅲ—1 Flow Chart of Cluster Analysis

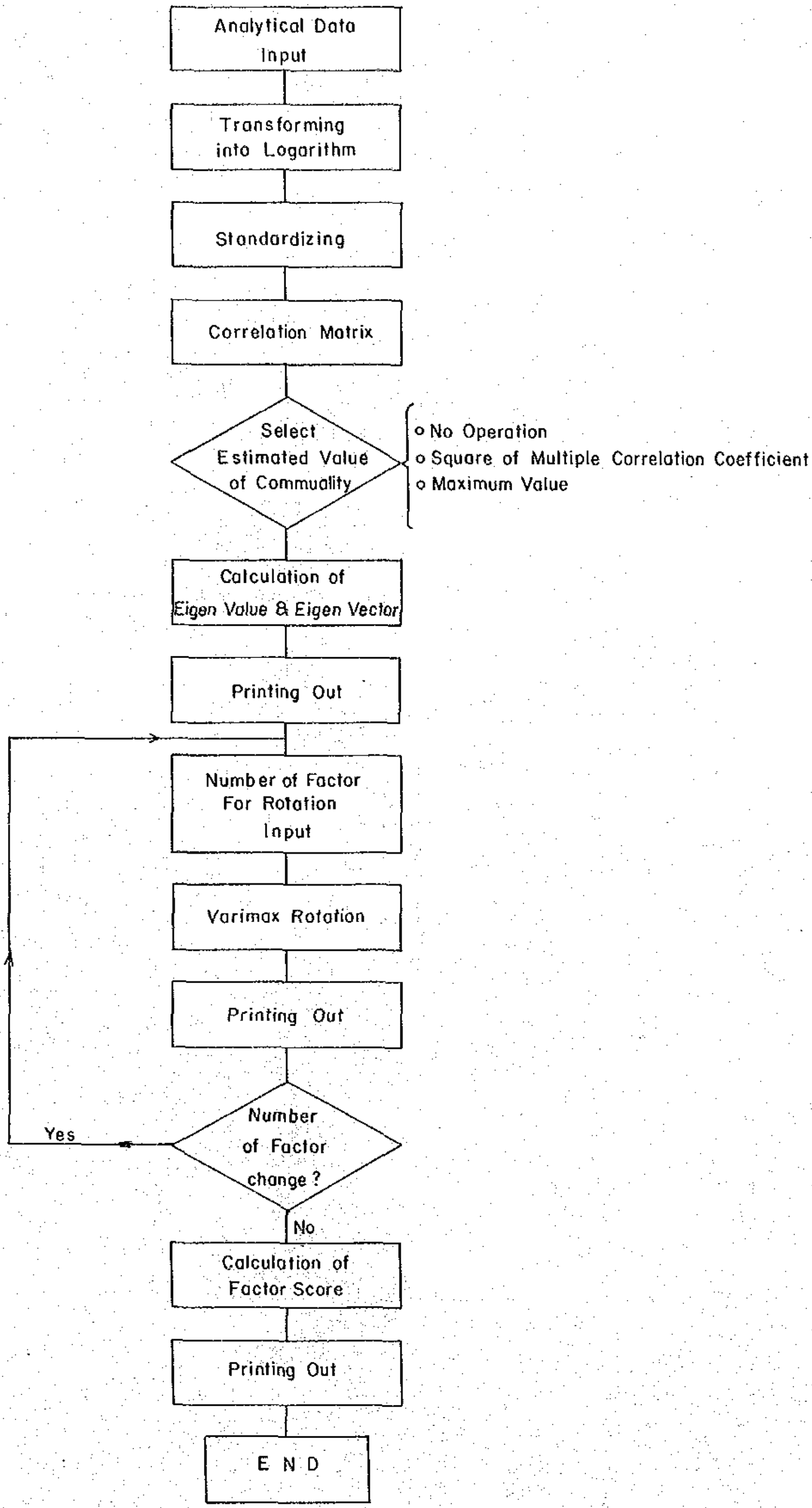


Fig. Ⅲ—2 Flow Chart of Factor Analysis

most of the anomalous values have been elevated considerably as opposed to any naturally caused anomalous values, had there been no such activities in the area. Nevertheless, the anomalous values do indicate the known mineralization in the area. In evaluating anomalous values in areas where there is relatively no such activities, care must therefore, be taken not to allow the highly anomalous values obtained in the disturbed area to overshadow the importance of the not so highly anomalous values in these areas.

2–4–1 Gold (Au)

The distribution of gold in stream sediments is illustrated on Map III–1(1). All detected values of 0.1 ppm and greater are well above the extrapolated threshold of 0.04 ppm ($\overline{X} + 2S$). Such values represent 10% of the 663 samples analysed. As expected most of the anomalous values are concentrated in the heavily prospected and mined, limestone area around Bau town. There are 9 highly anomalous samples of greater than $\overline{X} + 3S$ with values ranging from 5.7 to 61.2 ppm in this area. The anomalous results verify the known old gold workings and reported occurrences of gold in this area except for 5 anomalous values with 2 carrying 15.1 and 17.9 ppm south of the G. Ropih Tertiary intrusive.

