MALAYSIA

REPORT ON THE COLLABORATIVE MINERAL EXPLORATION OF THE BAU AREA, WEST SARAWAK

CONSOLIDATED REPORT

MARCH 1985

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request by the Malaysian Government for bilateral assistance, the government of Japan agreed to undertake a joint mineral exploration programme in Sarawak, Malaysia. The joint exploration programme was proposed by the Geological Survey of Malaysia, the implementing agency of the Government of Malaysia, as part of a Fourth Malaysian Plan project. Subsequent to further discussions, the scope of work of the project to be known as the "Collaborative Mineral Exploration in Sarawak, Malaysia" was agreed upon on June 16, 1982 between officials of the Economic Planning Unit of Malaysia and the implementing agencies of the Japanese Government, the Japan International Cooperation Agency and the Metal Mining Agency of Japan.

The project is divided into three phases beginning in July 1982 and was completed in March 1985. Phase I was completed in March 1983, Phase II in February 1984 and Phase III in March 1985. The results of each phase are summarized in an interim report which had been submitted to the Government of Malaysia. Except for the printing of all reports which was done in Japan, most of the work up to the stage of report preparation was undertaken in Sarawak, jointly by the Japanese aid team and the staff of the Geological Survey of Malaysia, Sarawak.

This final consolidated report records the overall results of the three year collaborative endeavour and should serve as a useful guide for further exploration and mining activities in the Bau area.

Lastly, we wish to express our grateful thanks to the various organizations, particularly the government departments in Kuching, Sarawak and the local people in the project area for any assistance rendered during the course of the project.

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

D. Santokh Singh
Director General
Geological Survey of Malaysia

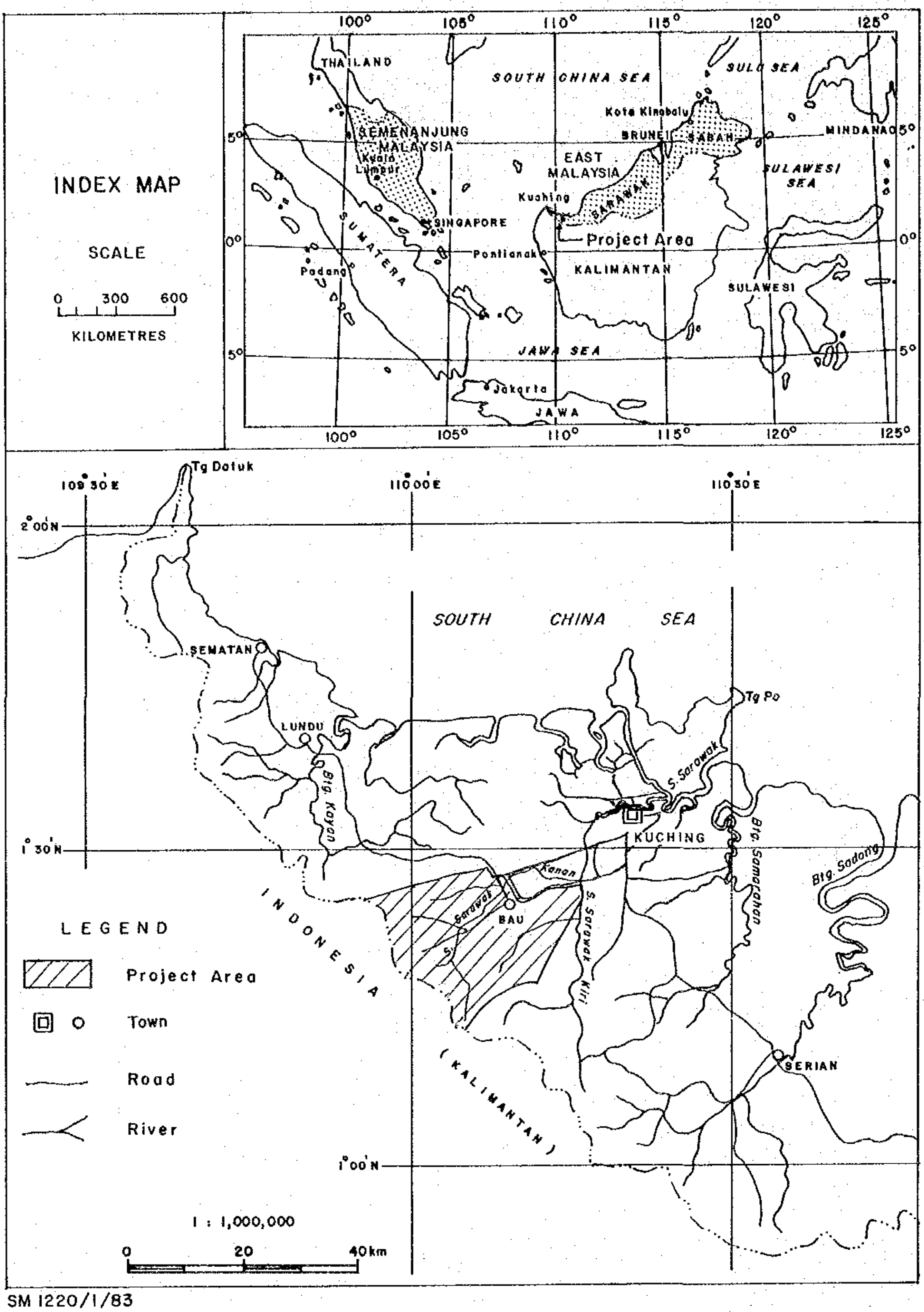

Fig. 1 Location Map of Project Area

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NOTES

The following Malay and Dayak geographical words are used in this report:

Batang	....	Main river
Pangkalan	....	Jetty
Bukit (Bt)	....	Hill
Arong	....	Valley
Kampung (Kg)	....	Village
Plaman (Plm)	....	New Village
Sungai (S)	....	River
Gunung (G)	....	Mountain
Ulu (U)	....	Headwaters of river or surrounding country
Besar (B)	....	Large
Kecil (K)	....	Small
Kanan	....	Right
Kiri	....	Left

ABSTRACT

The project, "Collaborative Mineral Exploration in Sarawak, Malaysia", undertaken jointly by a Japanese aid team and staff of the Geological Survey of Malaysia, Sarawak covers the Bau area of 540 km² in West Sarawak, Malaysia. The objective of the project is to assess the mineral potentials of and to explore for mineral ore deposits in the area.

A three phase strategy was adopted to narrow down continuously target areas with good potentials for further follow-up exploration work in each succeeding phase. Phase I work which included a geochemical stream sediment and a geological survey covering the whole Bau area of 540 km² and a semi-detailed geological survey covering 70 km² around the Bau town, was completed in March 1983. Based on this work, four smaller priority areas with the total coverage of 68 km² were selected for follow-up work in Pahse II. Phase II work involving detailed geological, geochemical soil, geochemical stream sediment, lithogeochemical and geophysical surveys was completed in February 1984. As a further follow-up to the findings of this phase, detailed lithogeochemical, geochemical, geological and geophysical surveys, exploration drilling and trenching were carried out during Pahse III in six areas totalling 4.8 km². Phase III work was completed in March 1985.

The results of each Pahse's work may be summarized as follows:

Phase I

(i) The known ore deposits may be classified as the epithermal vein type genetically related to Miocene intrusive stocks and further grouped as Au–Sb ore deposits in the Bau Limestone, Cu–Pb–Zn ore deposits in the Tertiary intrusives and limestone near the intrusives, and Hg ore deposits in shale and sandstone of the Pedawan Formation. The emplacement of the ore deposits was structurally and to some extent, lithologically controlled. The main important structures include the major ENE Bau Anticline especially of the intersection with the NNE alignment of Tertiary intrusive stocks, the NE–SW (including NNE–SSW) and NW–SE faults, and subsidiary joints and fractures with similar trends in limestones.

(ii) The general distribution of known ore deposits and mineral occurrences shows good correlation with results of the geochemical stream sediment survey 4 broad zones of metal enrichment may be delineated, a zone in the limestone area around Bau town where Au, Sb, W and As enrichments occur, a zone along the NNE alignment of Tertiary intrusives where Cu, Pb and Zn, and minor Ag and Mo enrichments are found in close association, a zone of Hg enrichment stretching from Gunung Tegora in a northeaster-

ly direction to Gunung Sta'at and a zone of U enrichment within the Jagoi Granodiorite. 19 anomalous areas may also be delineated by combining the anomalous values and the catchment areas of the anomalous stream sediment samples. From the panned concentrate samples, three main areas, the Jambusan, the Gunung Ropih and the Gunung Api areas show clusterings of samples with gold grains.

(iii) It is estimated that there exists not less than 1 million tonnes of old mine tailings in the Bau Mining District with grades rainging from 1.2 to 2.0 g/t Au. The largest tailing dump at the old Bau airstrip was assessed to have a reserve of about 261,000 tonnes with an average grade of 2.01 g/t Au.

Phase II

(i) Results of detailed investigation of some of the old mine workings show that gold ore veins in marble with calc silicates and/or quartz as the principal minerals contain the highest gold grades. The study also indicates good possibilities of finding further extensions of the gold ore veins in three of the old mine workings, the Arong Bakit, Saburan and Rumoh old mine workings.

(ii) The lithogeochemical survey of limestone in the Jambusan–Tai Parit area shows good overlapping of the "high anomalies" of the anomaly surfaces for As, Sb, Hg and Mn in three areas. Since one of these areas coincide with the area in which most old mine workings for Au and Sb are located, the other two areas, the Seromah North and the Gunung Batu areas are indicated to have good potentials for Au and Sb mineralizations.

(iii) Detailed geochemical soil and geological surveys in the Gunung Juala–Gunung Ropih Area confirm the occurrence of Cu–Mo mineralization possibly of the porphyry copper type in the southern part of the Gunung Ropih stock.

(iv) Spectral induced polarization survey in the Tai Ton area indicates that at places the Bidi ore deposit continues at depth. The survey also show that the method in suitable for detecting and estimating the shape and continuity in depth of ore bodies similar to that of the Bidi ore deposit which contains abundant sulphide minerals such as stibnite and arsenopyrite, and arsenic.

(v) The detailed geochemical stream sediment, geological and panned concentrate surveys, particularly the latter, in the Gunung Api–Sungai Putih indicate two small areas of possible primary gold mineralization – the Sungai Sinyi and Sungai Matung areas. The source of the placer gold found in these areas is suggested to be most proably quartz veins in the Pedawan Formation near its contacts with intrusive dikes and stocks and in fault ones in the formation.

Phase III

(i) The results of the detailed lithogeochemical survey in the Seromah North and Gunung Batu areas indicate three anomalous zones of metal enrichment.

(ii) Detailed mapping and rock sampling in the Arong Bakit area show that the gold ore vein of the old working No. 2 extends along strike for a distance of about 71 m with an average thickness of 4.3 m. The average grade of the ore is calculated to be 6.3 g/t Au and 10.2 g/t Ag. Assuming a down-dip extension of equal to and half the strike length, ore reserves available are 55,800 and 27,000 tonnes respectively. Assuming a cut off mineable grade of 10 g/t Au, the high grade section of the vein with a strike length of 26.4 m and an average thickness of 5.1 m may be calculated to contain an average ore grade of 14.7 g/t Au and 21.4 g/t Ag. Based on similar assumptions of down-dip extensions, the corresponding reserves are 9,200 and 4,600 tonnes.

(iii) In the Sungai Sinyi area, the probable primary source of the placer gold occurring in stream sediments has been traced by panned concentrate and geochemical soil surveys to an anomalous area in the upper reaches of Sungai Sinyi. Similar work in addition to trenching in the Sungai Matung area, indicates that the primary source of the placer gold found in the area may be located in the upper reaches of river. The source however, is indicated to be of very small extent.

(iv) Drilling results in the Gunung Ropih area rpove that subeconomical disseminated Cu mineralization of the porphyry copper type exists in the southwestern part. Two of the holes drilled intersected disseminated Cu mineralization with an average grade of about 0.18 % Cu between a depth of 139 m and 190 m in one hole and 0.23 % Cu between a depth of 50 m and 114 m in the other hole. By correlation of the results of the various work undertaken in the area including geological mapping, geochemical soil survey and IP and magnetic surveys, it may be inferred that areas with moderate to high FE, accompanied by silicification and little or negative magnetic contrast, have potential for disseminated Cu mineralization. Areas of low resistivity within a wider high resistivity zone in the intrusive and showing the above characteristics in indicated to be the best areas.

Based on the results of the work undertaken during the project period, the following follow–up work are recommended:

(i) The northwestern part of the Seromah North area should be followed up by very detailed mapping and channel sampling of the extensions of the thick calcite veins found in this area to explore for Au and Sb mineraliztions.

(ii) The area underlain by marble immediately west and north of the Gunung Juala intrusive should be further followed up by very detailed mapping and rock smapling in order to explore for gold ore veins similar to that of the Old Working No. 2 of the Gunung Arong Bakit Area.

(iii) The anomalous area for Au and As in the upper reaches of Sungai Sinyi should be followed up initially, by detailed geochemical soil survey to delineate the extent of the openended anomaly. Trenching and exploration drilling should follow to confirm bedrock Au mineralization.

(iv) Further exploration drilling is recommended in the southern and eastern parts of the Gunung Ropih area to examine the extent and grade of Cu mineralization.

(v) Geochemical anomalous area delineated during phase I of the project not followed-up yet should be further explored. These areas include, the Bt. Pangga, G. Sirrenggok, Serambu, Jagoi 3, Jagoi 5, Kg S. Maung, G. Tra'an, G. Tegora, Kisam 1 and Kisam 2 areas. The metals of interest in these areas include Au, Sb, W, Pb, Hg, Ba and U.

(vi) The Tai Ton area which is covered by alluvium should be further explored by geophysical method(s) in order to study the geology and possible Au and Sb mineralizations beneath the alluvium.

(vii) The geophysical anomaly detected in depth over the Bidi ore deposit should be further explored by the spectral or conventional IP method on the northern side in order to determine the northern limit of the anomaly. This should be further followed up by drilling.

(viii) Most of the known old workings and present mines for Au and Sb operated very near surface deposits. The possibility of larger deposits with higher grades at depth cannot be ruled out. Very detailed geological mapping and sampling to be followed by exploration drilling are required at most of the old working and present mine sites to explore for possible Au and Sb mineralizations at depth.

PART I GENERAL

CHAPTER 1. INTRODUCTION

1–1 Background and Objective of Project

The Government of Malaysia, in its effort to revive mining activities in west Sarawak, planned a comprehensive and systematic mineral exploration programme of the Bau and Lundu-sematan areas as part of its Fourth Malaysia Plan (1981 – 1985). This exploration programme was proposed by the Geological Survey of Malaysia to be undertaken with foreign bilateral aid.

The Government of Japan, in response to the Malaysian Government's request for aid, despatched a preliminary survey mission to discuss the details of the proposed exploration programme with Malaysian Government officials including staff of the Geological Survey of Malaysia. An agreement was reached to commence the exploration project in the Bau Area in July 1982 in collaboration with the Geological Survey of Malaysia.

The mission also agreed to extend the programme subsequently to the Lundu-sematan area if finance and time permit. The scope of work of the project known as the "Collaborative Mineral Exploration in Sarawak, Malaysia" was signed on June 16, 1982 between the Japanese mission and the Economic Planning unit of the Prime Minister's Department of Malaysia. This joint project is divided into 3 phases beginning in July 1982 and to be completed by March 1985. Though Japanese aid became available only in July 1982, initial work by the Geological Survey of Malaysia, Sarawak, including acquisition of past information, design and planning of the project, upgrading of laboratory facilities and partial geochemical sampling fieldwork was already in progress since 1981.

1–2 Project Area and Coverage

The project area covers 540 km^2 and includes the Bau Mining District of approximately 260 km^2 located mainly in the vicinity of the Bau town (Fig. 1).

A three phase strategy was adopted to narrow down continuously target areas with good potentials for further follow-up exploration work. Phase I work which included a geochemical stream sediment and a geological survey covering the whole Bau area of 540 km^2, and a semi-detailed geological survey covering 70 km^2 around the Bau town was completed in March 1983. Based on the results and recommendations of this work, 4 smaller priority areas with a total coverage of 68 km^2 were selected for follow-up work in Phase II. Phase II work involving detailed geological, geochemical soil, geochemical stream sediment, lithogeochemical and geophysical surveys in these areas was completed in February 1984. As a further follow-up to the findings of Phase II, detailed lithogeochemical, geochemical, geological and geophysical surveys, exploration drilling and trenching were undertaken during Phase III in six areas totalling 4.8 km^2. The coverage of each phase is as shown in Figure I–1.

1–3 Outline of Work Done and Results

Various geological, geochemical and geophysical methods and exploration drilling were employed to achieve the objective in each area during each phase. (Table I–1)

Table I-1 Outline of Field Work, Phase I, II and III

	Phase I	Phase II	Phase III
Field Work	July 29 ∿ Oct. 20, 1982	May 11 ∿ May 19, 1983	June 5 ∿ Nov. 4, 1984
Geological Survey	July 29 ∿ Oct. 20, 1982	June 6 ∿ Aug. 10, 1983	June 10 ∿ Aug. 4
Area Surveyed	540 km^2	66 km^2	3.8 km^2
Length of Route Traversed	620 km	254.6 km	69.7 km
Geochemical Survey	July 29 ∿ Oct. 20, 1982	May 20 ∿ Aug. 6, 1983	June 17 ∿ Aug. 4
Area Surveyed	540 km^2	66 km^2	3.6 km^2
Stream Sediment Samples Collected	663	255	–
Panned Concentrate Samples Collected	454	212	296
Soil Samples Collected	–	1,019	897
Rock Samples Collected	–	493	423
Geophysical Survey	–	Aug. 29 ∿ Oct. 15, 1983	June 10 ∿ July 24, 1984
I. P. Method			
Total Length Surveyed	–	–	9.9 km
Spector I. P. Method			
Total Length Surveyed	–	3.3 km	–
Drilling Exploration	–	–	July 27 ∿ Nov. 5, 1984
Number of Holes		–	3
Total Depth Drilled		–	693
Data Processing, Interpretation and Report Preparation in Malaysia	Oct. 21, 1982 ∿ Feb. 16, 1983	Oct. 3 ∿ Jan. 21, 1984	Aug 5 ∿ Dec. 28, 1984
Printing of Report in Japan	Feb. 17 ∿ Mar. 10, 1983	Jan. 22 ∿ Feb. 10, 1984	Dec. 29, 1984 ∿ Mar. 5, 1985

An outline of the work done during each phase and the results are described below:

1–3–1 Phase I

The main objective of this phase is to obtain a better understanding of the stratigraphy, geological structure, igneous activities, geochemical characteristics and their mutual relationships in the project area, and the geological setting of known ore deposits. To achieve this, reconnaissance and semi-detailed geological surveys, reconnaissance geochemical stream-sediment and panned concentrate sampling, photogeological work and investigation of some old mine workings were undertaken.

The reconnaissance geological survey covered an area of 470 km^2, and the results were presented as a 1 : 50,000 geological map. The semi-detailed geological survey was conducted in

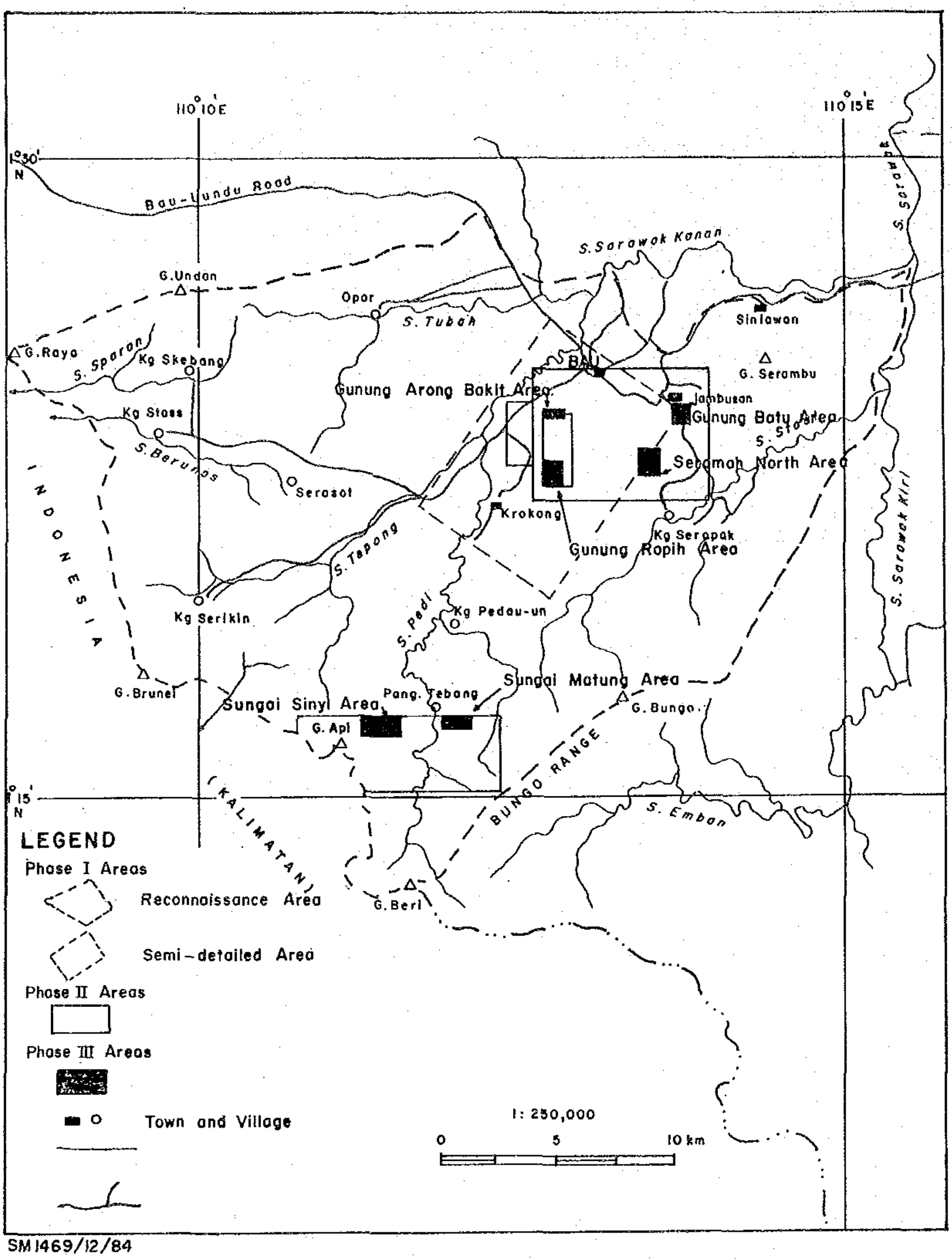

Fig. I-1 Location Map of Phase II and Phase III Areas

a selected area of 70 km^2 where numerous old mine workings are concentrated and the results described on a 1 : 10,000 geological map. Detailed investigations of some of the known ore deposits were also undertaken and the results compiled in detailed maps 1 : 1,000 to 1 : 2,000 in scale. A preliminary assessment of the tailing dumps including a detailed examination of the 2 main dumps found in the area was also carried out.