South of the traditional mining area, anomalous values are few and scattered. Three values of greater than $\overline{X} + 2S$ (0.1 ppm) are recorded in 3 contiguous, parallel streams draining the south slope of the Jagoi granodiorite north of Kg. Duyoh. Reported occurrences near Kg. Bogag and Kg. S. Aup are also reflected in 4 anomalous value of greater than $\overline{X} + 2S$. The old gold working NE of G. Api, is picked up by a value of greater than $\overline{X} + 2S$. The occurrence reported by local inhabitants in S. Puteh which drains hydrothemally altered intrusive and pyroclastics/epiclastics, gave a highly anomalous value of 19.8 ppm in the stream sediments. One other anomalous value of the greater than $\overline{X} + 2S$ is found in a tributary of S. Nolan, draining the Pedawan Formation.

Outside the Bau town area, the anomalous areas for Au, in their order of importance may be considered as, the catchment area of S. Puteh, the area north of Kg. Duyoh where mineralization is hitherto unknown and the G. Api area.

2–4–2 Antimony (Sb)

The distribution of antimony in stream sediments is illustrated on Map III–1(2). The threshold of $\overline{X} + 2S$ is 2.6 ppm, obtained from the partitioned background population. Most anomalous values as in the case of gold, are clustered around the Bau town area. Of the total 663 samples analysed, about 17.4% are above threshold and 72 samples highly anomalous

(X + 3S) with values ranging from 21.0 ppm to 10,640 ppm . Obviously many of the high values are elevated artifically to varying degrees by contamination from past mining activities. Their distribution however, reflects all known old workings and stibnite occurrences, and a few localities where there is no previously known mineralization. The latter include, an anomalous sample of 211 ppm from a tributary of S. Sta'at just E. of Kg. Sogo, 3 samples of 28.0 to 36.6 ppm just SW of Kg. Skio, and 2 possibly road-contaminated samples, one of 34.0 ppm from S. Sijaik and the other of 1,110 ppm from S. Kapok.

Outside of the Bau town area, S. Puteh again shows up with two anomalous values of greater than $\overline{X} + 2S$. The old Gading Mercury Mine near Bt. Tebang also gave anomalous values of greater than $\overline{X} + 3S$ in two samples.

2–4–3 . **Arsenic (As)**

The distribution of arsenic in stream sediments is illustrated on Map III–1(3). Out of the 663 samples analysed, about 15.1% are above the threshold value, $\overline{X} + 2S$, of 40 ppm obtained from the partitioned background population. Highly anomalous samples of greater than 105 ppm ($\overline{X} + 3S$) range from 105 to 7,952 ppm. The general pattern of distribution of the anomalous values conforms to those for Sb and Au.

2–4–4 **Tungsten (W)**

The distribution of tungsten in stream sediments is illustrated on Map III–1(4). Out of the 663 samples analysed, about 9.4% are above the threshold value, $\overline{X} + 2S$ of 4 ppm obtained from the partitioned background population. 30 samples have values greater than $\overline{X} + 3S$, ranging from 10 to 450 ppm. Clustering of anomalous values occurs in the Jambusan, Bt. Pangga, G. Umbut and G. Ropih areas and may be correlated with those for Au, Sb and As. High values, several times $\overline{X} + 3S$ are detected in the first three areas which are underlain by the Bau Limestone. Other minor anomalies with 1 or 2 samples slightly above $\overline{X} + 3S$ are found in two tributaries of S. Pinyawan draining the Tertiary intrusive of G. Ngian, in a tributary of S. Skunyit B near Plaman Segah, S. Pejiru, a tributary of S. Pedau-un, S. Sebuloh, a tributary of S. Serikin near Kg. Serikin and in a tributary of S. Tuban near Kg. Skebang Opar.

2–4–5 **Silver (Ag)**

The distribution of silver in stream sediments is illustrated in Map III–2(5). Of the 662 samples analysed, about 4.8% falls above the threshold, $\overline{X} + 2S$ of 1.2 ppm obtained from the cumulative-probability plot. 16 samples have values greater than $\overline{X} + 3S$ ranging from 2.8 to

34 ppm. There is only 1 major cluster of anomalous values located in the limestone area around G. Tabai. Other anomalous values are singly located or in small groups of 2 or 3. Of these, 1 sample from S. Duyan draining the Tertiary intrusive of G. Duyan analysed to contain 34.0 ppm and 1 sample from a tributary of Ulu S. Pedau-un, 8.3 ppm.

2–4–6 Molybdenum (Mo)

The distribution of molybdenum in stream sediments is illustrated in Map III–2(6). Out of the 663 samples analysed, 17 are above the threshold, $\overline{X} + 2S$ of 1.75 ppm obtained from the partitioned background population. 5 of these have values greater than $\overline{X} + 3S$, ranging from 4.4 to 6.0 ppm. Only 1 cluster of anomalous values shows up - in the streams draining the G. Ropih Tertiary intrusive. Outside this area anomalous values are singly distributed and are of the order of greater than $\overline{X} + 2S$, except for 1 from S. Pejiru with a greater than $\overline{X} + 3S$ value.

2–4–7 Copper (Cu)

The distribution of copper in stream sediments is illustrated in Map III–2(7). Out of the 662 samples analysed, 27 are above the threshold $\overline{X} + 2S$ of 28 ppm obtained from the partitioned background population. Of these, 11 have values greater than $\overline{X} + 3S$ ranging from 50 to 174 ppm. A major cluster of anomalous values occurs around the Tertiary intrusives of G. Juala and G. Ropih. Outside this area, anomalous values are singly distributed.

2–4–8 Lead (Pb)

The distribution of lead in stream sediments is illustrated in Map III–2(8). Out of the 662 samples analysed, 32 are above the threshold, $\overline{X} + 2S$ of 35 ppm obtained from partitioned background population. Of these, 19 have values greater than $\overline{X} + 3S$ ranging from 69 to 740 ppm. A major cluster of anomalous values occurs around the Tertiary intrusives of G. Juala and G. Ropih. Limestone areas around Bt. Pangga, G. Krian and G. Tabai also show some clustering of anomalous values. 3 anomalous values occur in the tributaries of S. Pinyawan draining the G. Sebwad and the south slope of the G. Tra'an Tertiary intrusives. In general the distribution of anomalous values for Pb is correlatable with that of Cu.

2–4–9 Zinc (Zn)

The distribution of zinc in stream sediments is illustrated in Map III–3(9). Out of the 662 samples analysed, 27 are above the threshold, $\overline{X} + 2S$ of 142 ppm obtained from the partitioned background population. Of these, 9 have values greater than $\overline{X} + 3S$ ranging from 296 to 910 ppm. Generally, anomalous values are singly distributed and confined to areas of past mining activities and most probably are caused artifically. 2 anomalous samples with 1 containing 545 ppm from the area of the G. Juala Tertiary intrusive probably reflect the known massive sulphide veins in the area. Single values greater than $\overline{X} + 3S$ are also obtained from S. Pejiru, S. Kapok and a tributary of S. Mungang.

2–4–10 Iron (Fe)

The distribution of iron in stream sediments is illustrated in Map III–3(10). All values plotted belong to the background population and no significant anomalies exist.

2–4–11 Manganese (Mn)

The distribution of manganese in stream sediments is illustrated in Map III–3(11). All 662 samples analysed, plot as a single background population. 37 have values above the threshold, $\overline{X} + 2S$ of 500 ppm and 18 of these are equal or greater than $\overline{X} + 3S$ ranging from 1,000 to 4,320 ppm. With the exception of 6 samples, anomalous values are concentrated in the limestone area around Bau town where past mining activities were most intense. A cluster of 4 samples with values greater than $\overline{X} + 3S$ occurs in the S. Pinyawan area just NE of Kg. S. Maung and may be correlated with anomalous values for silver and barium. Single high values also occur in S. Kapok and S. Pundon near Kg. Boring.

2–4–12 Uranium (U)

The distribution of uranium in stream sediments is illustrated in Map III–3(12). Of the 663 samples analysed, 58 are equal or above the $\overline{X} + 2S$ value of 1.8 ppm obtained from the partitioned background population. Of these, 24 are above $\overline{X} + 3S$ ranging from 3.2 to 9.0 ppm. The anomalous values are all clustered in and around the Jagoi granodiorite and in all likelihood, reflect the expected normally higher uranium content of the granitic body. A local concentration of high values of greater than $\overline{X} + 3S$ occurs in the area just NW of Kg. Serikin may however, be worthy of a follow-up check with a scintillometer.

2–4–13 Barium (Ba)

The distribution of barium in stream sediments is illustrated in Map III–4(13). Of the 663 samples analysed, 26 are equal or above the $\overline{X} + 2S$ value of 340 ppm obtained from the partitioned background population. Of these, only 1 sample with a value of 3,280 ppm is above the $\overline{X} + 3S$ value and is from the stream draining the old Tegora Mercury Mine. Minor cluster of values of greater than $\overline{X}$ + 2S occur in the S. Pinyawan area coincident with anomalous values for silver and manganese, in S. Pinyawan draining the south slope of the G. Tra'an Tertiary intrusive and in the Jagoi granodiorite.

2–4–14 Mercury (Hg)

The distribution of mercury in stream sediments is illustrated in Map III–4(14). Out of the 608 samples analysed, 116 have values greater than $\overline{X}$ +2S of 210 ppb obtained from partitioned background population. Of these, 68 are above $\overline{X}$ + 3S ranging from 543 to 157,000 ppb. Mercury enrichment forms an extensive zone stretching from the old Tegora Mercury Mine at G. Tegora along a NE direction to as far as G. Sta'at. There appears to be no correlation with other elements in this zone. Outside of this zone, clustering of anomalous values occurs in the Jambusan area coincident with Au, Sb, As and W, in the Bt. Pangga area where it is correlatable with Au, Sb, As and W enrichments and in the old Gading Mercury Mine area near Bt. Tebang.

2–5 *Results of Multivariate Analysis*

2–5–1 Cluster Analysis

The resulting dendrogram constructed by the median method of the agglomerative hierarchical cluster analysis technique is as shown in Fig. III–3. As is obvious from the dendrogram a very close association exists between Zn and Fe which are further related to Cu, Pb, and Mn to form a group. This association may be taken to mean that any base metal mineralization in the area would have these elements closely associated.

The dendrogram also reveals that Sb is closely related to As and subsequently to Au and W to form another group of associated elements. This group association may be correlated to the Au-Sb mineralization which produced most of the known ore deposits in the Bau Mining District, such as, the Lucky Hill, the old Tai Parit and the Tai Ton Mines. It is interesting to note that W is associated with Au and Sb. This fact is borne out by a survey for scheelite by panned concentrate sampling undertaken by the Geological Survey of Malaysia, in the Bau area before the commencement of this joint project. During the survey gold and stibnite grains were commonly detected in samples containing scheelite.

The dendrogram also shows that Hg is only very distally related to the two groups. The 3 groups of elemental associations described so far may be correlated to the possibility of a general zonal arrangement suggested by the distributions of elements discussed earlier.