In conjunction with the geological survey work, reconnaissance geochemical stream-sediment and panned concentrate sampling were undertaken over the project area. 663 samples of stream-sediments collected were analysed for Au, Ag, Cu, Pb, Zn, Fe, Mn, Sb, As, Mo, W, Hg, Ba and U and 454 panned concentrate samples collected counted for gold grains under the binocular microscope.

As a further aid particularly in geological mapping, a brief photogeological interpretation of the area was also made using 1 : 25,000 monochromatic aerial photographs and a landsat imagery in order to delineate major geological structures and lithological boundaries.

Results of the geological surveys show that the area is characterized by the large ENE Bau Anticline and 4 sets of faults, E–W, NE–SW (including NNE–SSW), ENE–WSW and NW–SE. Most of the known gold and antimony ore deposits occur along or close to the major NNE–SSW faults in limestone surrounding stocks of acidic intrusive rock of Tertiary age. Indications of possible Cu–Mo mineralization were also found in an acidic intrusive stock. It is estimated that there exists not less than 1 million tonnes of old mine tailings in the Bau Mining District with grades varying generally between 1.2 to 2.0 g/t Au. The tailing-dump at the old Bau Airstrip was assessed to have a reserve of about 261,000 tonnes with an average Au grade of 2.01 g/t.

4 broad zones of metal enrichment may be delineated by the geochemical stream sediment survey; a zone in the limestone area around Bau Town where Au, Sb, W and As enrichments occur, 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 G. Staat and a zone of U enrichment within the Jagoi granodiorite. 19 anomalous areas may also be delineated by combining anomalous values obtained and the catchment areas of the anomalous samples. The panned concentrate samples show three main areas where samples with gold grains are clustered, the Jambusan area, the G. Ropih area and the G. Api area.

Based on the results, four areas with a total coverage of 68 km^2 were selected for follow-up work in Phase II.

1–3–2 Phase II

Follow-up work consisting mainly of detailed geological, geochemical and geophysical surveys was conducted in the four selected areas. Accurate topographic maps of 1 : 5,000 and 1:10,000 scales were prepared over an area of 70 km^2 encompassing the three target areas of Jambusan–Tai Parit, G. Juala–G. Ropih and Tai Ton, before the start of the field season.

An outline of the work done and the results obtained in each of the four areas are summarized below:

(1) Jambusan – Tai Parit Area (36 km^2)

For the purpose of exploring for new gold and antimony ore deposits in limestone and possible ore extensions of known ore deposits, detailed geological mapping and a lithogeochemical survey of the area and detailed investigations of some of the known ore deposits were carried out.

Results of the work done on the old known ore deposits show that ore veins in marble with calc-silicates and/or quartz as the principal gangue minerals contain the highest gold grades. Calcite dominant veins are mostly barren or show very low gold values. The study also indicates good possibilities of finding further extensions of the ore veins in three of the old mine working sites investigated, the Arong Bakit, Saburan and Rumoh old mine workings.

493 rock-chip samples analysed for Au, Ag, As, Sb, Cu, Pb, Zn, Mo, Fe, Mn and Hg indicate three multi-element 'anomalous' areas particularly for Sb, As, Hg and Mn. Many old mine workings for Au and Sb are located within one of these areas which strongly suggest that there are good potentials for finding gold and antimony mineralizations in the other two areas, the Seromah North and G. Batu areas.

(2) G. Juala – G. Ropih Area (5 km^2)

Detailed geochemical soil survey on a grid pattern of 25 m x 100 m and 25 m x 50 m and geological investigation were undertaken as a follow-up to the anomalous stream sediment values for Cu, Pb, Zn, Mo, W, Au and Ag detected in and around the acidic intrusive stocks of G. Juala and G. Ropih. 1,019 soil samples collected were analysed for Cu, Pb, Zn, Mo, Au and Ag. The results confirm the occurrence of Cu–Mo mineralization in the G. Ropih stock, particularly in the southern part. Geological observations further indicate mineralization of the porphyry copper type although analysis of some floats shows hypogene Cu and Mo values to be lower than the typical porphyry deposit.

(3) Tai Ton Area (2 km^2)

A geophysical survey using the Spectral Induced Polarization (SIP) method was carried out in this area over three known gold and antimony ore veins to ascertain the applicability of the method in detecting gold-bearing, calcite-dominant veins in limestone.

Results show that the method is suitable for detecting and estimating the shape and continuity in depth of ore bodies similar to the Bidi ore deposit which contains abundant sulphide minerals such as stibnite and arsenopyrite, and native arsenic. However, only very weak SIP anomalies could be detected over veins such as the calcite vein of Tai Ton B deposit which are poor in sulphide minerals.

(4) **G. Api – S. Puteh Area (25 km²)**

As a follow-up to the anomalous values for Au an Ag detected in stream sediment and panned concentrate samples over this area, detailed geochemical stream-sediment and panned concentrate samplings were carried out. 225 stream sediment samples collected were analysed for Au, Ag, Cu, Pb, Zn, As, Sb, Mo, W and Hg and 212 panned concentrate samples counted for gold grains. Geological mapping was also undertaken in conjunction with the sampling.

Results show that panned concentrate samples with high gold grain contents are mostly concentrated near the contacts between shale-sandstone and Tertiary intrusive dikes and in fault zones where quartz veinlets are observed.

Based on the results of the Phase II work, six small areas totalling 4.8 km² were selected as the best potential areas for more detailed follow-up work in Phase III.

1–3–3 Phase III

In Phase III, more detailed follow-up work consisting of geological, geochemical and geophysical surveys, trenching and exploration drilling were carried out in the selected six areas.

Outline of this work and a summary of the results are described below:

(1) **The Seromah North Area (1.0 km²) and the Gunung Batu Area (0.6 km²)**

Based on trend surface analysis of the lithogeochemical survey undertaken during Phase II, both areas show high anomaly surface values for Sb, As, Hg and Mn. The same trend was also obtained for an area in which most known old mine workings for Au and Sb are located. In order to investigate further the multi-element 'anomalies' over the two areas for possible Au and Sb mineralizations, a detailed lithogeochemical and a detailed geological survey were undertaken. 166 rock-chip samples from the G. Batu area and 257 samples from the Seromah North area were collected and analyzed for Au, Ag, As, Sb, Mn and Hg.

The results indicate that a minor As–Sb–Mn enriched zone trending ENE exists in the northwestern part of the G. Batu area. Since Au is known to be associated with As, Sb and Mn, it is inferred that the zone may have same potential for Au and Sb mineraliztions. In the Seromah North area, two anomalous zones enriched in Au, Sb, As and Mn are recognized, a NE zone in the northwestern part of the area and a minor NW zone just north of the central part. These zones are fault-related and particularly the NE zone holds possibility for Au and Sb mineralization. Plots of calcite veinlets/veins in limestone also show that most of the thicker veins encountered are located within this zone.

(2) **The Arong Bakit South Area (0.2 km^2)**

The main objective in this area was to trace the extent of the ore vein of the old working No.2 where high grade Au mineralization was found during Phase II. The follow-up work reveals that the vein has a lateral strike extension of 71 m with an average thickness of 4.3 m and average grades of 6.3 g/t Au and 10.2 g/t Ag. It is also estimated that the higher grade part averaging 14.7 g/t Au and 21.4 g/t Ag extends along strike for 26.4 m with an average thickness of 5.1 m.

(3) **S. Sinyi Area (1.6 km^2) and S. Matung Area (0.4 km^2)**

Detailed geochemical stream sediment and panned concentrate samples, particularly the latter, together with geological observations during Phase II suggest that gold mineralization may be associated with the contacts between intrusive dikes and shale/sandstone and with faults. As a further follow-up to explore for primary gold mineralization, detailed geochemical soil survey, detailed geological mapping, panned concentrate sampling and trenching work were carried out in these two areas. 897 soil samples were collected on a grid pattern of 100 m x 25 m in these areas.

The panned concentrate sampling and trenching work indicate that the placer gold commonly observed in panned samples of the stream sediments is locally derived from secondary gold occurring in the alluvial bank deposits of gravel, sand and clay. No bedrock mineralization was detected by the panned concentrate sampling and trenching.

The geochemical soil samples analysed for Au, Ag, Sb, As, Hg and Mn, however indicate a distinct anomaly for As and high class Au values in the upper reaches of S. Sinyi just SE of a wide swampy area. It is clear that this anomalous area is the most likely primary source of the alluvial gold found in the S. Sinyi area. A possible primary source of the alluvial gold in the S. Matung is also indicated by the geochemical soil survey to be in the upper reaches of S. Matung. However, even if present, it is suggested to be of a very small extent.

(4) **G. Ropih Area (1.0 km^2)**

For the purpose of confirming that Cu–Mo mineralization of the porphyry type exists in this area and in order to undertake preliminary assessment of the extent of this mineralization, a geophysical survey using the Induced Polarization (IP) method and exploration drilling were carried out. The IP survey was conducted over 8 lines totalling 9.9 line km. The IP anomalies and the geochemical soil anomalies obtained in Phase II were tested by diamond drilling of three holes with an aggregate depth of 692.8 m. Results of drilling indicate that the anomalies are caused mainly by disseminations of chalcopyrite, pyrite and pyrrhotite. Copper mineralization of the porphyry copper type consisting of disseminated chalcopyrite in intensely altered and quartz veined porphyry were encountered in two holes. Analysis shows an average of about 0.18 % Cu between a depth of 139 m and 190 m in one hole and 0.23 % Cu between a depth of 50 m and 114 m in the other hole. By correlating the results of the drilling exploration, IP and magnetic surveys and geological observations, it may be inferred that areas with moderate to high FE accompanied by Cu or no magnetic constrast and silicification in the form of networks of quartz veinlets, have potential for disseminated copper mineralization.

1–4 List of Project Personnel

The following personnel were involved in the implementation of this project.

1–4–1 Phase I of Project

(1) Planning and Consultation

Malaysia

Dr. Mohd. Yusof Ismail	Economic Planning Unit
Miss Ho Yok Ling	- do -
Miss Wong Peg Har	- do -
Mr. Chung Sooi Keong	Geological Survey of Malaysia, Kuala Lumpur
Mr. Kho Chin Heng	Geological Survey of Malaysia, Sarawak
Mr. Chen Shick Pei	- do -
Mr. Victor Hon	- do -

Japan

Mr. Kyuzo Tadokoro	Metal Mining Agency of Japan
Mr. Yasushi Kambe	- do -
Mr. Kyoichi Koyama	- do -
Mr. Yozo Baba	- do -
Mr. Tetsuo Echigo	- do -
Mr. Jiro Osako	- do -
Mr. Youichi Fukuda	Ministry of International Trade and Industry
Mr. Takeshi Kasama	- do -
Mr. Hideaki Mukai	Japan International Cooperation Agency

Mr. Hirofumi Taniguchi	Metal Mining Agency of Japan
Mr. Kenji Wakita	- do -

(2) Professional Implementation

Malaysia (Geological Survey of Malaysia, Sarawak)

Mr. Victor Hon	(Leader, Overall Works)
Mr. Dorani bin Johari	(Geological and Geochemical Surveys, Report)
Mr. Paul Ponar Sinjeng	- do -
Mr. Charles Chin	(Geochemical Analysis)

Japan (Metal Mining Agency of Japan)

Mr. Hirofumi Taniguchi	(Leader, Overall Works)
Mr. Ikuhiro Hayashi	(Geological and Geochemical Surveys, Report)
Mr. Masakazu Kawai	(Geological and Geochemical Surveys, Photogeology)
Mr. Atasumu Nonami	(Geological and Geochemical Surveys)
Mr. Tetsuo Sato	- do -
Mr. Toshiro Ohuchi	(Geochemical Analysis)

1–4–2 Phase II of Project

(1) Planning and Consultation

Malaysia

Dr. Mohd. Yusof Ismail	Economic Planning Unit
Mr. Husniarti Tamin	- do -
Mr. Mohd. Aminuddin Hashim	- do -
Miss Ho Yok Ling	- do -
Mr. Santokh Singh	Geological Survey of Malaysia, Kuala Lumpur
Mr. Kho Chin Heng	Geological Survey of Malaysia, Sarawak
Mr. Chen Shick Pei	- do -
Mr. Victor Hon	- do -

Japan

Mr. Shozo Sawaya	Metal Mining Agency of Japan
Mr. Toshio Sakasegawa	- do -
Mr. Yozo Baba	- do -
Mr. Jiro Osaka	- do -
Mr. Tatsu Kasai	Japan International Corporation Agency
Mr. Mitsuo Yasunaga	Metal Mining Agency of Japan

Mr. Hirofumi Taniguchi	Metal Mining Agency of Japan

(2) **Professional Implementation**

Malaysia (Geological Survey of Malaysia, Sarawak)

Mr. Victor Hon	(Leader, Overall Works)
Mr. Dorani bin Johari	(Geological and Geochemical Surveys, Report)
Mr. Paul Ponar Sinjeng	(- do -)
Mr. Wan Zawawie bin Wan Akil	(Geophysical Survey, Report)
Mr. Charles Chin	(Chemical Analysis)
Mr. Pang Suh Cem	(- do -)

Japan (Metal Mining Agency of Japan)

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1–4–3 Phase III of Project

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Japan

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Mr. Yozo Baba	- do -
Mr. Ikuhiro Hayashi	- do -
Mr. Hirofumi Taniguchi	- do -

(2) Professional Implementation

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Mr. Victor Hon	(Leader, Overall Works)
Mr. Dorani bin Johari	(Geological and Geochemical Survey)
Mr. Ponar Sinjeng	(Geological and Geochemical Surveys, Report)
Mr. Wan Zawawie bin Wan Akil	(Geophysical Survey, Report)
Mr. Charles Chin	(Chemical Analysis)

Japan

Mr. Ikuhiro Hayashi	(Leader, Overall Works)
Mr. Hirofumi Taniguchi	(Geological and Geochemical Surveys, Report)
Mr. Manabu Kaku	(Geophysical Survey)
Mr. Kazuto Matsukubo	(- do -)
Mr. Tomie Tozawa	(Exploration Drilling)
Mr. Teruo Omori	(- do -)
Mr. Mahito Hamazaki	(- do -)

CHAPTER 2. GEOGRAPHIC INFORMATION

2–1 Location and Accessibility

The project area is situated within the Bau district, in the 1st Division of Sarawak, and occupies the whole drainage basins of S. Sta'at and the S. Sarawak Kanan between the junction of the S. Sarawak Kanan and the S. Sarawak Kiri and the Indonesian (Fig. I–1).

Some 53 small towns and kampungs (villages) are located within the area, mainly along roads and the principal rivers. Bau, the biggest town in the area, is located 35 km from Kuching via the main trunk road to Lundu which is paved for about 45 km. The main smaller towns and villages Siniawan, Jambusan, Bidi, Krokong, Kg. Opar, Kg. Skebang, Kg. Serikin, Kg. Seromah and Kg. Seropak are served by gravel feeder roads which branch off from the trunk road. Other villages are linked by footpaths and occasionally motorable earth roads.

Telephone service is available in Bau but not in the other towns and villages. In general, communication and accessibility in the project area presented little difficulties during fieldwork.

2–2 Topography and Drainage

The general topography of the project area may be classified into 3 relief categories: low-lying land of less than 150 m above sea level occupying about 85% of the project area, rugged and steep-sloped hills ranging from 150 m to 300 m high and steep-sided ridges more than 300 m high.

Five distinct topographic land forms may be recognized, namely, (i) Alluvium-covered limestone flats, (ii) Low and undulating hills, (iii) Rugged limestone hills, (iv) Steep-sloped hills and (v) Steep-sided ridges. These features reflect closely the underlying geology.

Limestone flats less than 50 m above sea level are developed mainly along the middle to lower reaches of the S. Sarawak Kanan surrounding rugged limestone hills. Low undulating hills of less than 150 m high are composed of chiefly shale, mudstone and sandstone, and occupy a greater part of the low-lying land. The rugged limestone hills are the most prominent physiographic feature, and are characterized by a picturesque karst topography. These hills form precipitous tower karst with cliff-bounded sides, often rising contrastingly above limestone flats to heights of more than 300 m. They are frequently separated by deep gorges which are formed by dike rocks that had weathered more readily. Other karst land forms such as numerous cave systems, dolines, uvalas, karrenfelds, pinnacles and deep crevices are typically developed in the limestone area. Steep-sloped hills are composed mostly of stocks of acidic igneous rocks and a granodiorite mass. Massively bedded sandstone of Tertiary age forms the long, linear to curvilinear, steep-sided ridges of the Bungo and Undan Ranges located at the northwestern and southeastern boundaries of the project area. The highest peak in the area is G. Bungo (996 m), situated at the Bungo Range.

The drainage system in the project area is dominated by the S. Sarawak Kanan and S. Sta'at, a tributary of the S. Sarawak Kiri. Other principal rivers are S. Tubah, S. Tepong, S. Pedi and S. Pedau-un which are tributaries of the S. Sarawak Kanan.

In the middle to lower reaches, rivers are often sluggish and meandering with alluvial flood plains. In the upper reaches of rivers, streams are shallower and straighter with poor bank development. Rapids and waterfalls are commonly encountered in the uppermost reaches of streams.

The drainage pattern in the area are controlled largely by the structure and lithology of the underlying rocks. In general, major tributaries such as S. Sta'at, S. Tepong and S. Tubah appear to follow the regional bedding trend in the NE–SW direction. S. Pedi may be controlled partly by faults and the regional strike. The small tributaries between the Bungo Range and G. Jagoi are apparently dictated by a set of NW–SE trending faults and fractures. More resistant rocks of massively bedded sandstone in the Bungo Range and G. Undan Range and intrusive bodies, often form water divides. In the limestone area, drainage density is very low, largely as a result of the development of common underground streams.

Dendritic and lattice patterns in the predominantly shale and sandstone areas and a parallel pattern in the Tertiary sandstone ridge areas are also recognisable.

2–3 Climate and Vegetation

The climate of the project area is typically that of a humid, tropical lowland, characterized by a very heavy rainfall, high temperature and high relative humidity. Two monsoonal periods of four months each, the Northeast and Southwest monsoons, and two shorter transitional periods may be recognized. The Northeast monsoon period from November to February brings heavy rain, and is locally considered as the rainy season. The Southwest monsoon period from May to August is milder and considered to be the dry season.

According to statistical data for the years 1971 to 1981 as recorded by the Malaysian Meteorological Services at the Kuching Airport, the monthly rainfall ranges from 500 mm to 700 mm for the period from December to February, 170 mm to 240 mm from May to August, and 300 mm to 380 mm during other months. The mean annual rainfall is about 4200 mm. The daily mean temperature for the months of the year over the period of 1968 – 1981 varied from 25.4°C in January to 26.9°C in May, and the daily maximum mean temperature from 29.7°C in January to 32.8°C in May. The daily mean relative himidity varied from 81.9% in July to 86.5%

in February.

Vegetation in the area is very dense. About 85% is covered by primary forest and secondary forest with thick undergrowth. Out of the 85%, 30% confined mainly to the montain regions of the Bungo Range, G. Undan Range, and G. Jagoi, and the limestone hill area, is covered by primary hill forest of chiefly mixed Dipterocarps, and 55% by secondary forest in various stages of regrowth. The remaining 15% of the project area is being used for agriculture, settlement and mining. Settlements are concentrated along the main roads and rivers and mining in the area around Bau town.