As is also clear from the distribution of elements, the dendrogram shows U to behave almost independently and is only very distally related to Ba.

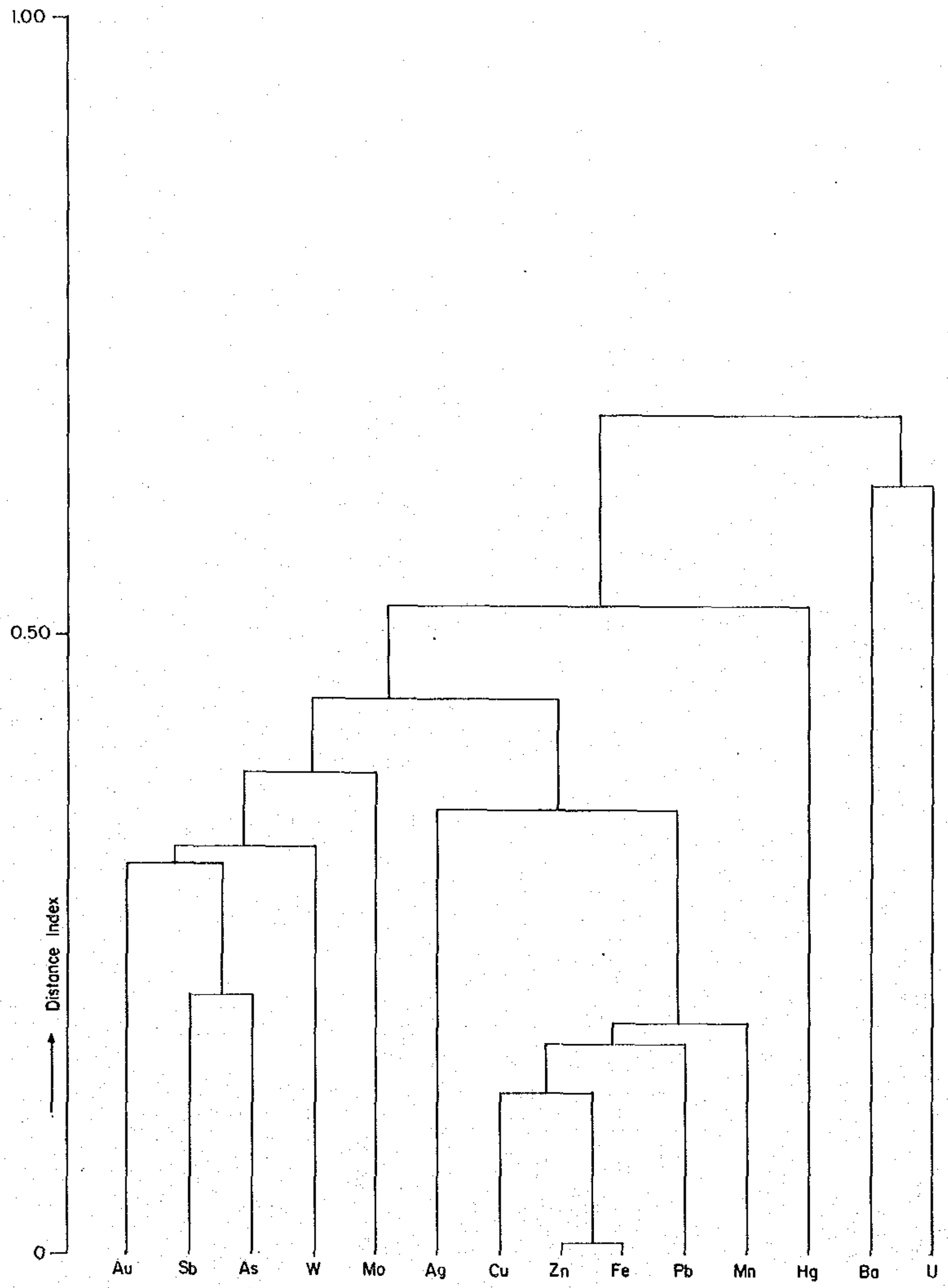


Fig. Ⅲ—3 Dendrogram of Analysed Elements by Median Method

2–5–2 Factor Analysis

The results of the R-mode factor analysis is summarized in Table III–3. The factor loadings shown were rotated for 4 factors which represent 4 elemental associations derived from the dendrogram of cluster analysis described in the preceding section.

The geological significance of each factor may be considered as follows:

i) Factor 1 has high loadings of more than 0.5 for Cu, Pb, Ag and Zn and accounts for 16.3% of the data variability. This suggests that any mineralization in the area of one of this element will be accompanied by the others in the group. The Cu-Pb-Zn association is in fact well known in many hydrothermal ore deposits and is also recognized in some known deposits in the Bau Mining District.

ii) Factor 2 has high loadings of more than 0.65 for Sb, W, Au and As and accounts for 17.7% of the data variability. This correlates well with the Sb-Au-As association commonly found in epithermal Sb-Au deposits and recognized in most of the known ore deposits in the area. As mentioned earlier, W as scheelite is also found associated with Au and Sb. Factor 2 therefore, is related to the principal type of mineralization known in the Bau Mining District.

iii) Factor 3 has a loading of 0.588 for U and accounts for 8.6% of the data variability. Although it is not known whether any U mineralization exists in the area, it is clear from the distribution of U in stream sediments, that this factor is related to the relatively higher content of U in the Jagoi granodiorite.

iv) Factor 4 has negative high loadings of less than –0.55 for Fe, Zn and Mn and accounts for 13.7% of the data variability. The association of these elements is probably related to sphalerite and the scavenging of these elements by stream sediments.

2–5–3 Distribution of Factor Scores

Factor scores for all stream sediment samples were computed, using the two important factors 1 and 2 which are considered to be related to mineralization in the Bau area.

Factor 1 (Cu-Pb-Ag-Zn Association)

The distribution of factor 1 scores for stream sediment samples is illustrated in Map III–5(1). 8 very high score samples of more than 2.0 (equivalent to $\overline{X} + 2S$ values) are found near G. Juala, G. Ropih, G. Sebwad, G. Duyan and G. Baran. Samples with scores of more than 1.0 (equivalent to $\overline{X} + S$) are distributed mainly around these areas. The rest of the samples with scores of more than 1.0 but less than 2.0 are concentrated in the limestone area just south of Bau town and near G. Badud in the southernmost extremity of the project area.

In general, most of the high score samples appear distributed in close relationship to the

Table Ⅲ−2 Correlation Matrix of 14 Elements in Stream Sediments

	Au	Ag	Cu	Pb	Zn	Sb	As	Hg	Mo	W	Fe	Mn	Ba	U
Au	1.000													
Ag	0.206	1.000												
Cu	0.105	0.499	1.000											
Pb	0.355	0.552	0.674	1.000										
Zn	0.151	0.464	0.738	0.669	1.000									
Sb	0.478	0.195	0.213	0.405	0.351	1.000								
As	0.434	0.169	0.264	0.446	0.380	0.626	1.000							
Hg	0.123	0.136	0.267	0.211	0.335	0.273	0.404	1.000						
Mo	0.284	0.229	0.343	0.361	0.338	0.397	0.332	0.157	1.000					
W	0.458	0.208	0.150	0.341	0.208	0.511	0.470	0.194	0.396	1.000				
Fe	0.027	0.374	0.633	0.500	0.782	0.234	0.259	0.296	0.207	0.101	1.000			
Mn	0.239	0.381	0.531	0.594	0.636	0.308	0.317	0.198	0.240	0.234	0.680	1.000		
Ba	−0.170	0.294	0.352	0.291	0.204	−0.160	−0.202	−0.076	−0.083	−0.185	0.269	0.338	1.000	
U	−0.067	0.023	−0.260	−0.118	−0.289	−0.254	−0.290	−0.234	−0.105	−0.083	−0.157	0.021	0.292	1.000

Table Ⅲ—3 Result of R-Mode Factor Analysis

	factor loadings (varimax rotation)				
	Factor				communality
	1	2	3	4	
Au	0.086	0.676	0.018	−0.008	0.464
Ag	0.647	0.203	0.086	−0.167	0.495
Cu	0.743	0.057	−0.290	−0.366	0.774
Pb	0.650	0.401	−0.060	−0.351	0.710
Zn	0.564	0.157	−0.377	−0.574	0.814
Sb	0.067	0.711	−0.265	−0.177	0.612
As	0.049	0.651	−0.384	−0.224	0.624
Hg	0.055	0.203	−0.430	−0.248	0.290
Mo	0.297	0.446	−0.167	−0.034	0.317
W	0.102	0.692	−0.073	−0.027	0.495
Fe	0.391	0.006	−0.244	−0.758	0.786
Mn	0.367	0.261	0.085	−0.709	0.713
Ba	0.408	−0.255	0.347	−0.295	0.439
U	−0.041	−0.095	0.588	−0.001	0.356
factor contributions	16.3%	17.7%	8.6%	13.7%	

NNE trending alignment of Tertiary intrusive stocks. The concentration of very high score samples along the intrusives from G. Juala to G. Baran suggests good potential for base metal mineralization of the type Cu-Pb-Ag-Zn.

Factor 2 (Sb-W-Au-As Association)

The distribution of factor 2 scores is illustrated in Map III–5(2). Very high score samples of more than 2.0 (equivalent to $\overline{X} + 2S$) are distributed in mainly three areas, namely, the G. Pangga, Jambusan and G. Tabai areas. High score samples of more than 1.0 (equivalent to $\overline{X} + S$) are found mainly surrounding these areas. Factor 2 in general appears to be related to mineralization in the limestone area around Bau town.

Outside this area, samples with high scores of more than 1.0 are few and widely scattered. One such sample comes from S. Puteh which drains hydrothermally altered Tertiary intrusive and pyroclastics/epiclastics.

It may be concluded that factor 2 score distribution confirms the known potential of Sb-Au mineralization in the limestone area around Bau town which has already undergone intensive prospecting and mining. Outside this area, possible potential for mineralization exists in the S. Puteh area.

2–6 General Features of Elemental Distribution

From the distribution of elements and the multivariate analyses described in the preceding sections, a generalized pattern of element associations and their distributions may be deducted. This pattern suggests the different types of mineralization that can be expected to occur over various broad zones in the project area.

(1) Au, Sb, W and As enrichments are closely related and generally occur in the limestone area around Bau town. The centres of enrichment in this zone appears to be around Bt. Pangga, Jambusan and G. Tabai.

(2) Cu, Pb and Zn enrichments partly coincident with minor Ag and Mo enrichments occur mainly along the NNE zone of Tertiary intrusive stocks particularly from G. Juala to G. Baran.