CHAPTER 3. BRIEF REVIEW OF PREVIOUS WORKS

West Sarawak, particularly the Bau district has a long mining history and numerous accounts and a large amount of data on the geology and mineralization of the area have been accumulated since the 1840s. The more important works are described below:

The first geological survey in West Sarawak was carried out in 1845 by Hiram Williams along the Sarawak River from its estuary to Bau and he pointed out that gold and antimony deposits in Bau occur as veins formed in limestone and are related to intrusive rocks which intruded into limestone.

The next major work was by Wilford (1955) who carried out a regional geological survey of the area between Kuching and the western end of Sarawak covering an area of approximately 5,300 km^2. He described the stratigraphy, geological structure, igneous activity and mineralization in detail and prepared geological maps on a scale of 1:125,000 for the whole area and 1:50,000 for the Bau mining district.

Systematic surveys since were undertaken by the Department of Geological Survey of Malaysia, Sarawak on the regional geology and mineral resources in West Sarawak and accounts of the works are reported as The Sematan Lundu Area (Wolfenden, Haile, 1963), Bau-Lundu Road Area (Wolfenden & Kho, 1964), The Penrissen Area (Wilford, 1965), The Serian Area (Pimm, 1965), The Kuap Area (Hon, in manuscript) and the Kuching Area (Tan, in manuscript),

Detailed investigations of the Bau Mining District were also pursued by the department. Among them, the works of Wolfenden (1965) and Pimm (1967) proved to be most useful. These give detailed descriptions and interpretations of the stratigraphy, igenous activities, geological setting, mineralization, ore deposits and mineral occurrences of the Bau Mining District covering an area of 100 km^2.

Information on the general geology and mineral resources of East Malaysia are also available in works by Liechti, Roe and Haile (1960), Kirk (1968), Hutchison (1973) and Hamilton (1977). These also provided useful information for a better understanding of the regional geology, geological structure and geological history of West Sarawak.

The latest accounts on the mineral resources and mining activities in the Bau area and West sarawak are by Lau & Hon (1976), Hon (1981) and Kho & Chen (1982). Lau & Hon (1976) give a brief mining history of Sarawak, and Kho & Chen (1982) summarized the mineral resources of Sarawak. Hon (1981) studied the lithological and structural controls of mineralization in the Bau area.

Apart from the above, many short accounts, analytical data and prospecting reports on the geology and ore deposits of the Bau area are available as unpublished information in the Geological Survey of Malaysia, Sarawak. Some of these data are also referred to during the project work.

PART II GEOLOGICAL SURVEY

CHAPTER 1. GENERAL REMARKS

1–1 General Geology

Sarawak is built up of rocks of the West Borneo Basement and "the Northwest Borneo Geosyncline". The "geosyncline" is composed of mainly Cretaceous and Tertiary sedimentary rocks and occupies that part of Sarawak NE of the Batang Lupar. The West Borneo Basement is the exposed part of the Sunda Shield which forms the framework of the Borneo Island, and it is composed of Palaeozoic and Mesozoic sedimentary rocks, and pre-Tertiary plutonic rocks.

The project area is underlain chiefly by Basement rocks which are stratigraphically classified into four units termed the Serian Volcanics consisting of Late Triassic andesitic to basaltic volcanic rocks, the Bau Limestone of Late Jurassic to Cretaceous limestone and sandstone, the Pedawan Formation of Cretaceous shale, mudstone and sandstone, and the Jagoi Granodiorite possibly of at least Early Jurassic or Late Triassic age. In the northwestern and southeastern fringes of the area, the Pedawan Formation is overlain by a Late Cretaceous to Tertiary sedimentary pile termed the Kayan Sandstone deposited in localized sedimentary basins. Tertiary (Neogene) acidic intrusive rocks accompanied by a volcanic tuffaceout facies are emplaced along a NNE trend stretching from G. Api near the Indonesian border to G. Sirenggok just north of Bau town. The Mesozoic rocks have undergone extensive and strong tectonic movements since the end of Late Cretaceous time resulting in the development of a ENE–WSW trending major anticline and other folds and fault structures. After the deposition of the Kayan SAndstone, the area again underwent a tectonic episode accompanied by the emplacement of the Tertiary acidic igneous rocks and by mineralization (Fig. II–1).

1–2 Mineralization in General

Since the beginning of the 19th Century, many small gold, antimony and mercury deposits have been mined in the project area, particularly around the Bau town area. According to records, approximately 39 tonnes of gold, 91,000 tonnes of high grade antimony ore and 750 tonnes of mercury have been produced up to date in Sarawak, mostly from the Bau Mining District.

At present, more than 50 operating and abandoned small-scale mines and workings are known in the project area. Mineralization in the area can be generally divided into four types depending on the main ore minerals; Au–Sb vein type, Pb–Zn vein-shaped replacement type, Cu–Mo disseminations of the porphyry copper type (discovered during this project), and the mercury vein type.

Au–Sb and Pb–Zn mineralizations occur in limestone and marble of the Bau Limestone surrounding Tertiary acidic stocks, especially near NNE–SSW major faults. Cu–Mo porphyry copper type mineralization so far known is confined to a Tertiary acidic stock. Mercury deposits are found south of the gold and antimony mine area, where shale and mudstone of the Pedawan Formation and Tertiary intrusive rocks occur.

The exploration efforts of this project were geared chiefly to clarify the detailed geological setting of the area and characteristics of mineralization in order to find new mineable deposits within a limited three years duration. In consequence of the work done, a large amount of basic data on the geology and mineralization was collected and interpreted and the discovery of a porphyry copper type mineralization made.

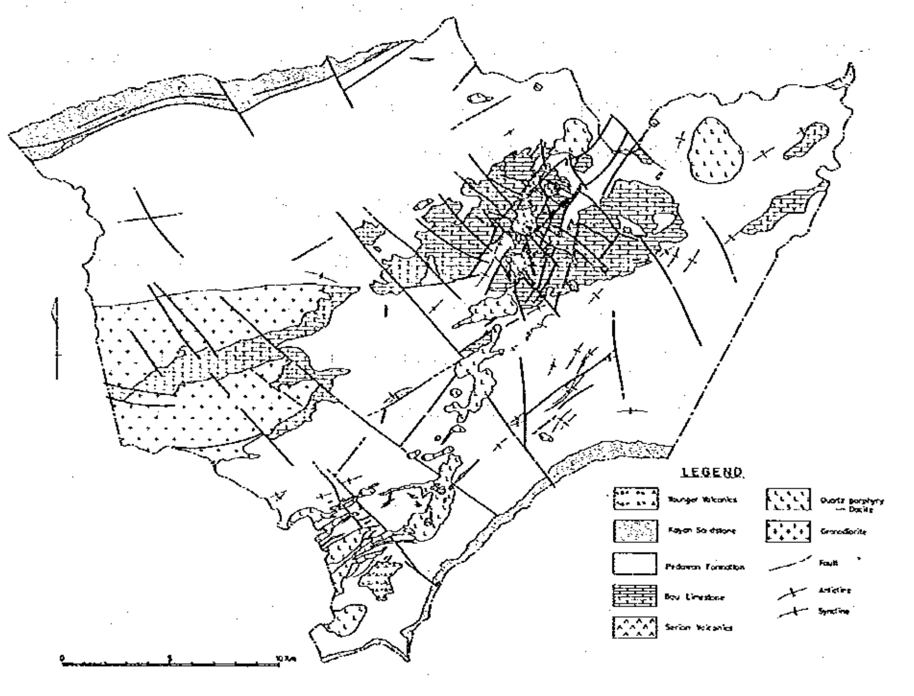

Fig. II-1 Geological Map of Bau Area

CHAPTER 2. GEOLOGY

2–1 Photogeological Interpretation

As an aid to geological mapping and the understanding of the regional geological structure, a brief photogeological interpretation of 1:25,000 scaled monochromatic aerial photographs and a lineament analysis of a 1:500,000 Landsat imagery for the whole project area were carried out by the project team at the beginning of the Phase I fieldwork.

2–1–1 Interpretation of Aerial Photographs

Four lithological units; (i) a young sandstone unit, (ii) a shale-limestone flat unit, (iii) a limestone hill unit and (iv) intrusive rock unit, and various geological structure such as faults and folds may be delineated.

The young sandstone unit can be easily distinguished from the other units by its characteristic ridge-forming feature and parallel drainage pattern, and it forms the peaks of the Bungo and G. Undan Ranges. The shale-limestone flat unit is characterized by an undulating low-lying to flat landform and a dendritic drainage pattern in the shale area. The unit occupies most of the area underlain by the Pedawan Formation and the flats of the Bau Limestone. The limestone hill unit covers the greater part of the Bau Limestone, forming typical karst topography with cliff-bounded, precipitous hills rising contrastingly above low-lying land. The intrusive rock unit consists of a major intrusive body, the Jagoi Granodiorite characterized by a relatively steep-sloped landform and a drainage pattern different from that of the shale-limestone unit, and a string of smaller stock-shaped bodies, the Tertiary acidic intrusives showing isolatory, usually conical, mountainous landform with sparse vegetation and drainage.

The principal geological structures interpreted from aerial photographs are lineaments, anticlines, synclines, and dome and basin structures. Lineaments, which are considered to be mainly faults, are recognized predominantly in the limestone hill unit. They are mainly of two sets; a NNE–SSW to NE–SW set and a NW–SE set which cuts the former. No lineaments are found in the Tertiary intrusive rock unit. This suggests that intrusion is evidently post-faulting. In the younger sandstone unit, the NW–SE and a NNW–SSE to N–S trending sets of lineaments are well-developed but no NE–SW set is recognized. This may suggest that the Bungo range area was involved only in the late tectonic movement.

The most prominent, major fold structures recognized in the area are the ENE–WSW trending syncline with an axial trace of approximately 20 km extending from Bau town to Kg. Stass, and the NE–SW trending syncline having an axial length of about 10 km, from Kg. Seropak to near Batu Kitang.

In addition to the above-mentioned structures, a concealed major NNE–SSW tectonic line is inferred in depth from the alignment of the Tertiary intrusive bodies.

2–1–2 Interpretation of Landsat Imagery

The lineament analysis of the Landsat imagery (identification No. E-30160-02132-7) resulted in the identification of three prominent sets of lineaments, a N50° – 60°E, N40° – 50°W, and N10° – 20°E sets of lineaments. The first set includes the longest lineament in the survey area measuring approximately 27 km long from G. Badud at the border to G. Staat near the S. Sarawak Kiri. These lineaments are consistent with the fold and fault structures retrieved from the aerial photographs. The NNE–SSW set is mainly confined to the limestone area where known gold and antimony mine workings in limestone appear to be concentrated near it and along the NW–SE set.

2–2 Stratigraphy

The stratigraphic succession in the project area is summarized in Figure II–2.

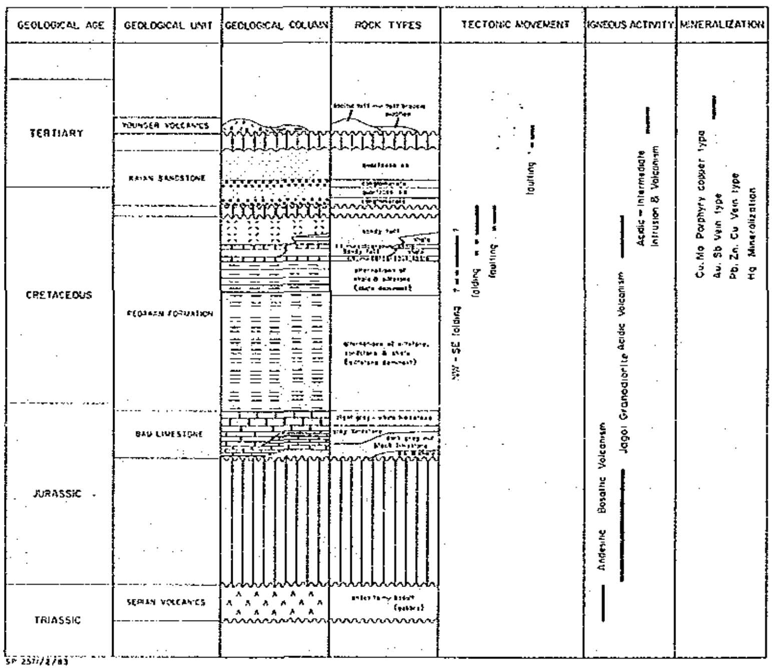

Fig. II-2 Stratigraphy and Geological Activities, Bau Area

2–2–1 Serian Volcanics

The Serian Volcanics are exposed as inliers in only two small areas near Batu Kitang at the junction of the S. Sarawak Kanan and the S. Sarawak Kiri, and in the uppermost reaches of Ulu S. Siniawan about 4 km SSE of Bau town.

The rock exposed at Batu Kitang consists of an intensely chloritized, dark green, medium-to coarse-grained gabbro. That exposed in the other area is a dark green, aphanitic and partially amygdaloidal two-pyroxene andesite. It also underwent intense chloritization and zeolitization.

The thickness of the Serian Volcanics in the area could not be estimated due to its small exposures but it is known to be 2,700 m or more in the adjacent Penrissen area (Wilford, 1965). The age is also not definitely known but may be inferred to be Late Triassic similar to that in the Penrissen area.

2–2–2 Bau Limestone

The distribution of the Bau Limestone stretches from Batu Kitang to the Jagoi Granodiorite area, in an ENE–WSW zone about 7 km width, along the crest of the Bau Anticline.

The limestone may be divided into two facies, a lower facies consisting of bedded, black, dark brown to dark grey argillaceous limestone with locally developed basal conglomerate and an upper facies of grey to light grey, massive, fossiliferous, pure limestone.

The lower facies is found in the Jagoi Granodiorite area, the SW part of Bau town and the G. Ropih–Seromah area. It is bedded with a general NE to SW strike and dips about 10° to 40° towards south. In the Jagoi area, small outcrops of sandstone and conglomerate containing granodiorite pebbles are found forming the base of the Formation. Poorly sorted sandstone and some shale and argillaceous limestone formerly mapped as the Krian Member also occur at the base of the limestone along the Tai–Parit fault area and in the upper reaches of the S. Siniawan. In the Seromah North area and west of Bekajang Lake, grey to light grey, thin siltstone-sandstone layers, about 1 to 5 m thick are found intercalated with dark brown limestone. Grey to light grey limestone is found chiefly in the vicinity of Bau town constituting the upper facies of the Bau Limestone. It is massive to crudely bedded in places with dips between 10° to 20°.

Abundant fossils have been reported to be found in the Bau Limestone (Wilford, 1965). During the Phase I survey, Pseudocyclammina lituus (Yokoyama) giving an age of Late Jurassic was found. From past information, however, the Formation is known to be of Late Jurassic to Cretaceous age.

The thickness of the Bau Limestone has been estimated to be about 300 m in the Jagoi area and 500 m just south of Bau town. Near the Tertiary intrusive bodies it is recrystallised and altered to marble with minor development of skarn.

The Bau Limestone unconformably overlies the Jagoi Granodiorite and the Serian Volcanics.

Most of the known gold, antimony, lead and zinc deposits occur in the Bau Limestone which is considered to be the most favourable host rock for these deposits in the area.

2–2–3 Pedawan Formation

The Pedawan Formation, of predominantly shale, mudstone, siltstone and sandstone with subordinate tuff, tuffaceous sediments, limestone and rare conglomerate, underlies most of the project area. The Formation is generally poor in fossils but west of Bau town many foraminifera were previously reported. During the Phase I survey, pollens and foraminifera were examined but no diagnostic species were found. The Pedawan Formation has been dated as Cretaceous (Wilford, 1965).

It overlies the Bau Limestone conformably for the greater part but locally appears to be unconformable on the limestone. Interfingering of the lower part with the top of the Bau Limestone is apparent at many places but not commonly observed in the field. The Pedawan Formation is unconformably overlain by the Kayan Sandstone.

The sequence of shale, mudstone, siltstone and sandstone is moderate to steeply dipping and have undergone intense tectonic movement which produced many fold structures. The strikes of the beds are variable. South of the limestone area the strikes are generally NE–SW with dips from 40° to 80° S whereas north of the limestone area, strikes are similar but dips vary from 30° to 60° N. At most outcrops, the sequence shows thickly to thinly bedded shale and mudstone interbedded with thin beds of siltstone and fine-grained sandstone. Carbonaceous siltstone and fine-grained sandstone commonly occur as laminae and thin beds within generally thicker beds of shale. The siltstone and sandstone are occasionally current bedded, and the siltstone in places shows convolute bedding. Beds of coarse-grained sandstone associated with pebbly mudstone and rare lenses of conglomerate interbedded with quartzose sandstone also occur within the sequence. The phenoclasts consist chiefly of granules and pebbles of vein quartz and chert.

Tuff and tuffaceous sandstone and mudstone occur mainly near the top of the Formation in the upper reaches of S. Pedi and along the Bau–Lundu Road with a maximum development of at least 500 m in the former area. The tuff exposed in a former gold mine south of the Jambusan Road, about 1 km southeast of Bau, is a fine-grained, light grey-brown rock with graded bedding, and consists of common biotite flakes and crystals of kaolinised feldspar, and rare quartz and shards of glass altered to a microcrystalline aggregate of clay minerals.

Rare argillaceous limestone occurs at the base and the lowermost part of the Pedawan Formation, between Bau town and Pangkalan Bau. The argillaceous limestone is a dark-grey, fine-grained rock consisting of scattered quartz grains, foraminifera, and small shell fragments in a matrix of finely crystalline calcite with clay minerals and rare granules of secondary pyrite. Lenses of limestone were also encountered near the top of the Formation below the tuffaceous sediments in the upper reaches of S. Pedi.

The Pedawan Formation underwent local hydrothermal alteration such as silicification, sericitization and garnetization especially near the contacts with the younger intrusive rocks.

2–2–4 Kayan Sandstone

The Kayan Sandstone is exposed in the Bungo and Gunung Undan Ranges overlying the Pedawan Formation with an angular unconformity. It consists mainly of thick, massive beds of clean, white, quartzose sandstone and some conglomerate. The sandstone beds in the Bungo Range strike NE–SW to ENE–WSW and dip from 40° to 70°S. In the Gunung Undan range the beds strike NE–SW and dip from 40° to 50° N.

The age of the Kayan Sandstone is known from previous information to be Tertiary, with possible extension into the Upper Cretaceous.

2–2–5 Younger Volcanics

This term is introduced to describe the extrusive part of the Tertiary intrusives and associat-d epiclastic sediments. The Younger Volcanics are only local in extent and are found mainly at Gunung Begah, in Sungai Da'an and near the Bau Hill. The unit consists chiefly of dacitic volcanic breccia, some volcanic mudflow deposits and minor dacitic lava flow. The rocks are commonly hydrothermally altered to a light grey, porous rock.

2–3 Intrusive Rocks

Intrusive rocks in the project area may be divided into two groups, namely the older Intrusive, Jagoi Granodiorite which is unconformably overlain by the Bau Limestone and the Tertiary Intrusive Rocks which intruded older formations.

2–3–1 The Jagoi Granodiorite

The Jagoi Granodiorite forms two mountain ranges on the sides of the Sungai Serikin valley.

The medium- to coarse-grained granodiorite is overlain unconformably by the Bau Limestone but the relation to the Serian Volcanics is not known. K/Ar dating of hornblende from the intrusive during Phase I and Phase II of the project suggests the emplacement of the Jagoi Granodiorite to be at about the boundary of Early Jurassic and Late Triassic.

2–3–2 Tertiary Intrusive Rocks

The Tertiary Intrusive Rocks are composed mainly of quartz porphyry and dacite stocks and dykes with minor diorite porphyry stocks and andesite dykes. They are the youngest group of rock found in the project area. Most of the rocks are granodioritic in composition and they are aligned along a NNE trending zone which cuts obliquely the axis of the Bau Anticline. Quartz porphyry stocks occur mainly in the limestone area and are hydrothermally altered. Alteration includes silicification, chloritization, sericitization and in places epidotisation. Dacite stocks are found mainly in the south and are also intensely altered. The stocks are believed to have been emplaced at shallow depths. Numerous dykes and sills of similar composition to the stocks also occur in the area. They are also intensely altered and in the limestone area were emplaced in faults and as apophyses of the stocks.

2–4 Chemical Composition and Age of Igneous Rocks

2–4–1 Chemical Composition of Igneous Rocks

During the project, a total of 40 samples of igneous rocks consisting of one andesite of the Serian Volcanics, one of the Jagoi Granodiorite and 38 of the Tertiary intrusive rocks were analyzed for their major elements to study their chemical characteristics. Their locations, analytical results and CIPW normative mineral compositions are shown in Figure II–3 and Tables II–1 and II–2.

SiO_2 content of all the intrusive rocks, excluding the Serian Volcanics ranges from 60% to 70% and thus belong to the intermediate to acidic rock types. Most of intrusive rocks contain less than 1.5% MgO and 5% CaO.

The relationship between each oxide and the differentiation index is shown in Figure II–4. Although not very distinct because of the narrow range of the differentiation index of 60–90, values of SiO_2, $FeO+Fe_2O_3$, MgO and CaO nevertheless tend to vary linearly against the differentiation index, a characteristic feature of magmatic differentiation.