(3) Hg enrichment appears independently distributed and is mainly confined to a zone underlain by the Pedawan Formation running in the NE direction from G. Tegora to G. Sta'at. The prominent NE lineament from satellite imagery lies within and is parallel to this zone.

(4) U enrichment is almost completely restricted to the Jagoi granodiorite particularly, in the area NE of Kg. Serikin.

Possibilities for Au mineralization not associated with limestone also occur in the G. Api and S. Puteh areas. These areas merit consideration for follow-up work particularly when the results of panned concentrate samples and the geology are taken into account.

2–7 Geochemical Anomalous Areas

Based on a combination of anomalous values for the various elements and on the catchment areas of the anomalous samples of stream sediments, a number of anomalous areas may be delineated as described in Map III–6 and Table A–9. The areas within the project area recommended for immediate follow-up work include the Jambusan, Tai Parit Fault, G. Ropih/G. Juala, G. Tegora, G. Api and S. Puteh areas. Selection of these areas also take into consideration, the results of panned concentrate sampling and the geology.

Jambusan Area

This area of approximately 13 km^2 falls within the general zone of Au, Sb, W and As enrichment discussed earlier. 39 anomalous samples were obtained in this area, the important main anomalous elements being Au, Sb and W. Anomalous values for Au range from 0.5 ~ 5.7 ppm, Sb from 3.8 ~ 1,592.0 ppm and W from 12 ~ 110 ppm. Gold grains of more than 10 per 50 ℓ of stream sediments were also detected in 6 panned concentrate samples. Though heavily prospected and mined before, the possibility of finding new and extensions of known deposits is good.

Tai Parit Fault Area

This area of greater than 9 km^2 also falls within the general zone of Au, Sb, W and As enrichment. 23 anomalous stream sediment samples were detected in the area. The important anomalous elements include Au, Sb and W with concentration ranges of 0.3 to 9.1 ppm, 3.3~ 612.0 ppm and 4 ~ 450 ppm respectively. Though heavily prospected and mined in the past, the potential for finding new and extensions to old known deposits remains good.

G. Ropih/G. Juala Area

The area covers approximately 6.5 km^2 and falls mainly within the zone of Cu, Pb and Zn enrichment and partly within that of Au, Sb, W and As enrichment. 25 anomalous stream sediment samples were obtained in this area, the important anomalous elements being Cu, Pb, Ag, Mo, Au, Sb and W. Anomalous values for Cu range from 29 ~ 174 ppm, Pb from 37 ~ 740 ppm, Ag from 1.2 ~ 7.6 ppm, Mo from 2.8 ~ 5.8 ppm, Au from 0.5 ~ 61.2 ppm, Sb from 6.1 ~ 157 ppm and W from 4 ~ 13 ppm. Gold grains of greater than 10 per 50 ℓ of stream sediments were also detected in 5 panned concentrate samples. The G. Juala area has been heavily prospected and partly mined. Nevertheless, potential still exists for finding new and extensions to known deposit particularly for Cu, Pb, Au, Sb and Ag. In the G. Ropih area, floats of massive pyrite cobbles and common stockwork-quartz veining of floats were found in the streams draining the intrusive. This provides important supportive evidence of potential mineralization, particularly for Cu, Pb, Au and Mo in this area.

G. Tegora Area

This area covers approximately 18 km^2 and falls mainly within the zone of Hg enrichment. Hg is anomalous in 26 stream sediment samples with values ranging from 251 to 105,000 ppb. The old Tegora Mercury Mine near G. Tegora is located in this area. Potential for finding extensions to this known deposit and of new deposits of Hg is good.

G. Api Area

This area is about 5 km^2 in extent. Though anomalous values for Au, W and Ag are detected in only 1 stream sediment for each element, the area is considered to bear good potential for Au mineralization as high gold grain counts were detected in 4 panned concentrate samples. Two of these samples gave counts of 27 and 56 gold grains. A small old Au working is known in the area.

S. Puteh Area

This area covers about 2.5 km^2 and is underlain mainly by hydrothermally altered Tertiary intrusive, volcanic breccia and volcanic mud-flow deposit. A very high Au content of 19.8 ppm was detected in 1 stream sediment sample and Ag of 2.2 and 8.3 ppm in 2 samples. Together with the favourable geology, the area is considered to possess good potential for Au and Ag mineralizations.

CHAPTER 3. GEOCHEMICAL SURVEY - PANNED CONCENTRATE SAMPLING

Sampling of heavy minerals in stream sediments were undertaken by hand panning, mainly for the purpose of prospecting for gold. Gold was physically detected in more panned concentrate samples than chemically in stream sediment samples. This is possibly because of the particulate method of dispersion of gold and the small amount of sample used in analysis. In cases where gold is chemically detected but not physically as gold grains in the panned concentrate samples, gold probably exists as very fine grains which were washed away during panning.

Panned concentrate samples were counted for gold grains and the results discussed.

3–1 Field Procedure

At most stream sediment sample sites, panned concentrate samples were also obtained by hand panning known volumes of sediments measured with 5 ℓ wooden boxes. Locally made wooden pans (dulang) with diameters of approximately 70 cm were used. Stream sediments were ideally collected at a depth of about 30 cm from natural traps of heavy minerals, such as the inner convex banks of streams and panned by 2 or more assistants until about 15 to 20 g of heavy minerals were obtained. This amount was however, not always possible as panning is time consuming and in such cases, no sample or a lesser amount of the sample was collected. Each panned concentrate sample is carefully washed into and stored in a small plastic bag. All relevant information relating to each sample including, sample number, geographic co-ordinates, elvataion, rock type, vegetation, possible source of contamination, original volume of sediments panned and visual estimation of gold grains were recorded in the field, on a standard coding form.