In the figure, the Tertiary intrusive rocks are plotted as three groups, the Juala stock, the Ropih stock and the other stocks groups. It is also apparent that TiO_2, MgO, CaO and N_2O+K_2O

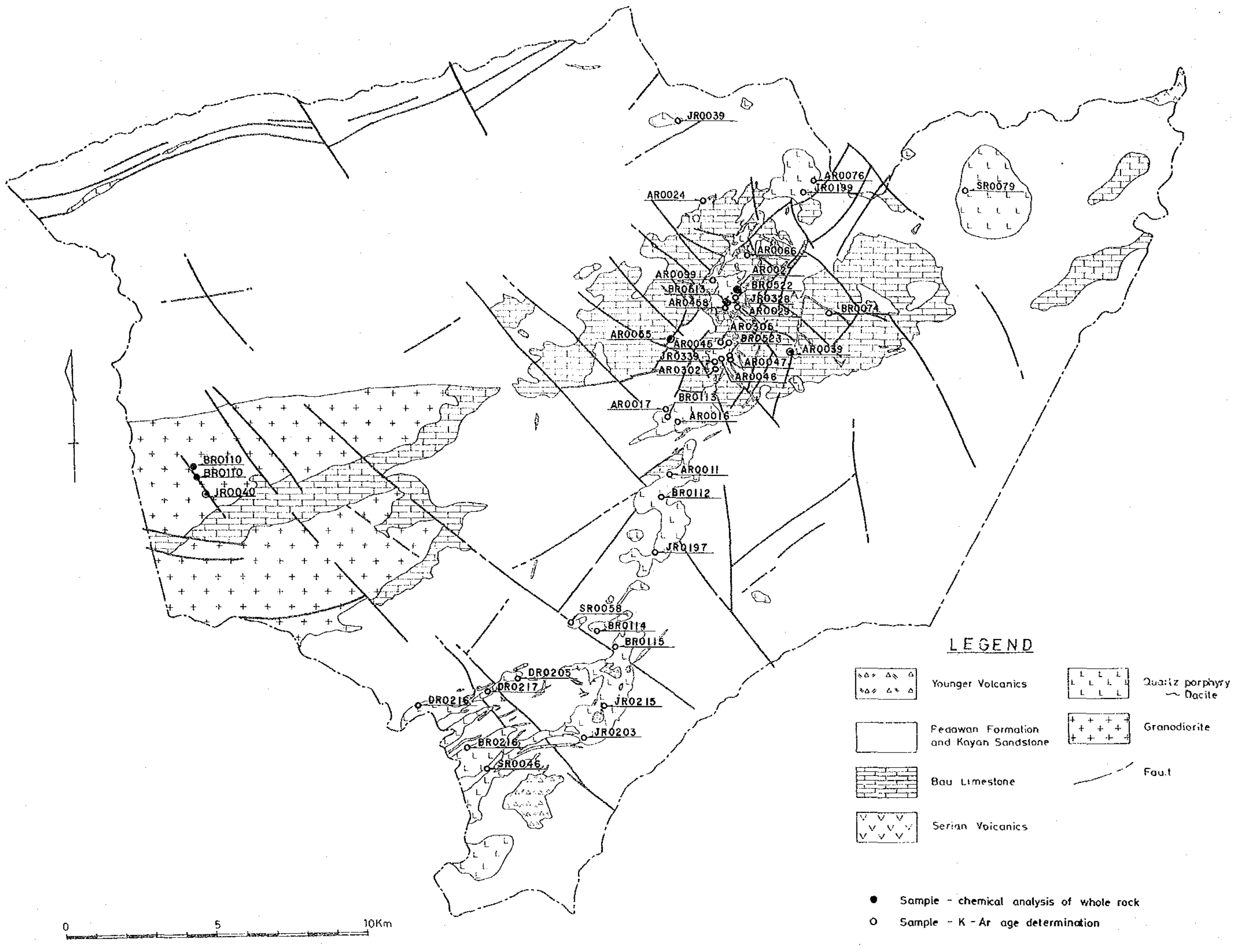

Fig. II-3 Location Map of Rock Samples for Chemical Analysis and K-Ar Age Determination
ination

Table Ⅱ-1 Chemical Compositions and CIPW Norms(Phase Ⅰ)

	Sample No.	AR0039	JR0040	SR0079	JR0039	AR0076	AR0027	AR0029	AR0066	AR0099	BR0074	AR0045	AR0046	AR0047	AR0055	AR0016	AR0017	AR0013	SR0038	SR0046	AR0024
	Coordinates X	91792	89865	92380	91420	91863	91620	91616	91651	91530	91914	91590	91559	91592	91397	91426	91389	91400	91150	90770	91486
	Coordinates Y	5173	4700	5720	5925	5830	5387	5354	5501	5428	5311	5214	5156	5158	5241	4975	4991	4777	1280	3825	5645
	Location	South of Bau	Kg. Serikin	G. Serambu	G. Otot	G. Sirenggok	G. Juala	G. Juala	Luckyhill Mine	Saburan Mine	South of Jambusan	G. Ropih	G. Ropih	G. Ropih	Bidi	G. Travan	G. Travan	G. Ngian	Bt. Tebang	G. Badud	West of Bau
	Rock Name	Andesite Serian V.	G-diorite	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Dike)	Q-porp (Dike)	Dacite (Dike)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Dike)	Andesite (Dike)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Dacite (Stock)	Dacite (Stock)	Andesite (Dike)
Chemical Compositions	SiO_2	53.79	71.73	67.96	67.58	68.70	65.39	69.43	64.82	66.43	60.01	63.60	69.76	65.85	65.89	66.33	67.69	67.84	69.43	68.16	64.74
	TiO_2	0.62	0.24	0.35	0.36	0.33	0.39	0.39	0.42	0.29	0.48	0.29	0.36	0.43	0.39	0.32	0.33	0.35	0.39	0.39	0.37
	Al_2O_3	17.23	13.56	15.64	15.51	16.34	15.26	15.75	15.53	14.99	14.66	14.55	13.43	15.69	14.90	15.09	16.07	15.03	16.16	16.31	15.18
	Fe_2O_3	0.71	0.84	1.47	1.35	1.39	0.56	1.31	0.64	2.27	0.52	1.00	0.96	0.20	0.56	0.08	0.64	0.20	2.43	1.11	0.64
	FeO	7.51	3.09	1.72	2.41	1.80	2.73	2.16	2.59	1.01	3.88	3.31	2.84	4.96	3.49	4.28	3.20	3.74	1.15	2.48	3.37
	MnO	0.14	0.06	0.02	0.07	0.06	0.06	0.05	0.04	0.05	0.07	0.12	0.06	0.08	0.07	0.06	0.06	0.09	0.06	0.04	0.07
	MgO	8.03	0.99	1.05	1.48	1.05	1.34	1.41	1.41	1.05	1.58	1.59	1.35	1.40	1.36	1.48	1.39	1.28	0.10	1.25	1.58
	CaO	0.93	2.63	4.57	4.12	2.63	3.50	0.52	3.35	3.17	6.31	7.49	3.63	3.95	3.74	3.65	3.45	3.28	2.92	2.27	4.06
	Na_2O	3.77	3.54	3.81	3.89	4.07	3.64	3.69	3.68	0.74	3.46	3.77	3.54	4.30	3.57	3.44	4.03	4.15	4.13	4.07	3.76
	K_2O	0.58	2.37	1.35	1.47	1.78	1.99	1.87	1.91	2.97	1.92	2.53	2.31	1.54	1.84	1.26	1.44	2.02	1.65	1.56	1.21
	P_2O_5	0.11	0.06	0.11	0.14	0.13	0.13	0.11	0.13	0.33	0.15	0.13	0.13	0.15	0.13	0.12	0.11	0.13	0.14	0.16	0.12
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO_2	-	-	-	-	-	2.51	-	2.52	2.64	5.37	-	-	-	-	1.74	-	-	-	-	-
	H_2O^+	5.14	0.51	1.01	0.58	0.95	1.63	2.50	1.93	2.70	0.96	0.78	0.45	0.44	2.25	1.59	0.98	0.67	0.74	1.09	2.84
	H_2O^-	0.52	0.24	0.30	0.86	0.66	0.64	0.48	0.13	0.84	0.36	0.24	0.36	0.28	1.16	0.42	0.28	0.08	0.34	0.22	1.46
	Total	99.08	99.86	99.41	99.82	99.59	99.77	99.67	99.29	99.48	99.76	99.43	99.21	99.27	99.38	99.86	99.67	99.86	99.39	99.11	99.3
Normative Minerals	q	10.3	33.0	29.0	27.4	30.6	31.9	36.8	31.4	49.2	27.5	16.2	29.8	21.0	25.9	32.8	27.3	24.5	32.8	30.8	25.2
	c	9.0	0.5	-	0.4	3.2	6.4	7.0	6.6	10.6	6.9	-	-	0.1	0.5	5.4	1.9	1.4	2.6	4.2	0.6
	or	3.4	14.0	8.0	8.7	10.5	11.8	11.1	11.3	17.6	11.3	15.0	13.7	9.1	10.9	7.4	8.5	11.9	9.8	9.2	7.2
	ab	31.9	30.0	32.2	32.9	34.4	30.8	31.2	31.1	6.3	29.3	31.9	30.0	36.4	30.2	29.1	34.1	35.1	34.9	34.4	31.8
	an	3.9	12.7	21.6	19.5	12.2	2.0	1.9	2.2	-	-	15.4	13.9	18.6	17.7	7.2	16.4	15.4	13.6	10.2	19.4
	wo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	wodi	-	-	0.2	-	-	-	-	-	-	-	8.7	1.3	-	-	-	-	-	-	-	-
	endi	-	-	0.1	-	-	-	-	-	-	-	3.9	0.6	-	-	-	-	-	-	-	-
	fsdi	-	-	0.1	-	-	-	-	-	-	-	4.9	0.7	-	-	-	-	-	-	-	-
	enhy	20.0	2.5	2.5	3.7	2.6	3.3	3.5	3.5	2.6	3.9	0.1	2.7	3.5	3.4	3.7	3.5	3.2	0.2	3.1	3.9
	fshy	12.4	4.7	1.4	2.8	1.7	4.0	2.3	3.6	-	6.0	0.1	3.2	8.4	5.4	7.4	4.9	6.3	-	3.1	5.0
	fool	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	faol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	mt	1.0	1.2	2.1	2.0	2.0	0.8	1.9	0.9	2.6	0.8	1.4	1.4	0.3	0.8	0.1	0.9	0.3	2.8	1.6	0.9
	hm	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	0.5	-	-
	il	1.2	0.5	0.7	0.7	0.6	0.7	0.7	0.8	0.6	0.9	0.6	0.7	0.8	0.7	0.6	0.6	0.7	0.7	0.7	0.7
	tn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	pf	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ap	0.3	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3
	cc	-	-	-	-	-	5.4	-	5.5	5.1	11.3	-	-	-	-	3.8	-	-	-	-	-
	pr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	93.4	99.2	98.2	93.4	98.1	97.4	96.7	97.2	95.9	98.2	98.5	98.3	98.5	95.8	97.8	98.4	99.1	98.2	97.7	95.0
	D.I.	48.8	77.6	70.4	70.1	76.9	76.4	81.7	75.9	76.2	69.3	64.0	74.7	67.5	69.9	70.8	71.0	72.1	78.9	76.1	67.5

Note : Serian V.: Serian Volcanics, G-diorite: Granodiorite, Q-porp: Quartz porphyry

Table Ⅱ-2 Chemical Compositions and CIPW Norms(Phase Ⅱ)

	Sample No.	AR0458	BR0513	BR0522	JR0328	AR0302	AR0305	BR0523	JR0339	JR0199	BR0113	BR0112	JR0197	BR0114	BR0115	JR0215	JR0203	DR0205	DR0217	DR0216	BR0216
	Coordinates X	91573	91570	91602	91580	91540	91558	91590	91552	91825	91380	91360	91340	91150	91210	91175	91105	90885	90735	90555	90715
	Coordinates Y	5330	5365	5360	5340	5127	5208	5160	5150	5705	4970	4710	4515	4260	4215	4020	3910	4110	4970	4030	3850
	Location	G. Juala	G. Juala	G. Juala	G. Juala	G. Ropih	G. Ropih	G. Ropih	G. Ropih	G. Sirenggok	G. Travan	G. Ngian	G. Duyan	Bt. Tebang	G. Ripoh	G. Begah	G. Begah	G. Jemos	S. Siayi	G. Api	G. Badud
	Rock Name	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Q-porp (Stock)	Dacite (Stock)	Dacite (Stock)	Dacite (Stock)	Dacite (Stock)	Dacite (Stock)	Dacite (Stock)	Dacite (Stock)	Q-porp (Stock)
Chemical Compositions	SiO_2	67.73	66.25	66.43	67.92	66.68	65.69	67.49	73.29	65.29	69.42	74.96	69.61	70.55	65.12	68.37	62.32	68.20	78.45	71.82	69.91
	TiO_2	0.44	0.47	0.42	0.50	0.44	0.47	0.47	0.43	0.33	0.38	0.41	0.40	0.35	0.33	0.31	0.32	0.49	0.10	0.29	0.29
	Al_2O_3	13.25	13.58	13.68	14.14	14.61	14.84	14.12	11.27	13.41	14.51	13.63	13.37	13.94	14.30	13.09	13.90	14.90	13.08	13.94	13.83
	Fe_2O_3	1.50	0.20	0.74	0.51	2.13	2.10	1.67	1.20	0.19	0.49	2.13	1.13	1.23	0.64	0.19	0.14	2.76	0.07	1.04	1.20
	FeO	1.07	2.52	1.79	2.19	0.86	0.49	0.53	1.07	2.06	1.99	0.27	1.45	1.39	2.19	2.39	2.33	0.67	0.34	1.07	1.20
	MnO	0.05	0.06	0.04	0.08	0.04	0.08	0.06	0.05	0.05	0.55	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.01	0.04	0.04
	MgO	1.15	1.09	1.22	1.21	1.23	1.18	1.28	1.30	1.10	1.21	0.49	1.09	0.97	1.15	0.56	1.31	1.42	0.13	0.69	0.70
	CaO	4.16	3.44	3.73	4.17	4.18	5.55	4.64	3.93	4.02	3.71	0.09	3.15	3.49	4.32	3.32	3.62	3.63	0.03	2.98	3.35
	Na_2O	4.00	4.48	3.60	3.76	4.28	4.12	3.70	3.15	3.27	4.04	0.40	4.08	4.16	3.72	3.90	2.67	3.98	0.52	4.14	3.78
	K_2O	4.15	2.68	2.15	2.35	2.29	3.97	3.90	2.35	1.27	1.96	4.43	2.06	2.31	1.23	1.27	2.55	1.96	2.43	1.92	2.31
	P_2O_5	0.10	0.10	0.10	0.10	0.09	0.11	0.13	0.11	0.09	0.09	0.05	0.10	0.11	0.10	0.09	0.10	0.10	0.02	0.06	0.08
	BaO	0.05	0.04	0.03	0.04	0.04	0.06	0.06	0.03	0.03	0.05	0.05	0.02	0.04	0.03	0.02	0.03	0.03	0.04	0.04	0.04
	Ig. Loss.	0.70	1.62	5.27	1.81	0.70	0.41	1.22	1.31	7.42	1.45	4.25	4.89	1.80	6.34	3.64	5.94	2.71	3.78	0.90	1.84
	Total	98.38	96.56	99.20	98.38	97.57	99.09	99.27	99.49	98.53	99.35	101.21	101.33	100.41	99.52	97.43	95.28	100.89	98.97	98.43	98.57
Normative Minerals	q	21.16	21.10	27.44	26.33	23.82	16.85	22.08	37.72	30.21	28.13	54.86	30.14	29.31	27.14	31.34	25.88	28.00	65.73	32.44	31.16
	c	-	-	-	-	-	-	-	-	-	-	8.10	-	-	-	-	0.39	-	9.56	-	-
	or	24.53	15.84	12.71	13.89	13.58	23.46	23.05	13.89	7.51	11.58	26.18	12.17	13.65	7.27	7.51	15.07	11.58	14.36	11.35	13.65
	ab	33.85	37.91	30.46	31.82	26.22	34.86	31.31	26.65	27.67	34.19	3.38	34.52	35.20	31.48	33.00	22.59	33.68	4.40	35.03	31.99
	an	5.94	9.03	14.82	15.04	13.89	10.27	10.40	9.67	18.16	15.67	0.20	12.08	12.54	18.69	14.46	17.35	17.00	0.09	13.78	13.95
	wo	2.42			-	-	3.55	1.27	-	-	-	-	-	-	-	-	-	-	-	-	-
	diwo	3.48	3.11	1.29	2.11	2.64	3.40	3.69	3.83	0.52	0.93	-	1.22	1.72	0.90	0.61	-	0.17	-	0.28	0.93
	dien	2.94	1.30	0.74	1.05	2.28	2.94	3.19	3.05	0.24	0.48	-	0.78	1.13	0.43	0.22	-	0.15	-	0.19	0.60
	difs	0.09	1.82	0.50	1.02	-	-	-	0.34	0.28	0.43	-	0.36	0.46	0.45	0.41	-	-	-	0.08	0.28
	hyen	-	1.41	2.30	1.96	0.78	-	-	0.19	2.50	2.54	1.22	1.71	1.28	2.44	1.78	3.26	3.39	0.32	1.53	1.15
	hyfs	-	1.98	1.56	1.90	-	-	-	0.02	2.90	2.28	-	0.80	0.52	2.59	3.38	3.73	-	0.36	0.62	0.53
	mt	2.17	0.29	1.07	0.74	1.63	0.19	0.54	1.74	0.28	0.71	-	1.64	1.78	0.93	0.28	0.20	0.87	0.10	1.51	1.74
	hm	-	-	-	-	1.01	1.97	1.30	-	-	-	2.13	-	-	-	-	-	2.16	-	-	-
	il	0.84	0.89	0.80	0.95	0.84	0.89	0.89	0.82	0.63	0.72	0.68	0.76	0.72	0.63	0.59	0.61	0.93	0.19	0.55	0.55
	ru	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
	ap	0.23	0.23	0.23	0.23	0.21	0.25	0.30	0.25	0.21	0.21	0.12	0.23	0.25	0.23	0.21	0.23	0.23	0.05	0.14	0.19
	Total	97.65	94.91	93.91	97.04	95.84	98.64	93.01	98.16	91.09	97.87	96.93	96.43	98.58	93.16	93.78	89.32	98.16	95.16	97.50	96.71
	D.I.	81.4	74.8	75.2	74.2	76.0	76.2	77.9	76.3	71.7	73.9	87.0	79.6	79.2	70.7	76.6	71.1	74.6	85.7	80.8	79.4

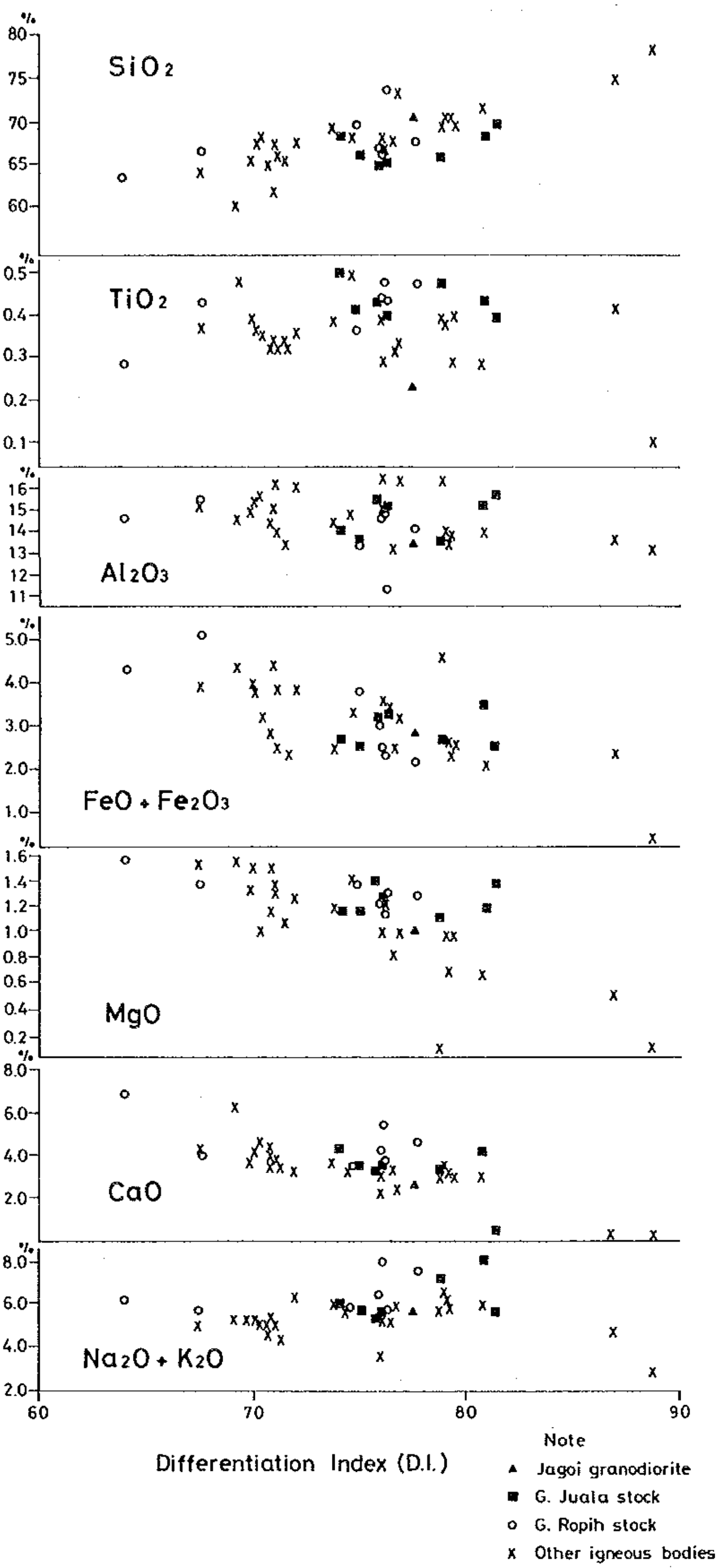

Fig. II-4 Variation Diagrams of Intrusive Rocks

contents of the Juala and Ropih stocks are slightly higher than those of the other stocks which show similar differentiation indices.

The variation diagrams of CaO plotted against the solidification index was drawn to examine the extent of assimilation of limestone by the intrusive rocks (Fig. II–5). The CaO content tends to vary linear with the solidification of magma. The samples collected from the intrusive bodies which intruded limestone, including the Juala and Ropih stocks plotted in the area between 9.0 and 15.1 solidification index. Three samples are very high in their CaO content. This may suggest some partial assimilation of the limestone host rock during emplacement of the intrusives.

Figure II–6 shows the normative quartz, plagioclase and orthoclase diagram. Most of the intrusive rocks plot in the granodiorite field and the rest in the granite and quartz-rich granite fields.

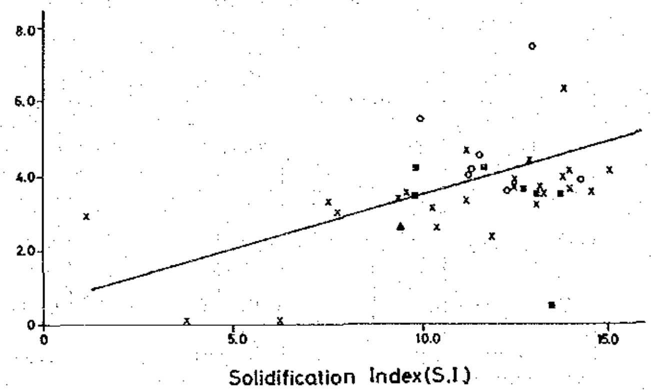

Fig. II-5 CaO Content against Solidification Index

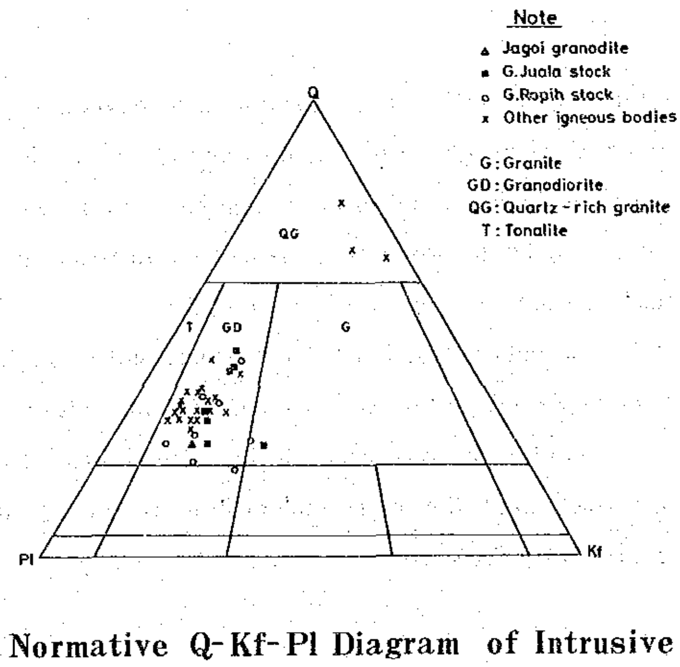

Fig. II-6 Normative Q-Kf-Pl Diagram of Intrusive Rocks

2–4–2 Age of Intrusive Rocks

During Phases I and II, six samples of intrusive rocks, three of the younger stocks and a dike, and three of the old intrusive body, the Jagoi Granodiorite, were age-dated by the K–Ar method. The locations of these samples are shown in Figure II–3. Table II–3 shows the results of the determinations.

Table II-3 K-Ar Age Determination of Igneous Rocks

Sample No.	AR0027		AR0055		JR0039		JR0040		BR0110		BR0111	
Coordinates X / Y	91620 5387		91387 5241		91420 5925		89865 4700		89820 4763		89808 4800	
Location	G. Juala		Bidi		Kg. Grogo		Kg. Serikin		Kg. Serikin		Kg. Serikin	
Rock Name	Quartz porphyry		Two pyroxine andesite		Quartz porphyry		Granodiorite		Granodiorite		Granodiorite	
Unit Name	Younger Intrusive		Younger Intrusive		Younger Intrusive		Older Intrusive		Older Intrusive		Older Intrusive	
Analysis: Material	Whole Rock		Whole Rock		Whole Rock		Whole Rock		Hornblende		Hornblende	
Analysis: K %	1.60	1.60	1.53	1.54	1.22	1.26	2.20	2.20	0.40	0.42	0.37	0.38
Analysis: $^{40}Ar_{rd}$ %	32.3	39.3	–	–	36.2	30.7	78.2	82.5	28.0	19.7	52.6	50.1
Analysis: $^{40}Ar_{rd}$, SCC/g x 10^{-5}	0.066	0.069	–	–	0.053	0.055	0.772	0.803	0.194	0.204	0.289	0.300
Isotope Age (m.y.)	10.8 ± 0.7		–		11.2 ± 0.8		89.3 ± 3.6		123 ± 15		192 ± 10	

(by Teledyne Isotopes, New Jersey, U.S.)

The two samples of the G. Juala and G. Orat quartz porphyry stocks gave ages of 10.8 ± 0.7 m.y. and 11.2 ± 0.8 m.y. These ages place the intrusion of the stocks at around the boundary between the Miocene and Pliocene, and are also consistent with field relationships. As all the younger intrusive rocks may be the products of the same magmatism, the age of the other younger intrusive rocks may also be inferred to be of the same age.

The samples from the Jagoi Granodiorite gave inconsistent ages. Two of the ages obtained are apparently too young because the Jagoi Granodiorite is unconformably overlain by the Bau Limestone which is palaeontologically assigned to the Late Jurassic. The third sample gave the most acceptable age, which places the emplacement of the granodiorite at the boundary between the Late Jurassic and the Early Triassic.

2–5 Metamorphism and Alteration

2–5–1 Metamorphism

The Tertiary intrusives have caused local contact metamorphism of its host rocks of limestone, shale and sandstone.

Limestone near the contacts with intrusive rocks, in particular the relatively larger stocks of G. Kolong Bau, G. Juala and G. Ropih, has been highly recrystallized and altered to marble. The limestone, especially between G. Kolong Bau and G. Juala, has been altered to a white to light grey occasionally dark grey, saccharoidal marble.

Marble is, however, generally confined to narrow zones very close to the contacts with intrusive stocks. In the G. Juala and G. Ropih area, marble is well developed on both the northern and southern sides but on the western side, recrystallization is only sparsely observed. No recrystallization is observed on the eastern side. This may suggest that the stocks are more widely extended in depth towards the north, south and west whereas the eastern contacts are relatively steeper.

Skarnitization is observed only as rare garnet-epidote lenses of up to several tens of cm in thickness near the boundary of the intrusive bodies. This appears to suggest that the intrusion of the stocks took place in a relatively low-temperature envirionment with only slight reaction with the country rock.

Shale and sandstone near intrusive stocks are locally altered to a dark grey to black, compact hornfels with slight pyritization and silicification, and occasionally altered to a gossanous material. This local extent of metamorphism also indicates that thermal reaction of the intrusive rocks took place at a relatively low temperature.

2–5–2 Alteration

Alteration caused by hydrothermal activity is observed in most of the Tertiary intrusives and other lithological units near the intrusives with the exception of the Kayan Sandstone. The Serian Volcanics have been subjected to intense chloritization and epidotization. Local pyritization, carbonitization and zeolitization are also observed. The Jagoi Granodiorite partly underwent local alteration such as silicification, sericitization and chloritization. Slight, local silicification and skarnitization are also recognized in the Bau Limestone near the intrusive rocks and ore deposits, but alteration is usually very weak. The Pedawan Formation is also subjected to local hydrothermal alteration such as silicification, sericitization and carbonitization with occasional chloritization and pyritization mainly near intrusive bodies. In the immediate vicinity of relatively larger intrusive stocks, epidote is also observed. Some mineralized zones of the Pedawan Formation, on the west side of Bekajang Lake and in the eastern part of Jambusan, underwent slight pyritization and intense silicification in the form of networks of thin quartz veins and very fine-grained granular quartz.

form of networks of thin quartz veins and very fine-grained granular quartz.

Most of Tertiary intrusive rocks and the Younger Volcanics have been subjected to widespread, intense hydrothermal alteration in which silicification, sericitization, chloritization and argillization are most common. Local K-alteration, kaolinitization, pyritization, zeolitization and rare epidotization are also observed. The G. Juala and G. Ropih stocks near Bau town and the two stocks in the Pangkalan Tebang area in particular underwent vigorous hydrothermal alteration.

In the G. Ropih stock, silicification, sericitization, chloritization, K-alteration and actinolite replacing hornblende are observed. These are superimposed as extensive overlapping zones over the southwestern half of the stock where a porphyry-copper type mineralization has been identified. Very fine-grained, granular quartz and numerous quartz veinlets, forming networks, occur in the intensely silicified zone. The K-alteration and occurrences of actinolite are widespread but relatively weak. At the western and southwestern parts of G. Ropih, three exploratory holes, drilled down to a maximum depth of 250 m show that intense alteration continued in depth. In the G. Juala stock, silicification, sericitization and K-alteration are recognized in the southeastern part of the stock although the data available is not sufficient to determine their extents.

Two distinct associations of metallic elements Cu–Zn and Sb–As–Mn may be deduced from analysis of 20 rock and ore samples collected from the area at between Luckyhill mine and the Juala stock. This is consistent with the Cu–Pb–Ag–Zn and Sb–W–Au–As associations obtained from the factor analysis of geochemical stream sediment data. The Sb–As–Mn assemblage is represented by the mineralization of the Luckyhill A and B ore deposits, and the Cu–Zn by that of the G. Tongga deposit which occurs in marble immediately adjacent to the quartz porphyry stock. The concentration of some metallic elements in the host rock similar to those of the ore deposits suggest some dispersion of metallic elements into the country rock.

2–6 Geological Structure and Geological History

2–6–1 Geological Structure

From the results of the photogeological interpretation of available aerial photographs and a

Landsat imagery, bedding fabric analysis of the Bau Limestone and the Pedawan Formation, and field traverses, it is deduced that the geological structure in the project area is fundamentally characterized by the major-scale ENE–WSW trending Bau Anticline and its small-scale congruent folds in the Pedawan Formation, four sets of faults, and a possible deeper tectonic line represented by the NNE–SSW trending alignment of the Tertiary intrusive stocks.

(1) **Folds**

The project area is characterized by the major Bau Anticline and numerous small-scale folds which are developed mainly in the Pedawan Formation.

The ENE trending Bau Anticline is deduced from the present distribution of the various rock units. Its crestal part composed predominantly of the Bau Limestone, the Jagoi granodiorite and the Serian Volcanics is extended over 35 km from the Border to Batu Kitang. The crest is overlain by the Pedawan Formation at two places, the west of Krokong and the south of Siniawan. These uneven distribution of the crestal rocks suggests a later superimposed NW–SE folding. This corroborates the results of the bedding fabric analysis described earlier.

The Pedawan Formation forms numerous small-scale folds with NE–SW to ENE–WSW axial trends parallel or almost parallel to the Bau Anticline. These folds are most likely congruent folds formed under the same stress field as that of the Bau Anticline.

In the Bau Limestone, folds are not clearly observable. This may be explained possibly by the competency of limestone which makes it more amenable to faulting rather than folding.

No fold is recognized in the Kayan Formation.

(2) **Faults**

A great number of faults are developed in the project area, particularly in the limestone hill area south of Bau town. These faults can be divided into four sets, namely E–W, NE–SW, ENE–WSW and NW–SE trending set.

(i) E–W Trending Faults

This set of faults are confined to and around the Jagoi Granodiorite. The most prominent fault of this set is that bounding the northern margin of the granodiorite mass and can be traced over 10 km from the border to near Krokong. The E–W faults are cut by NW–SE trending faults.

(ii) NE–SW Trending Faults

Faults of this set, including NNE–SSW trending faults are observed mainly in the limestone hill area. Some are also developed in the Pedawan Formation on the SE flank of the Bau Anticline. This is substantiated by the results of the bedding fabric analysis. In the limestone hill area, this set is composed of many short faults and several long parallel faults with a NNE–SSW trend. The most important one is the Tai Parit Fault which may be traced for more than 5 km from the Tai Parit Lake to south of the Rumoh mine. Only a few of the faults of this set are intruded into by Tertiary acidic dikes. Although acidic dikes did not intrude into the Tai Parit fault, many of the known old mine workings are found along the fault, which may suggest that the fault played an important role as a channel for ore solution. The NE–SW set of faults is cut by NW–SE trending faults.

(iii) ENE–WSW Trending Faults

Two ENE–WSW trending faults parallel to the axial trend of the Bau Anticline with dips of 30° and 35° are found at the upper reaches of S. Ma'an, a tributary of the S. Staat. In S. Sekam, a tributary of S. Pedau-un, a reverse ENE–WSW fault dipping 35° to 40° south was also encountered. Some faults with similar trends, probably reverse faults, steeply dipping towards the north, are observed at the foot of the G. Undan Range. It may be inferred that these faults are subsidiary faults formed at the same time as the Bau Anticline.

(iv) NW–SE Trending Faults

Numerous faults of this set are observed in the project area. They are found in the area between the Jagoi Granodiorite and the Bungo Range, the limestone hill area around Bau town and in the Undan Range, and they cut across all rock units except the Tertiary intrusives. A major fault of this set cutting the granodiorite is extended over 10 km along its strike length. In the limestone hill area, this set forms parallel faults and are intruded into by Tertiary dikes which may suggest that these faults are tensional and thus were open and suitable for magma emplacement. Many of the known old mine workings appear to be oriented along this set of faults near to the NE–SW set especially the Tai Parit Fault.

(3) Trend of Tertiary Intrusive Rocks

The shapes of the Tertiary stocks in the Bau-Siniawan area are distinctly different in plan view from those in the Pangkalan Tebang area. Whereas those in the north show generally circular shapes, those in the south are elliptical in shape. The difference is inferred to be a result of intrusion at the intersections of NW–SE and NE–SW trending faults in the former area and along NE–SW to ENE–WSW strike faults and the general bedding planes of the Pedawan formation in the latter area.

The regional NNE–SSW alignment of Tertiary stocks cannot be related to any major observable tectonic line but is parallel to the NNE–SSW faults in the limestone hill area. The results of the bedding fabric analysis and interpretation of Landsat imagery over the area also did not show any major structural lineament coincident with this alignment. These facts may suggest that the NNE–SSW trend indicates the possible existence of a deeper tectonic line such as a boundary between buried basement rocks or a major fracture zone in these rocks. The emplacement of magma are probably controlled by this tectonic line.

(4) **Stress field**

As the Kayan Sandstone of Tertiary age did not undergo much folding and faulting and the Tertiary intrusive rocks were not subjected to any faulting, it is inferred that the main structural features in the project area were produced in the Late Cretaceous. The palaeo-stress field can be restored based on the following aspects:

(i) The ENE–WSW trending Bau Anticline

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

(iii) The existence of the ENE–WSW trending reverse faults.

(iv) The observation that NW–SE trending faults are open (tensional) fractures and intruded into by Tertiary dikes whereas NNE–SSW faults with rare dikes appear to indicate shear fractures.

When considered thus, it may be inferred that the project area during Late Cretaceous time was involved in 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 folds of the Pedawan Formation. The NW–SE tensional faults and NNE–SSW to NE–SW shear faults were also produced essentially under the same stress field.

2–6–2 Geological History

The Jagoi Granodiorite is considered the oldest rock unit in the project area. The result of K–Ar determination of the granodiorite during this project however, indicated it to be of possible Early Jurassic age or Late Triassic age and thus may be only as old as the Serian Volcanics.

During Late Triassic time, the Serian, Penrissen and project areas were involved in violent volcanic activity which emplaced a thick pile of intermediate to basic volcanic rocks (Serian

Volcanics). During a period of uplift and subsequent erosion which accompanied the latest phase of the volcanism, the Jagoi Granodiorite was probably emplaced.

After the intrusion of acidic magma and erosion, the area experienced slight subsidence, and sedimentation initially of clastic materials commenced in small basins in Late Jurassic time. Continued subsidence with transgression expanded the sedimentary basins and resulted in to development of limestone reefs and an extensive carbonate shelf, followed by the deposition of a thick limestone sequence (Bau Limestone). Limestone deposition 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, mudstone, siltstone and sandstone (Pedawan Formation) continued till Late Cretaceous when volcanism took place and gave rise to beds of pyroclastic rocks.

During Late Cretaceous time, the project area was subjected to intense compression from the NNW and SSE direcitons. This resulted in strong folding and faulting. The Bau Anticline, the small-scale folds in the Pedawan Formation and most of the faults in the area were developed during this period. Large synclinal troughs formed, subsequently became the isolated sedimentary basins for the deposition of the Kayan Sandstone.

During the Late Miocene, the project area was again involved in a tectonic movement, mainly faulting. This movement caused the re-opening of the previously-formed faults and development of some of the NW–SE trending faults, followed by the intrusion of stocks, dikes and sills, local volcanism, and mineralization.

CHAPTER 3. ORE DEPOSITS

About 50 old mine workings and some mineral showings are found in the project area, particularly around the Bau town (Figure II–7). Most of these workings were mined mainly for gold and antimony. Two were for mercury. At the time of writing most have been abandoned and/or mined out. A few were recently reopened to mine for gold.

During the project, about half of the known ore deposits and mineral showings including the newly discovered porphyry copper-type mineralized area were investigated in detail to study their geology and characteristics of mineralization as well as their extensions. The other workings, however, were not investigated in detail because they were inaccessible or flooded.

Details of the investigated ore deposits and mineral showings are described in the following sections. Brief outlines are also given in Appendix 1. General features of the other old workings that could not be investigated in detail are summarized in the same appendix based mainly on Hon (1981), Wilford (1955), Wolfenden (1965) and Pimm (1967).

3–1 Description of Ore Deposits and Mineral Showings

3–1–1 Luckyhill A Ore Deposit

The mine, located about 1.2 km south of Bau town, was operated mainly by the Luckyhill Mining Sdn. Bhd. and had produced more than 5,000 t of antimony concentrates (60–68 % Sb) until it ceased operation in 1982.

The mine area is underlain mainly by limestone and marble of the Bau Limestone intruded into by small quartz porphyry dikes which are observed in a cross-cut adit towards the south.

As shown in Fig. II–8, the ore deposit occurs only in limestone as fracture-filling vein and replacement type ore bodies. Its extent is approximately 150 m along strike and 110 m down dip.

The vein type ore body is composed mainly of NW–SE to WNW–ESE trending quartz-calcite veins with abundant stibnite. These veins are usually small and normally a few tens of metres in strike extent and less than 50 cm in width. Stibnite occurs as massive aggregates of fine-grained crystals associated with pyrite, arsenopyrite and minor amounts of gold. Two samples collected from the stope face and pillars near the main-level adit contain 36 and 54% Sb, 6 and 14 g/t Au and 35 and 150 g/t Ag, but another sample from the stope face in a sub-level shows only 0.36% Sb, 3.6 g/t Au and 8.1 g/t Ag.

The replacement type ore body occurs as elongated lenses 2–3 m in width and extends in the NW–SE direction to about 20 m, swells and pinches rapidly both laterally and vertically. Besides a mineral assemblage similar to that of the vein type deposit, the ore is characterized by common calc-silicate minerals such as wollastonite, grossularite and epidote. Sarabauite is also found as a subordinate mineral in the ore. Two samples taken from the ore dump at the entrance of the main-level adit contain 4 and 12 % Sb, 3 and 7 g/t Au, 8 and 21 g/t Ag and 1 and 2 % As.

Under microscopic observation, stibnite usually occurs as fine- to coarse-grained, interstitial, anhedral crystals. Some coarse-grained stibnite crystals show the lamellar texture of polysynthetic twinning. Fine-grained crystals occasionally form a banded and/or colloform texture with jamesonite. Most of the stibnite are associated with arsenopyrite and rare sarabauite. The sample (AR0069-a) contains three minute grains of native gold, very likely electrum in the gangue minerals.