A total of 454 panned concentrate samples were collected over the project area in the manner described, giving a sampling density of 0.84 sample per km^2.

3–2 Laboratory Procedure

Panned concentrate samples were first air-dried and separated using bromoform (s.g. 2.89). The light fractions were discarded whereas the heavy fractions were weighed and further separated by hand magnet. The magnetic fractions were weighed and the non-magnetic fractions counted for gold grains under the binocular microscope. Mounted heavy minerals of the non-magnetic fractions of some samples were also prepared using the minus 0.180 mm plus 0.150 fractions for future mineralogical studies.

3–3 Data Treatment

Knowing the original volume of stream sediments panned, the number of gold grains per 50 ℓ of stream sediments for each sample was calculated (Table A–10). All calculated values of less than 1 is treated as 1. The calculated results were then plotted on a 1:100,000 drainage map of the project area using symbols to denote 4 classes of greater than 20 gold grains, 11–20 gold grains, 1–10 gold grains and none. The lower limits of the higher 3 classes correspond to approximately the 97.6, 95.6 and 81.5 percentiles.

3–4 Distribution of Gold Grains

The districution of gold grains in panned concentrate samples is shown as the number of gold grains per 50 ℓ of stream sediments in Map III–18. Out of the 454 samples collected, gold grains were detected in 87 (19.5%) in the laboratory using the binocular microscope. There are three main clusters of gold detected samples – in the Jambusan limestone area, the G. Ropih Tertiary intrusive area and the G. Api Tertiary intrusive area. In the Jambusan area, gold grain contents ranging from 21 to 175 per 50 ℓ stream sediments were counted in 6 samples, in the G. Ropih area, 27 and 58 in 2 samples, and in the G. Api area, 27 and 56 in 2 samples. Several old gold workings are known in the Jambusan area and 1 in the G. Api area. None is known in the G. Ropih area where the samples were collected. The high contents of gold grains in the samples from the Jambusan and the G. Ropih area agree with the geochemical anomalous values for Au in the stream sediments in these areas. In the G. Api area however, only 1 anomalous value was detected in stream sediment samples.

Outside these 3 areas, gold grains mainly of less than 10 per 50 ℓ of stream sediments were also detected in a few samples in the Bt. Pangga, G. Tabai and G. Juala areas. In other areas, detected samples are singly located and generally in streams draining the north-northeasterly aligned string of Tertiary intrusives.

At many sample locations, gold is detected in panned concentrate but not in the stream sediment samples because gold was most probably dispersed as particles. An example of this, in the G. Api area where gold grains of greater than 10 per 50 ℓ stream sediments are detected in 4 samples but chemically anomalous only in 1 stream sediment sample. The reverse situation in also true in some cases such as in the G. Tabai, Kg. Duyoh, Kg. Bogag, Kg. S. Aup and the S. Puteh areas. For example, gold grains were not physically detected in panned concentrates from S. Puteh but a stream sediment sample gave a highly anomalous value of 19.8 ppm. This suggests the possibility that gold exists as very fine particles which were not retained in the panned concentrate sample.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Based on the distribution of elements in stream sediment samples and on multivariate analyses of the geochemical data, the following summarized conclusions may be drawn:

(1) 4 broad zones of Metal enrichment exist in the project area; a zone in the limestone area around Bau town where Au, Sb, W and As enrichment occurs, a zone along the NNE alignment of Tertiary intrusives particularly from G. Juala to G. Baran where Cu, Pb and Zn, and minor Ag and Mo enrichments are found in close association, a zone of Hg enrichment stretching from G. Tegora in a northeasterly direction to as far as G. Staat and a zone of U enrichment almost completely restricted to the Jagoi granodiorite.

(2) By combining anomalous values for various elements and the catchment areas of the anomalous samples, 19 anomalous areas may be delineated in the project area.

6 of the anomalous areas are recommended for immediate follow-up work when considered in conjunction with geology and the results of panned concentrate sampling in these areas. The areas include the Jambusan, Tai Parit Fault, G. Ropih/G. Juala, G. Tegora, G. Api and S. Puteh areas.

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APPENDICES

A–1 Detection Limits

Detection limits of the various analytical methods used for the 14 elements are shown below:

Element	Dection Limit	Remarks
Au	0.1 ppm	analysed by Geological Survey of Malaysia, Sarawak (Au to Hg)
Ag	0.1 ppm	
Sb	0.5 ppm	
Cu	1.0 ppm	
Pb	1.0 ppm	
Zn	1.0 ppm	
Fe	0.1 %	
Mn	1 ppm	
As	1 ppm	
Mo	0.5 ppm	
Hg	25 ppb	dependent on vapour pressure of Hg
W	2 ppm	analysed by Chemex Labs Ltd., Vancouver, Canada
Ba	10 ppm	
U	0.5 ppm	

A–2 Analytical Method of Each Element

A–2–1 Analysis of Au

1) Weigh 2 g of sample into breaker.
2) Add 10 ml HC1 and 5 ml HNO_3.
3) Heat unitl paste-like.
4) Dissolve in 10 ml HC1 and 1 ml HNO_3 and make up to 100 ml.
5) Shake and allow to settle.
6) Take 50 ml aliquot in a separating funnel and add 5 ml of MIBK.
7) Shake vigorously for 2 minutes.
8) Transfer organic phase into test tube and measure for Au by AAS.

The AAS setting for Au is wavelength 242.8 nm, slit width 0.7 nm and current 10 mA.

A–2–2 **Analysis of Cu, Pb, Zn, Ag, Fe and Mn**

Cu, Pb, Zn, Ag, Fe and Mn were analysed using the Perkin Elmer 2380 ASS after the samples has been prepared according to the procedure below:

1) 1g of sample weighed and transferred into a beaker.
2) Add 10 ml HCl and 1 ml HNO_3.
3) Stir, cover with watch glass and heat in sand bath for 1 hour.
4) Cool and transfer solution to a graduated test tube.
5) *Make-up to 20 ml.*
6) Shake and allow to settle over night.
7) Measure with AAS.

Settings of AAS:

Element	Wavelength (nm)	Slit width (nm)	Current (mA)
Cu	324.7	0.7	15
Pb	283.3	0.7	10
Zn	213.9	0.7	15
Ag	328.1	0.2	12
Fe	248.3	0.2	30
Mn	279.5	0.2	20

A–2–3 **Analysis of As**

1) Weigh 0.5g of sample into test-tube.
2) Fuse with 2 g of $K_2S_2O_7$.
3) Cool and add 10 ml of 1:3 H_2SO_4 (As free).
4) Leach in a water bath until completely dissolved.
5) Add 10 ml 1:3 H_2SO_4 (As free), shake and allow to settle over night.
6) Take 5 ml aliquot in flask and add 20 ml of 1:3 H_2SO_4 (As free).
7) Make up to 50 ml mark with distilled water and add 5 ml of KI solution (15%) and 0.2 ml of $SnCl_2$ solution (40%).
8) Wait for 15 minutes and add about 8 g of zinc pellets (As free).
9) Connect flask to arsenic apparatus.
10) Allow gas to bubble through chloroform - Ag DDTC solution* via a patch of lead acetate-soaked glass wool until reaction stops.
11) The resulting colour is compared against similarly prepared standards using a photo-spectrometer (wavelength 550 nm).

* Chloroform - Ag DDTC solution is prepared by dissolving 1.25 g silver-diethyl dithiocarbamate and 0.82 g ephedrine in 500 ml chloroform.

A–2–4 Analysis of Mo

1) Weigh 1 g of sample into test tube.
2) Fuse with 3 g of $K_2S_2O_7$ and fuse.
3) Cool and add 20 ml of 1:1 HCL.
4) Shake and allow to settle.
5) Take 5 ml aliquot and add 2 ml of reduction solution*.
6) Add 1 ml of zinc-dithiol solution**.
7) Mix thoroughly and wait for 10 minutes.
8) Add 1 ml of petroleum spirit and shake vigorously for 30 seconds.
9) Compare visually with prepared standards. If concentration is above 0.5 ug/1 ml, the photospectrometer set at wavelength 670 nm is used for comparison. Step 5 onwards is repeated with a lesser aliquot if concentration appears to be above standards.

* Reduction solution - 75 g citric acid + 100 g ascorbic acid made up to 1 1.

** Zinc dithiol solution - 0.3 g zinc dithiol digested until clear with 2 ml ethanol, 4 ml H_2O and 2 g NaOH. 1 ml thioglycollic acid, 40 ml H_2O and 50 5% KI solution added and made up to 100 ml with H_2O.

A–2–5 Analysis of Sb

1) Weigh 1 g of sample into test tube.
2) Add 3 g $K_2S_2O_7$ and fuse.
3) Cool and add 20 ml of 1:1 HC1.
4) Shake and allow to settle.
5) Take 5 ml aliquot and add 0.2 ml $Ce(SO_4)_2$ solution,* 0.1 ml 1% $HONH_2Cl$ solution, 5 ml 8% $(NaPO_3)_6$ solution, 1 ml 0.05% brilliant green solution followed immediately by 5 ml toluene.
6) Shake vigorously for 30 seconds.
7) Compare with prepared standards using the photospectrometer set at wavelength 625 nm. Step 5 onwards is repeated with a lesser aliquot if concentration appears to be above standards.

* Cerium sulphate solution - 0.1M $Ce(SO_4)_2$ in $1M H_2SO_4$.

A–2–6 Analysis of Hg

Hg is analysed using the Jerome Gold Film Mercury Detector, model 301. 0.1 g scoop of sample is normally used but for sample suspected to be high in Hg, the 0.01 g scoop is sufficient.

A–2–7 Analysis of W

0.5 g of sample is fused with potassium bisulphate and leached with HC1. The reduced form of W is complexed with toluence 3, 4 dithiol and extracted into an organic phase. The resulting colour is visually compared with similarly prepared standards.

A–2–8 Analysis of U

1.0 g of sample is digested with a mixture of HNO_3 and perchloric acid for approximately 2 hours on a hot water bath. An aliquot of the sample solution is extracted with MIBK after addition of an aluminium nitrate tripropyl anmonium nitrate solution. An aliquot of the extract solution is analysed fluorimetrically against aqueous standards that have been carried through the same procedure.

A–2–9 Analysis of Ba

0.2 g of sample is digested with a mixture of hydrofluoric, nitric and perchloric acids in a teflon vessel. The mixture is allowed to evaporate to dryness on a hot plate. The solid residue is leached with 25 ml of 10% by volume HC1. NaCl is added as a ionization suppressant in the AAS flame.