The structural control of mineralization is evident in that the ore bodies are confined to the NW–SE trending fractures. Slight silicification and numerous small calcite veinlets are also observed near the ore bodies.

3–1–2 Luckyhill B Ore Deposit

This deposit mined by the same company is smaller than the Luckyhill A deposit and is situated 500 m south of it.

The deposit occurs as a lenticular replacement body in a dark grey, argillaceous marble, along a fracture with a strike of N20°–30°W and a dip of 35° towards the northeast. It consists mainly of quartz, calcite, stibnite and wollastonite and subordinate pyrite, arsenopyrite, gold, grossularite and epidote. The mode of occurrence and mineral assemblage are almost the same as that of Luckyhill A. However, the physical control of mineralization is clearly different in that the deposit has replaced only argillaceous limestone along a fracture. In the light grey pure limestone adjacent to the deposit only small calcite veinlets are found.

The analytical results of two ore samples from the ore dump at the entrance of the inclined shaft are as follows:

	Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
Stibnite-rich ore	15.3	148.0	15,38	1.65	0.02	tr.	0.05
Stibnite–calcite-Wollastonite ore	5.1	17.6	14.02	–	tr.	tr.	0.02

(–: not analyzed)

These two samples were also examined under the microscope. Stibnite occurs as coarse-grained, prismatic crystals with rare lamellar texture, and as fine-grained acicular, feather-shaped

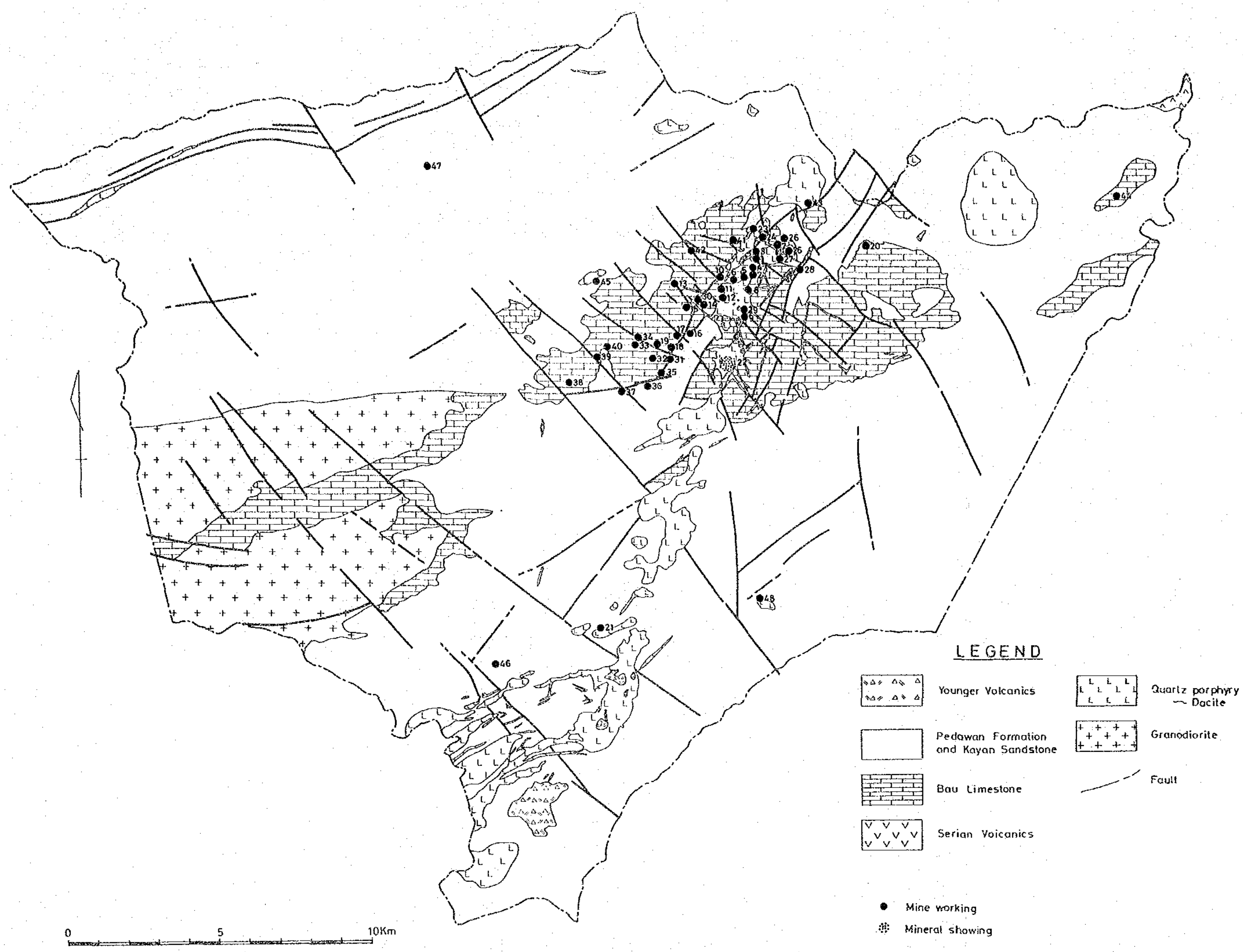

Fig. II-7 Location Map of Ore Deposits and Mineral Showings

and occasionally aggregated, very fine-grained crystals. Rare fine-grained pyrite is found but other metallic minerals are not observed.

3–1–3 G. Krian Ore Deposit

The deposit is located on the north–northeast trending spur of G. Krian, about 1.2 km to the southeast of Bau town. This deposit was prospected and mined between 1950 and 1978, producing about 50 kg of gold. Nine old working in this deposit were investigated.

The area is underlain by the Bau Limestone intruded into by NW–SE and NE–SW trending dikes. A large part of the limestone has been metamorphosed to a saccharoidal marble.

The G. Kiran deposit is composed of al least three groups of vein swarms, the northern, the central and the southern groups, consisting mainly of quartz and/or quartz-calcite veins trending NW–SE (Fig. II–8). The northern group comprises workings No. 1, No. 2, No. 3 and No. 9, the central one, workings No. 4 and No. 5, and the southern group workings No. 6, No. 7 and No. 8.

Details of each of the mine workings are as follows:

Working No. 1

The vein of about 20 m long and 4 m wide consists mainly of calcite with a network of quartz veinlets which are probably the later stage of mineralization. Stibnite and native arsenic are occasionally found in the quartz veinlets. Analytical results of three spot samples are as follows:

		Au (g/t)	Ag (g/t)	Sb (%)
AR0358	Vein quartz	9.17	19.1	–
AR0359	Quartz-calcite Stibnite ore	6.30	79.5	1.17
AR0361	- do -	9.10	30.6	0.07

Working No. 2

This working was drifted for about 14 m along a network zone of calcite veinlets. Metallic minerals are not observed but a sample taken from the drift face gave 20.00 g/t Au and 12.6 g/t Ag.

Working No. 3

This is only a small pit without any veins.

Working No. 9

This working was probably excavated to locate the southeastern extension of the northern group of veins. The quartz-calcite vein encountered in this working contains a small amount of stibnite and analysed 2.33 g/t Au and 2.3 g/t Ag.

Working No. 4

The ore body in this working is 10 m wide and consists of a network of quartz-calcite veinlets. The veinlets are macroscopically barren of metallic minerals but the average Au and Ag values of 10 samples analysed are 1.17 g/t and 4.0 g/t, respectively.

Working No. 5

The ore body consists apparently of two veins. The larger vein trending N50° – 60°W with a dip ranging from 60°N to 70°N is composed mainly of very coarse calcite crystals with rare quartz veinlets. Three channel samples taken from the working face gave 0.20 – 0.75 g/t Au and 1.7 – 3.7 g/t Ag. One lump sample of quartz veinlets contains 23.00 g/t Au and 20.2 g/t Ag. The smaller vein shows a similar mineral assemblage but its contents of Au and Ag are very low.

Working No. 6

This working appears to have been worked in order to locate the extension of the southern group of veins but none was encountered.

Working No. 7

This is a trench of about 8 m long. The ore body exposed in the trench consists of a network of quartz veinlets with a considerable amount of pyrite, but analytical results of a channel sample show extremely low contents of Au and Ag.

Working No. 8

This working is underlain by marble and a dacite dike intruding into the marble. The vein occurs along a fracture. It consists of calcite, occasionally very coarse crystals, with rare amounts of stibnite. The analytical results of three samples are as follows:

		Width (m)	Au (%)	Ag (g/t)	Sb (%)
AR0368	Calcite vein (channel)	0.80	0.80	8.8	0.01
AR0369	Gossanous clay in vein	–	26.25	29.27	–
AR0370	Calcite-stibnite ore (lump)	–	4.00	6.10	1.75

It may be conclusively inferred that the Au and Ag grades of the G. Krian ore deposit are generally low with only a few places containing high Au and Ag, and also that the Au content of quartz-rich veins is obviously higher than that of calcite dominant veins. Selective mining on a small scale of the high grade quartz-rich veins may be feasible.

Two ore samples containing galena and sphalerite were also obtained from the mine waste just below the No. 5 Working during Phase I, but the source could not be traced.

3–1–4 G. Bau Ore Deposit

The deposit is located about 300 m south-southwest of Luckyhill A mine at about 130 m above its main level. This deposit was explored and mined by the Ban Lee Gold Mining Company between 1948 and 1959.

The deposit occurs in marble of the Bau Limestone as two parallel calc-silicate veins extending in the NW–SE direction with a dip of 65° – 70° towards the southwest, (Figure II–8). The upper vein 90 cm in width, consists of wollastonite, epidote, garnet and quartz with a small amount of stibnite. Two channel samples gave values of less than 0.2 g/t Au, 0.2 g/t Ag and 0.39 –0.55% Sb. The lower vein ranging from 50 to 100 cm in width was mined by a main level tunnel and an upper sub level, 3 m higher. The vein is composed of wollastonite, epidote and quartz. Analytical results of four channel samples and two lump ore samples from this vein assayed as follows:

		Width (m)	Au (g/t)	Ag (g/t)	Sb (%)	
AR0380	calc-silicate vein	0.50	1.43	0.9	–	(main level)
AR0381	- do -	0.40	7.50	0.5	0.83	(- do -)
AR0382	- do -	0.20	6.00	7.1	–	(- do -)
AR0383	calc-silicate ore	(lump)	5.71	1.2	–	(- do -)
AR034	calc-silicate vein	1.00	21.00	36.4	–	(sub level)
AR035	calc-silicate ore	(lump)	11.67	4.2	–	(- do -)

The G. Bau ore deposit is characterized by abundant calc-silicate minerals, and its genral features and ore grade are very similar to some of the G. Krian old workings.

3–1–5 G. Arong Bakit A Ore Deposit

Three old mine workings denoted No. 1, No. 2 and No. 3, in this deposit are located on the eastern slope of G. Arong Bakit, about 2 km southwest of Bau town. The No. 1 and No. 3 workings were prospected and mined during the 1950's and the No. 2 in the 1960's.

The area is underlain by marble of the Bau Limestone near the G. Juala stock, located just south of it.

Working No. 1

The vein striking N30°W with a dip of 40° towards the southwest was prospected by means of a trench 10 m long. It consists mainly of quartz and wollastonite with minor amounts of epidote and garnet. In the footwall, many quartz-wollastonite veinlets are observed. Analytical results of two channel samples are as follows:

		Width (m)	Au (g/t)	Ag (g/t)
AR0402	calc-silicate-quartz vein	0.80	5.75	0.8
AR0403	- do -	0.80	1.83	0.5

Working No. 2

Some irregular calcite veinlets are found in fractures in marble at this working site. These veinlets contain abundant native aresenic, magnetite and stibnite. Under the microscope, arsenopyrite, berthierite and pyrite were also found. Assays of three spot samples are as follows:

		Au (g/t)	Ag (g/t)	Sb (%)
AR0406	stibnite-arsenic ore	7.50	2.4	2.62
AR0407	- do -	7.80	7.8	2.31
AR0408	- do -	8.60	9.5	–

Working No. 3

This is a small trench prospecting irregular calcite veinlets with calc-silicate minerals. A spot sample of the calcite veinlets containing calc-silicates and a gossanous material shows an Au grade of 4.75 g/t and Ag, 10.8 g/t. The Au content of the G. Arong Bakit A ore deposit is generally relatively higher compared to the G. Krian deposit. However, the small, irregular veins and steep topography would handicap further prospecting and any mining work.

3–1–6 G. Arong Bakit B Ore Deposit

Three old mine workings of this deposit are located on the southern cliff-bound slope of G. Arong Bakit, about 1.3 km south of Bau town. The area is underlain by intensely recrystallized marble of the Bau Limestone. The marble shows vague bedding striking WNW–ESE to ENE–WSW with dips of 10° – 30° towards the north. The G. Juala stock is exposed about 100 m south of these workings (Fig. II–9).

The vein of Working No. 1 strikes N60°W and dips gently towards the north. It is traceable for about 8 m along its strike length and has a maximum thickness of at least 2 m in width. The vein consists mainly of calcite with a quartz-wollastonite zone which usually shows a banded texture. The analytical results of three channel samples show 0.50 – 4.70 g/t Au and 3.7 – 26.4 g/t Ag, and three spot samples consisting mainly of quartz and wollastonite, contain 1.80 – 3.33 g/t Au and 1.4 – 25.5 g/t of Ag.

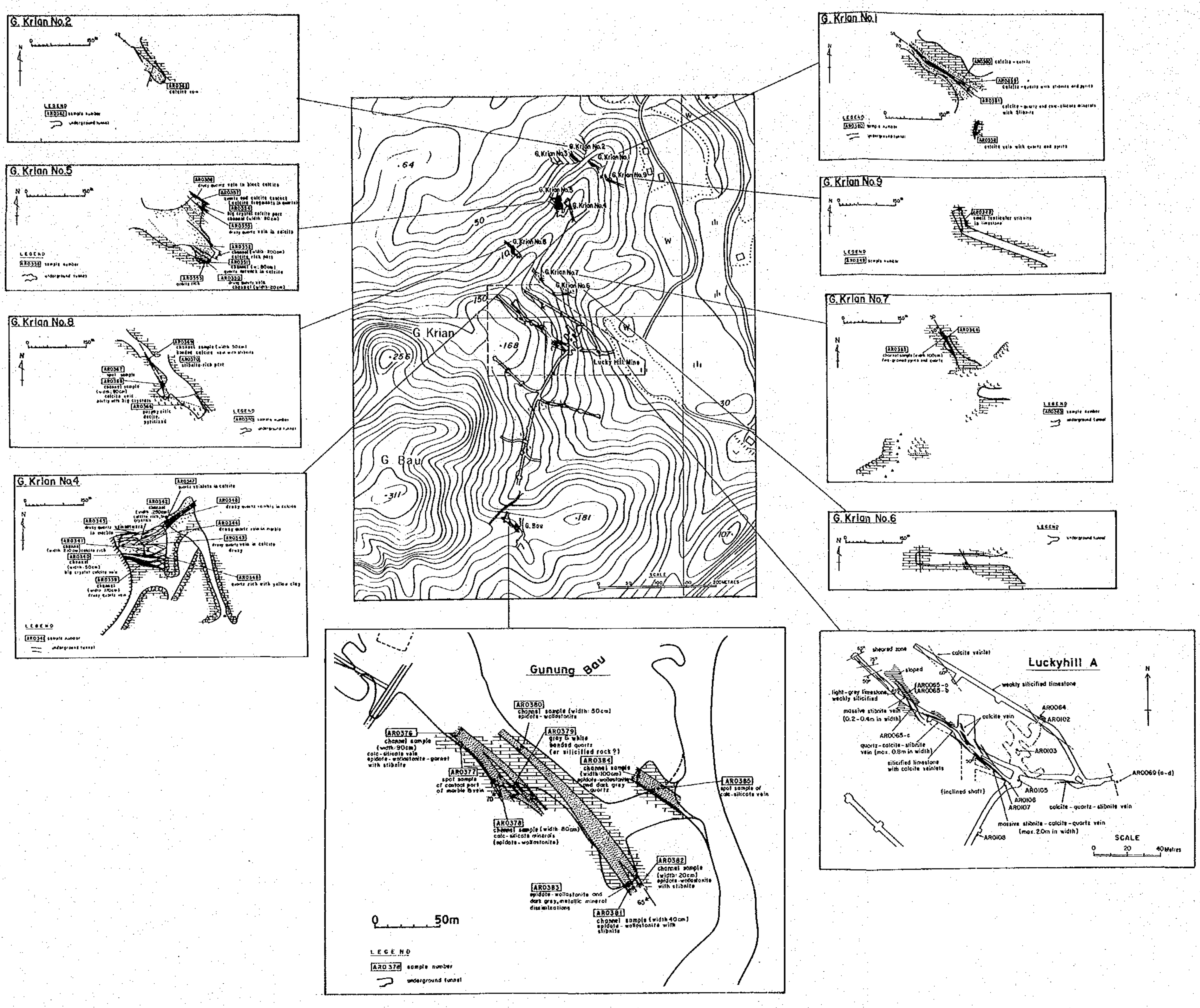

Fig. II-8 Old Mine Workings, Gunung Krian, Luckyhill and Gunung Bau Ore Deposits

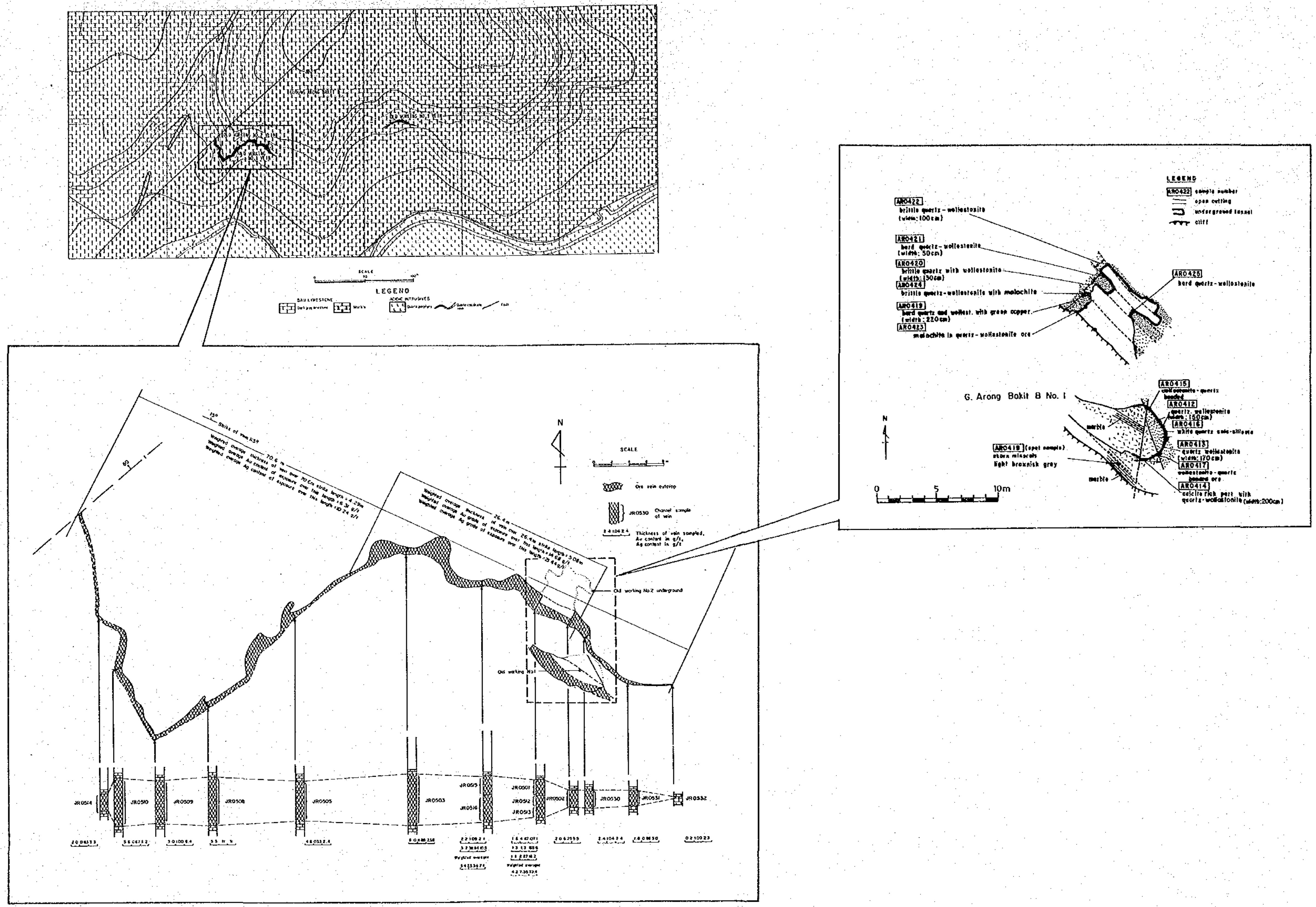

Fig. II-9 Old Mine Workings, Gunung Arong Bakit B Ore Deposit

Working No. 2 in a NW–SE to WNW–ESE striking vein with a dip of about 10° towards the north, is located about 10 m above Working No. 1. The vein consists of mainly quartz and some wollastonite with subordinate calcite and is usually very hard to slightly brittle. Metallic minerals are usually invisible but rare blebs of chalcopyrite, pyrite and malachite are found as discontinuous streaks within the very hard zone.

During Phase II, four channel samples assayed gave the following results:

		Sampling Width (m)	Au (g/t)	Ag (g/t)
AR0419	very hard zone	2.20	123.90	58.9
AR0429	slightly brittle zone	1.30	1.20	5.5
AR0421	very hard zone	0.50	26.00	34.0
AR0422	slightly brittle zone	1.00	0.10	0.3

Sample AR0419 was taken from the zone with chalcopyrite blebs. One spot sample from that zone also gave values of 1,197.00 g/t Au and 973.8 g/t Ag. Under the microscope, this sample is observed to contain abundant chalcopyrite and tetrahedrite with some pyrite, electrum and hessite. The vein was re-investigated in detail in Phase III to ascertain its lateral extension and ore grade. It is traceable along a strike length of 71 m with an average width of 4.3 m. A total of 15 channel samples collected, were assayed to contain an average grade of 6.3 g/t Au and 10.2 g/t Ag. Assuming a cut-off mineable grade of 10 g/t, the higher grade section of the vein with a strike length of 26.4 m and an average thickness of 5.1 m may be calculated to give an average grade of 14.7 g/t Au and 21.4 g/t Ag.

Working No. 3 is situated about 140 m east of Working No. 2 at almost the same elevation. The vein extends for about 34 m along a NE strike with a dip of 5°–15° towards the NW. It is emplaced parallel to the bedding of marble, replacing the host rock. The vein with a maximum thickness of 1 m, consists of quartz, calcite and wollastonite. 4 channel samples were analysed to contain 0.16–14.09 g/t Au and 0.5–129.1 g/t Ag.

It may be summarized that the veins of the G. Arong bakit B ore deposit investigated occur in almost the same marble horizon parallel to the bedding plane and/or parallel to fractures. They are found as lensoidal-shaped bodies replacing the host rock and consist mainly of quartz and some calc-silicate minerals. Au and Ag contents are highly variable within the veins but are generally of a higher grade than other deposits investigated.

3–1–7 West Batu Bekajang Lake Ore Deposit

The deposit is located on the western fringe of the Batu Bekajang Lake, just southwest of Bau town. The area was mined in the early 1900's and between 1955 and 1979. Recently, mining of the area was revived by the Bukit Lintang Enterprise Sdn. Bhd.

The geology of the area, is shown in Figure II–10. Shale and soundstone of the Pedawan Formation overlie the Bau Limestone in the area. The present western edge of the lake is located along the boundary of the two formations. An acidic intrusive stock and a few dikes are exposed around the mineralized zone.

The deposit occurs at the limestone-shale contact zone as veinlets of quartz and calcite in limestone and as a widespread silicified, network zone of quartz-calcite veinlets in shale and sandstone. Pyrite, arsenopyrite and native arsenic are common but some veinlets also contain galena, sphalerite, chalcopyrite and stibnite. Three channel samples of the quartz and quartz-calcite veinlets and two spot samples of silicified shale with pyrite were assayed to give the following results:

	Sampling Width (cm)	Au (g/t)	Ag (g/t)	Sb (%)	As (%)	Cu (%)	Pb (%)	Zn (%)
BR003	2	33.2	85.0	0.33	3.98	0.03	0.65	0.90
BR0491	5	1.00	157.1	–	–	0.05	0.32	2.83
BR0501	(spot)	2.40	12.0	–	–	0.01	0.08	0.05
BR0502	25	0.50	0.7	–	–	–	–	–
BR0507	(spot)	6.00	42.2	–	–	0.07	0.43	0.90

The deposit is characterized by a widespread network of veinlets in the highly fractured and silicified shale and sandstone, the main host rocks of the deposit. Though individual veinlets are very thin, the extensive and dense network and silicification developed with some encouraging Au contents, as well as very easy accessibility, suggest a good possibility for further opencast mining.

3–1–8 G. Siriung Mineral Showing

The mineral showing is located on the southern foot of G. Siriung, about 2 km south of Bau town.

The vein at the site occurs along the bedding plane of limestone, with a general strike of N5°E and a dip of 30°SE. It consists predominantly of white and some black, very coarse, calcite

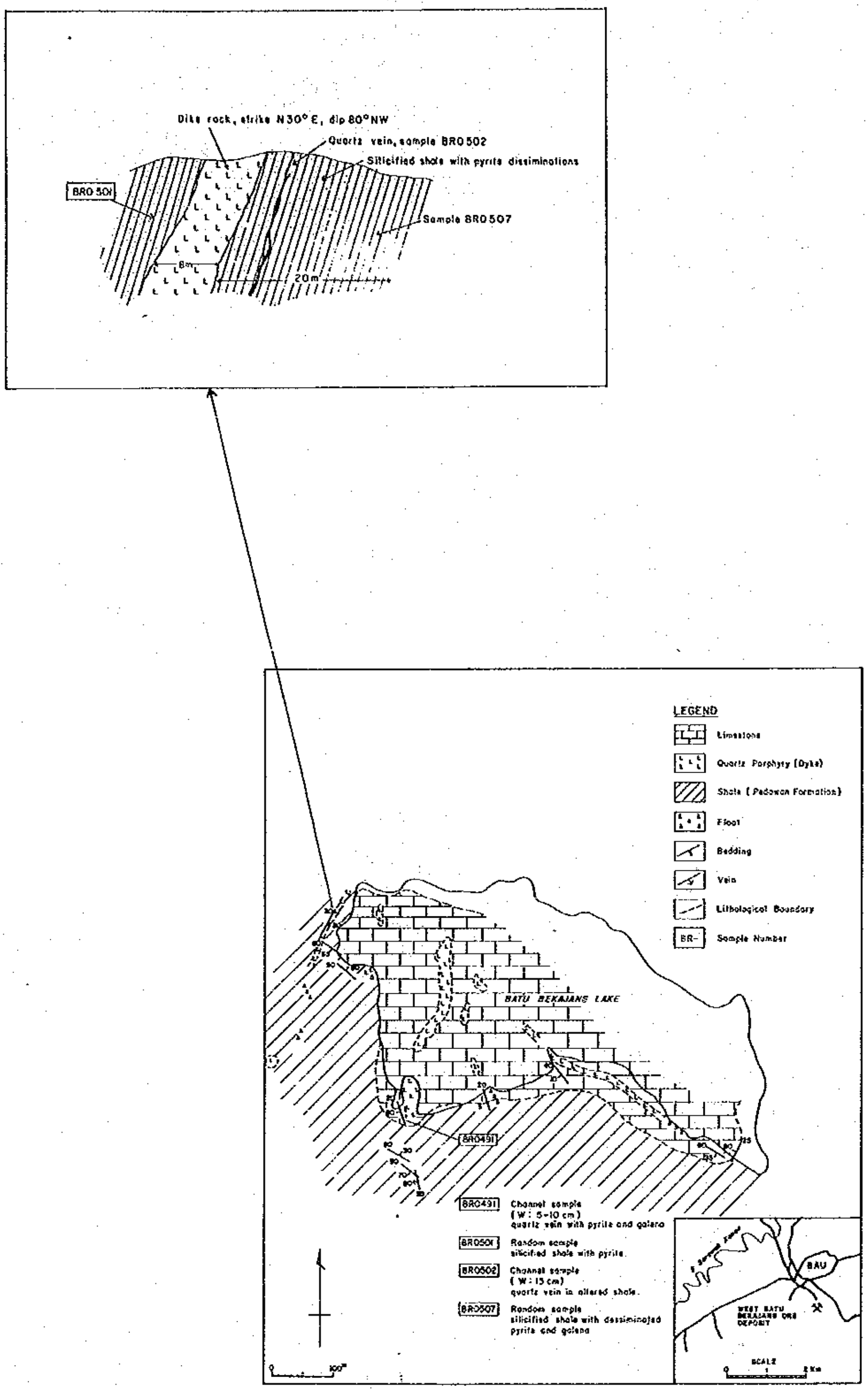

Fig. II-10 Old Mine Working, West Batu Bekajang Lake Ore Deposit

crystals. The analytical results of four samples show 1.00–3.60 g/t Au and 0.4–1.1 g/t Ag. The mineralization is extremely local and the gold content is also low.

3–1–9 G. Tongga Ore deposit

The Tongga deposit is located about 3 km south of Bau town and it was prospected and mined by several mining companies in the past.

The area is underlain by highly metamorphosed marble of the Bau Limestone and the G. Juala stock of quartz porphyry. The deposit occurs in marble on the western foot of G. Tongga, just adjacent to the southern boundary of the stock. It consists of an elongated, lenticular ore body, probably of the replacement type, with a N40°–60°E strike and a dip of 70°SE to 80°NW (Fig. II–11).

The ore body is composed mainly of massive sulphide ore minerals, predominantly galena, sphalerite and arsenopyrite with small amounts of chalcopyrite and pyrite. Gangue minerals include calcite and minor quartz. Seven channel samples collected assayed as follows:

		Sampling Width (cm)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
BR0387	sulphide ore	10	7.50	102.8	0.33	8.34	5.19
BR0389	gossan	80	1.25	3.2	–	–	–
BR0390	gossanous clay	8	2.20	2.7	–	–	–
BR0391	sulphide ore	15	19.25	117.9	–	–	–
BR0392	calcite vein	50	tr	tr	–	–	–
BR0393	gossanous clay	100	18.75	119.4	–	–	–
BR0394	sulphide ore	30	21.10	158.0	0.52	15.20	8.86

There is about 120 t of stockpile sulphide ore near the entrance of the working. Three lump ore samples from this stockpile assayed as follows:

		Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Sb (%)	As (%)
AR0032-a	galena-sphalerite ore	7.0	268.0	1.54	5.39	4.25	0.46	–
AR0032-b	pyrite-arsenopyrite ore	3.3	129.0	0.64	2.62	1.20	0.26	14.28
AR0032-c	galena-sphalerite-calcite ore	20.0	84.3	0.24	4.05	7.90	tr	–

Under microscopic observation, the first two samples were seen to contain abundant galena, sphalerite, arsenopyrite, pyrite and chalcopyrite, and rare amounts of bournonite and boulangerite. No silver minerals were observed in both sections though the Ag content of these two samples is high.

The Tongga deposit shows appreciable contents of Au, Ag, Pb and Zn. The ore body however is apparently not extensive to merit much importance in terms of mining for its base metals. Small-scale mining for its Au and Ag contents may however be possible.

3–1–10 Saburan Ore Deposit

The Saburan ore deposit is situated about 2 km southwest of Bau town. It was mined for gold by the Saburan Gold Mining Company between 1947 and 1964. During the operation, approximately 14,000 t of crude ore were treated by the cyanidation process producing about 109 kg of gold. In the mine area, there are ten old underground workings (Fig. II–12).

The area is underlain chiefly by greyish white and black, argillaceous limestone of the Bau Limestone. The limestone is in places intercalated with calcareous sandstone and intruded by several small quartz porphyry dikes which are considered to be apophyes of the G. Juala stock, located just west of the area. The NNE–SSW to NE–SW trending Tai Parit Fault cuts across the center of the mine area.

The deposit consists of many small calcite and quartz-calcite veins with NE–SW, N–S and NW–SE trends, and these veins occur in fractures, joints and along the bedding planes of the limestone.

Working No 1. was mined by two levels denoted Level 1 and Level 2. The latter is about 15 m below Level 1

The main vein of the Working No. 1 is steeply dipping at 65° towards the southeast and strikes N60°E. Smaller veins which branch out from the main vein have a strike of N80°E and dip of 20°–30°SE. These smaller veins are parallel to the bedding planes of the limestone. The veins are composed predominantly of calcite with minor amount of pyrite, arsenopyrite, realgar and orpiment. Numerous other small veinlets are also observed in the limestone. The average grade of 12 channel samples from Level 1 is 11.21 g/t Au and 4.6 g/t Ag and 19 channel samples from Level 2 gave an average grade of 3.09 g/t Au and 4.1 g/t Ag. The main vein consisting of large calcite crystals in argillaceous limestone is often accompanied by network zones of calcite veinlets with disseminations of arsenic minerals. These network zones contain relatively high values of gold. The lump samples of black argillaceous limestone taken from the stockpile at the entrance of the Level No. 2, for instance, assayed 77.6 g/t Au, 8.1 g/t Ag, 1.53% As. A polished slab of the

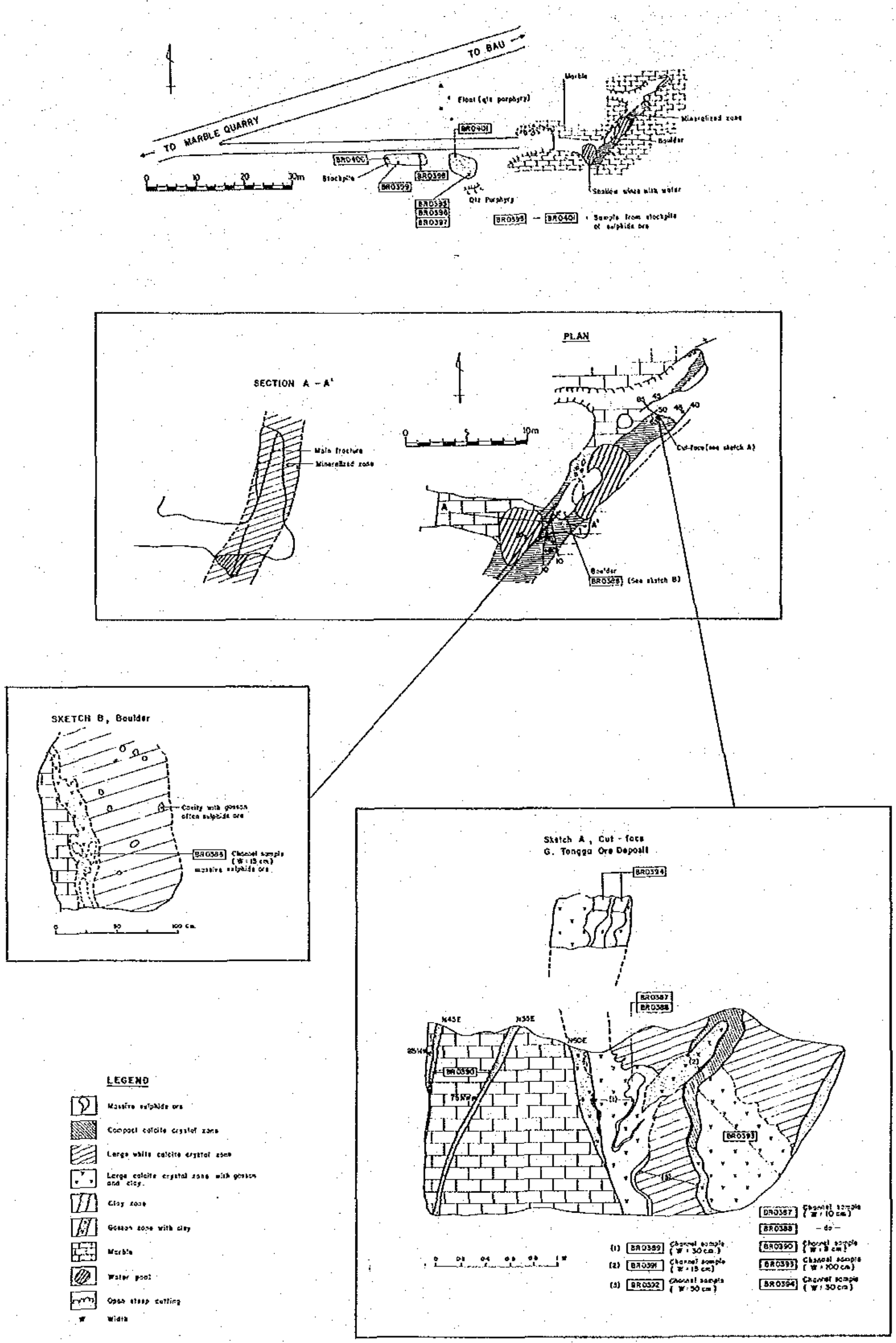

Fig. Ⅱ-11 Old Mine Working, Gunung Tongga Ore Deposit

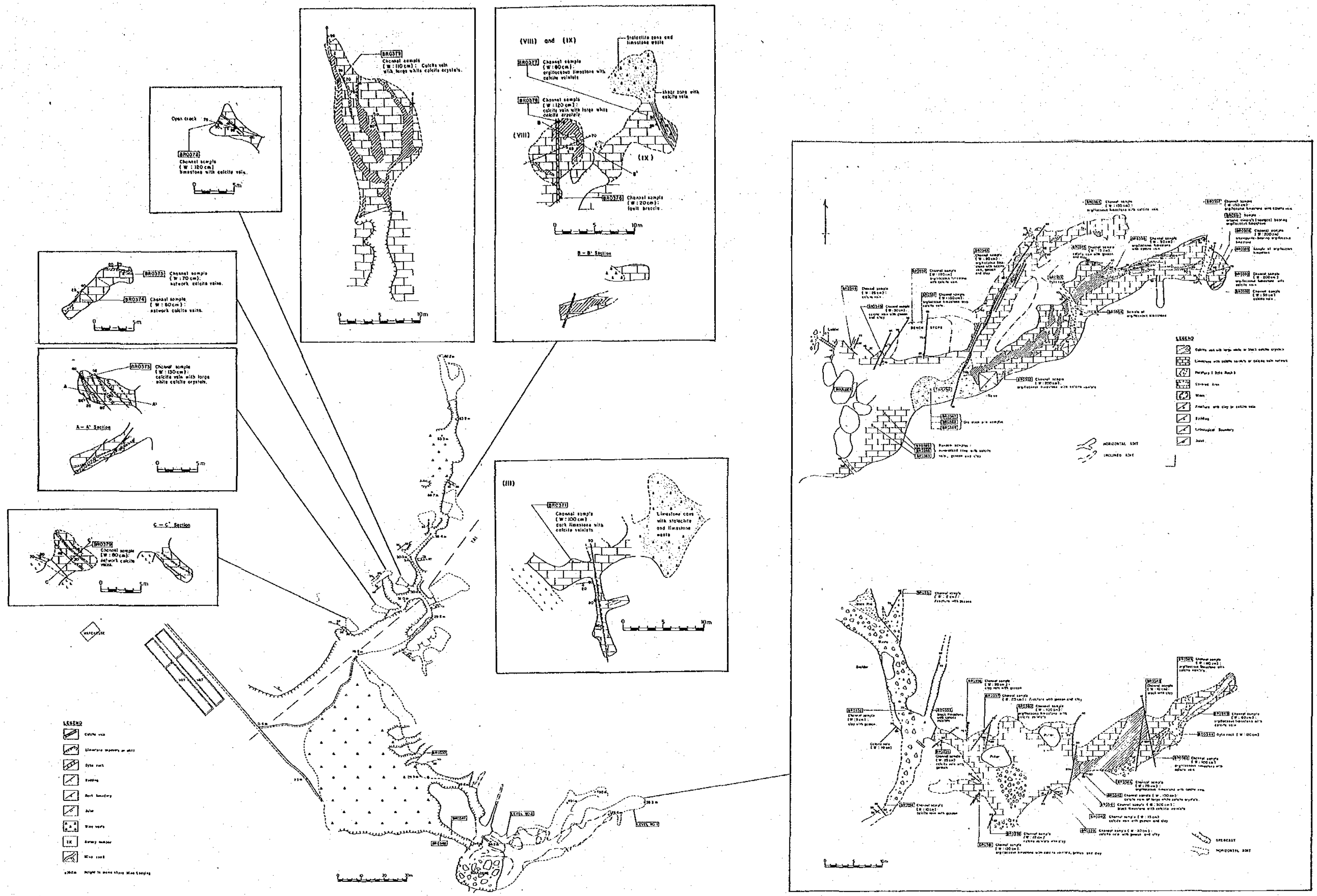

Fig. II-12 Old Mine Workings, Saburan Ore Deposit

sample is observed to contain minor amounts of arsenopyrite, pyrite, marcasite and rare stibnite. In spite of the high gold content, gold grains could not be observed in this section.

The vein in Working No. 2 occurs along the bedding plane of limestone with a strike of N45°E and a dip of 30°NW. It is a composite vein consisting of a calcite vein and a network of calcite veinlets. Metallic minerals could not be seen megascopically. A channel sample from the vein contains 2.5 g/t Au and 9.7 g/t of Ag. The vein appears to replace selectively only blackish argillaceous limestone intercalated with light grey, purer limestone.

Working No. 3 appears to have been mined for the gossanous clay which occurs along a NNW–SSE fracture in limestone. Irregular networks of calcite veinlets are observed in the working and analysed samples gave 3.17 g/t Au and 0.2 g/t Ag.

Working No. 4 is an opencast working which however could not be studied due to a thick bush cover.

The veins in Working No. 5 ~ 7 are similar to that of Working No. 2. Analytical results of four channel samples range from 2.75 to 7.86 g/t Au and 3.3 to 10.0 g/t Ag.

Working No. 8 and No. 9 are of an irregular calcite vein with large, white, calcite crystals and a network of calcite veinlets. A sample of the calcite vein assayed 0.13 g/t Au and 0.7 g/t Ag, and that of the network 1.5 g/t Au and 7.1 g/t. There is a N–S trending fault breccia zone with a width of 0.2 m in Working No. 8 and a sample of this breccia zone analysed 1.63 g/t of Au and 4.9 g/t Ag.

Working No. 10 is in a NNW–SSE trending vein consisting chiefly of very coarse, white, calcite crystals. A channel sample of the vein assayed 0.25 g/t Au and 0.8 g/t Ag.

Features of the Saburan ore deposit may be summarized as follows:

(i) The Saburan ore deposit is dominated by two types of calcite veins, a steeply dipping fracture-filling type, and a gently dipping type of networks of small calcite veinlets. The latter type appear to be emplaced along bedding planes with selective replacement of the argillaceous limestone host rock.

(ii) Macroscopically metallic minerals are generally rarely observed and where seen are mainly associated with the network of calcite veinlets at Working No. 1.

(iii) The average ore grade of all the workings based on the samples analysed, is approximately 6 g/t Au and 4 g/t Ag. Au content of the coarsely crystalline calcite veins is low whereas calcite veins with networks of calcite veinlets contain a higher grade of Au and Ag.

(iv) Working No. 1 gave the highest average gold content of 11.21 g/t, but requires further work to estimate its ore reserves.

(v) The other workings are relatively small but some, such as Workings No. 2, No. 5, No. 6 and NO. 7, gave interesting gold grades, and should be further explored.

(vi) The overall results of the investigation suggest that the area has good potential for further mining though the association of gold and arsenic minerals may present some difficulties in the extraction of gold by the cyanidation method.

3–1–11 G. Saburan ore Deposit

Two old mine workings in the deposit are located at the northeastern and southern sides of G. Saburan. The deposit was mined by the Ban Lee Gold Mining Company during 1948 and 1959.

Working No. 1 is a tunnel of about 20 m long along a N55°E direction. It was described as the G. Saburan A ore deposit in Phase I and is located on the northeastern side of G. Saburan.

The veins in the working occur in marble of the Bau Limestone as irregular calcite veins and lenticular quartz-wollastonite veins which cut the calcite veins. The analytical result of a lump ore sample of the quartz-wollastonite veins gave 1.5 g/t Au and 0.2 g/t Ag. At the drift face, stibnite could not be observed but some lump ore of the quartz-wollastonite veins stocked in the tunnel contain a small amount of stibnite. The analytical result of a sample of the stock ore gave only trace values for Au.

Working No. 2, formerly called the G. Saburan B in Phase I, is located on the southern side of G. Saburan, and it consists of two sets of quartz-wollastonite vein networks trending N45°W and N75°W, and dipping 40°NE and 50°SW respectively. These networks occur in marble and show similar vein features as that of the Luckyhill B ore deposit. Two channel samples of the quartz-wollastonite vein networks and one spot sample of banded quartz-wollastonite ore assayed as follows:

		Sampling width (m)	Au (g/t)	Ag (g/t)
AR0439	channel	1.60	12.00	104.0
AR0440	channel	0.60	3.83	2.6
AR0441	lump	–	14.00	60.0

Results of the investigation shows that the gold contents of the G. Saburan ore deposit in Working No. 2 is essentially high though reserves are probably very small.

3–1–12 Tai Ton B Ore Deposit

The Tai Ton B ore deposit is located about 800 m south of Bau town, and mined for gold by the Tai Ton Gold Mining Syndicate from 1931 to 1954. In late 1984, mining operation was revived by the Priority Trading Company Limited.

The deposit consists of a thick calcite vein striking N45°W and dipping 40°–80°NE, with a width ranging from 2 to 6 m. It was drifted for about 350 m along the strike length.

The vein is generally composed of large white and black calcite crystals, accompanied in places by quartz veinlets and/or quartz veinlet networks. Dark grey, fine-grained quartz also forms small lenses containing minor amounts of stibnite and arsenic minerals.

A total of 20 samples were analysed and divided into groups as shown below:

	Number of samples	Au (g/t)		Ag (g/t)	
Calcite vein	7	tr	0.1	tr	0.1
Calcite vein with quartz	4	1.1	11.25	tr	28.6
Gossanous clay	4	5.7	18.00	7.0	24.3
Fine-grained quartz veinlets/lenses	5	9.2	36.70	1.9	39.6

The Au and Ag contents of the large calcite crystal vein are extremely low but parts of the vein containing quartz, particularly quartz-rich ores with minor stibnite and the gossanous clay show higher grades of Au and Ag. This suggest that gold is closely related to quartz which should serve as a guide for future mining of this ore deposit.

3–1–13 G. Tai Ton Ore Deposit

The deposit which was described as the G. Tabai ore deposit in Phase I, is situated about 1.5 km southeast of Tai Ton village. Five small old mine workings aligned in the N20°W direction are located in this deposit. These workings were worked by the Tai Ton Gold Mining Company during the 1950's.

Working No. 1, small underground working, is found on the northern slope of G. Tai Ton, near the top of a high precipice above a flooded open pit old working. The lenticular ore body occurs in limestone of the Bau limestone, and strikes N20°–55°W with a vertical dip and a width varying from 2 m to 10 m. it consists predominantly of calcite with drusy quartz aggregates and/or networks of quartz veinlets. The ore body shows numerous fractures filled by gossanized clay and small blocks of the limestone host rock.

Analytical results of two channel and three spot samples are as follows:

		Sampling width (m)	Au (g/t)	Ag (g/t)
AR0426	calcite-quartz vein with clay	3.00	20.67	37.8
AR0427	calcite-quartz vein with clay	2.60	tr	tr
AR0430	black, gossanized clay	(spot)	13.00	9.8
AR0431	light grey clay with calcite	(spot)	17.50	7.9
AR0432	calcite with drusey quartz	(spot)	11.83	41.8

Working No. 2 and No. 3 are small open pits located near the top of G. Tai Ton at elevations of 201 m and 210 m. Working No. 2 consists of a calcite vein network, 1.0 m in width trending N20°W. Gossanized clay is found in places. A channel sample of the clay gave 10.50 g/t Au and 31.0 g/t Ag. Working No. 3 comprises reddish brown clay developed along parallel joints trending N15°W in limestone. A spot sample of the clay shows 1.00 g/t Au and 1.5 g/t Ag.

Working No. 4 and No. 5 are also small pits located on the southern slope of G. Tai Ton at elevations of 100 m and 120 m. The ore body in Working No. 4 is composed of a network of predominantly calcite and minor quartz veins. Large calcite crystals are well developed in the calcite veins. Analysis of a channel sample of 1.5 m sampling width, gave 7.50 g/t Au and 5.3 g/t Ag. At Working No. 5, no veins were observed but an ore sample consisting of veined quartz-calcite from a stockpile at the site assayed 27.0 g/t Au and 14.2 g/t Ag.

The G. Tai Ton ore deposit in general shows a high content of gold which appears to have been caused by secondary enrichment in the form of gossanized clay developed predominantly in fractures in the calcite veins. Gold should be easily extractable from the high grade clayey ore by the cyanidation process. Hence, selective mining on a small scale is feasible though accessibility may present some difficulties.

3–1–14 G. Nanui Ore Deposit

The deposit is located on the southeastern clope of G. Nanui, about 1 km north of Bidi. The deposit was mined as several old mine workings by the Ng Kui Hiung Mining Company in the past.

The ore deposit occurs in limestone and consists mainly of a calcite vein with some quartz, striking N20°E and dipping 20°–70°SE. The width of the vein is very variable, pinching and swelling, with a maximum thickness of more than 15 m at one place. The vein contains large crystals of white and black calcite and gossanized clay with manganese oxides. Analytical results of five samples range from trace to 4.00 g/t Au and trace to 14.2 g/t Ag. The gold content of the G. Nanui Ore Deposit is low and it is concluded that even selective mining may not be feasible.

3–1–15 G. Jabul Ore Deposit

This deposit is situated about 150 m northwest of the G. Nanui ore deposit. Two old mine workings in a limestone hill and many small, flooded workings in the adjacent limestone flats are located in this deposit.

The veins in the workings are composed mostly of large, white, calcite crystals with sporadic patches of black calcite crystals. They are almost similar to that of the G. Nanui ore deposit. Analytical results of six samples from the workings in the limestone hill show trace to 1.83 g/t Au and trace to 11.4 g/t Ag. Three samples from the limestone flats shown only trace values for Au and Ag. These results suggest that the gold content of what is left of the G. Jabul deposit is very low and as in the case of the G. Nanui ore deposit, even selective mining may not be feasible.

3–1–16 Rumoh Ore Deposit

The Rumoh ore deposit is located 300 m northwest of Bidi, about 6 km southwest of Bau town. The area was worked by the Rumoh Gold Mining Company from 1949 to the 1970's. The mine extracted about 165 kg of gold from approximately 36,000 tonnes of crude ore by the cyanidation process between 1949 and 1964. The workings were concentrated in three main underground tunnels with NNE–SSW and N–S trends. Mining of this deposit was recently revived by the Syarikat Tabai Sdn. Bhd.

The mine area is underlain by the Bau Limestone and the Pedawan Formation. The deposit is in the Bau Limestone which is faulted against the Pedawan Formation in the west by the Tai Parit Fault. NW–SE trending joints are well developed in limestone.

Figure II–13 shows the old mine workings comprising three main levels, Level No. 1, No. 2 and No. 3. The veins in the workings consist mainly of coarsely crystalline, white and black calcite with minor quartz. Most of the veins are highly irregular in shape and continuity. They are chiefly lenticular but at places form chambers with widths reaching 5 m.

Analytical results of 10 samples from Level No. 1 gave trace to 4.67 g/t Au and trace to 11.3 g/t Ag. One sample of the quartz-rich ore with comb-quartz crystals contains 2.67 g/t Au and 393.4 g/t Ag. 18 samples collected from Level No. 2 assayed trace to 5.5 g/t Au and trace to 36.3 Ag and three samples from the same level gave high gold grades as shown below:

		Sampling width (m)	Au (g/t)	Ag (g/t)
BR0407	large calcite	1.80	10.63	26.2
BR0422	gossanized clay	0.70	10.75	4.5
BR0482	black calcite-gossan-clay ore	1.00	68.30	48.4

Assays of six samples of calcite veins with gossan and clay materials collected from Level No. 3 show trace to 2.50 g/t Au and trace to 15.8 g/t Ag.

From the above results, the average Au content of the Rumoh ore deposit appears to be in the range of 2–3 g/t. However, black calcite veins with gossanized clay contains relatively high gold. Selective mining of these veins, particularly veins rich in gossanized clay may be profitable.

3–1–17 Bidi Ore Deposit

The deposit which was formerly named the Kusa ore deposit in the Phase I report, is situated at Bidi, about 400 m southwest of the Rumoh ore deposit. It was first mined for gold by the Jong Kuet Syn Mining Company during the 1960's, and later by the Kusa Mining Sdn. Bhd for gold and antimony in the 1970's. At present many flooded shallow opencast workings can be seen in the mine area where the Bau Limestone is widely exposed.

The deposit consists mainly of calcite veins with subordinate quartz trending N–S, ENE–WSW and NW–SE (Fig. II–14). The veins observed in the workings are mostly barren of metallic minerals but lump ores of the stockpile contain abundant native arsenic and stibnite with some arsenopyrite and realgar.

Analytical results of four channel samples taken from the opencasts gave the extremely low contents of Au and Ag. A sample of the crushed stocked ore and five lump ore samples however, gave high values as shown below:

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)
AR0053	crushed stock ore	9.0	18.0	1.69	11.15
AR0054-d	stibnite-realgar ore	20.0	237.0	13.10	17.89
AR0054-e	stibnite-native arsenic	24.0	272.0	2.10	7.48
AR0054-f	realgar-rich calcite ore	74.4	211.0	0.53	46.44
AR0054-g	banded black calcite	0.2	26.1	1.26	1.33
AR0054-h	brecciated limestone with calcite veins	6.0	14.7	1.22	–

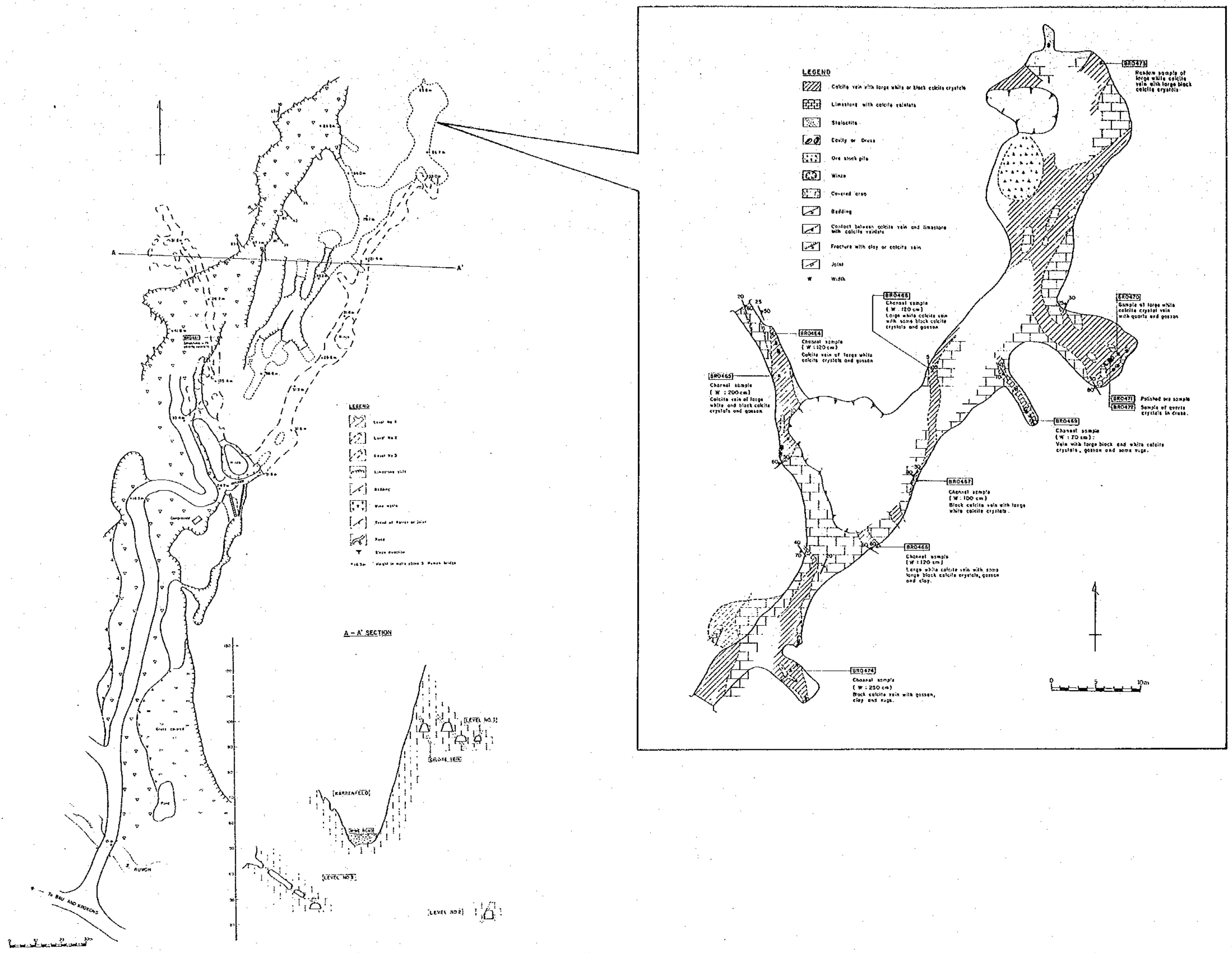

Fig. II-13 Mine Workings, Rumoh Ore Deposit

The Bidi ore deposit is characterized by a very high content of arsenic, particularly in the form of native arsenic and a corresponding high values for gold and silver. The analytical results of lump samples clearly indicate that gold and silver are closely related to arsenic minerals. Under microscopic examination of three polished sections, a few grains of creamy yellow electrum in rounded and/or sub-angular grains of native arsenic were observed.

Investigation of the Bidi ore deposit using the spectral IP method during Phase II gave encouraging results which indicate that mineralization most likely extends in depth. Mining and the extraction of gold by the cyanidation method however, would face difficulties due to abundant arsenic minerals.

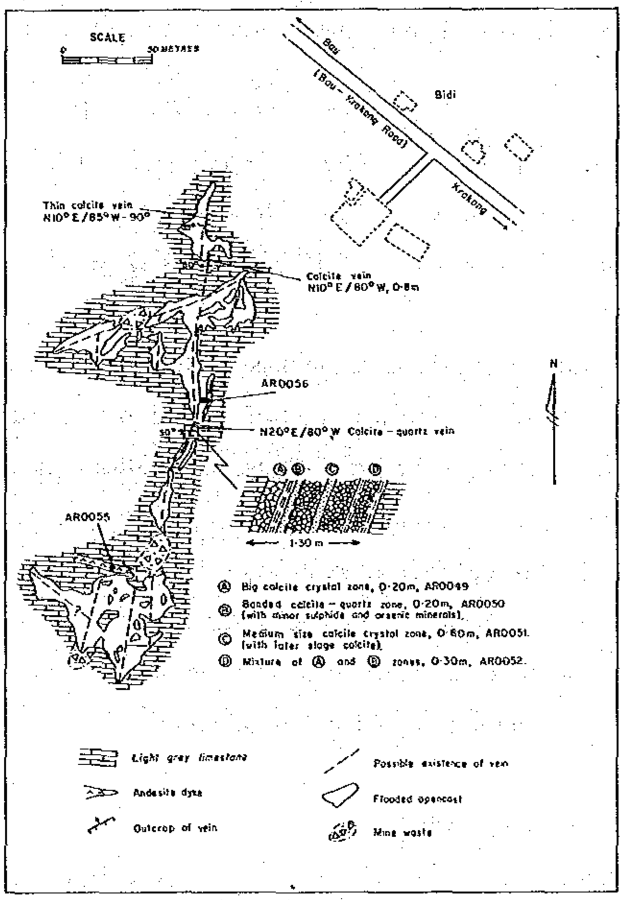

Fig. Ⅱ-14 Old Mine Workings, Bidi Ore Deposit

3–1–18 Bidi South Ore Deposit

This was formerly called the Associated ore deposit in Phase I. The Bidi South ore deposit is located just south of the Bidi ore deposit, and was worked by a series of aligned, flooded, shallow, open pit workings. The deposit was discontinuously mined by many mining companies from the 1900's to the 1970's

The mine area is mostly underlain by the Bau limestone. Small exposures of the Pedawan Formation and acidic intrusive rocks are found in the eastern part of the area.

The mode of occurrence of the deposit is not clear because all the workings are at present flooded and only a few thin veins consisting mainly of calcite with a small amount of quartz in limestone and a little stockpile of ore can be observed. A vein of 30 cm width exposed at the eastern margin of the area consists of calcite and quartz with abundant native arsenic and rare stibnite. Analysis of a sample of this vein gave 31.9 g/t Au, 12.3 g/t Ag and 0.71% Sb. Three lump ore samples containing arsenic minerals, stibnite and quartz assayed as follows:

		Au (g/t)	Ag (g/t)	Sb (%)	As (%)
AR0061-a	stibnite-quartz ore	69.6	29.1	1.36	1.91
AR0061-b	stibnite-arsenic ore	20.4	89.8	1.78	–
BR0487	quartz with stibnite	5.17	27.5	0.27	–

The analytical results and mineral assemblage of the area suggest that the general feature of the Bidi South ore deposit is very similar to that of the Bidi ore deposit.

The ENE–WSW alignment of the old workings may indicate the general trend of the deposit in the middle to eastern part of the mine area. Three lines of the spectral IP survey carried out in Phase II however, did not indicate mineralization at depth except for a small and very weak spectral IP anomaly detected at the eastern end of the alignment of the workings. Further mining of the deposit may encountered some difficulties because of the probable shallow extent of mineralization and the association of gold and arsenic minerals.

3–1–19 Nam Loong B ore Deposit

The deposit is located just west of the Bidi South ore deposit, 1.5 km south-southwest of Bidi. It was mined in the middle of the 1900's, and presently by some local miners. Present mining is carried out mainly along highly weathered, calcite veins in limestone associated with abundant brown to dark brown clay. This clay is formed most probably from the weathered calcite veins. The veins consisting of predominantly calcite with minor quartz and rare stibnite strike NNW–SSE to NW–SE and NE–SW with steep dips. They have been mined for more than 180 m along the strike length (Fig. II–15). Four clay ore samples and two samples of primary calcite show the following analytical results:

	Number of samples	Au (g/t)	Ag (g/t)
Clay in vein and limestone	2	0.2 – 2.4	trace
Clay ores in stockpile	2	11.25 – 19.20	11.3 – 14.3
Primary calcite ore	2	trace – 4.2	trace – 16.2

One clay ore sample taken from a fracture in limestone contains 65.2 g/t Au, 43.8 g/t Ag and 5.71% of Sb. It is not clear whether the clay was formed from the weathering of primary calcite veins or transported from other places by water. In general, ore of the Nam Loong B ore deposit is mainly in the form of auriferous clay and thus reserves is very small and further mining may be feasible only on a small scale.

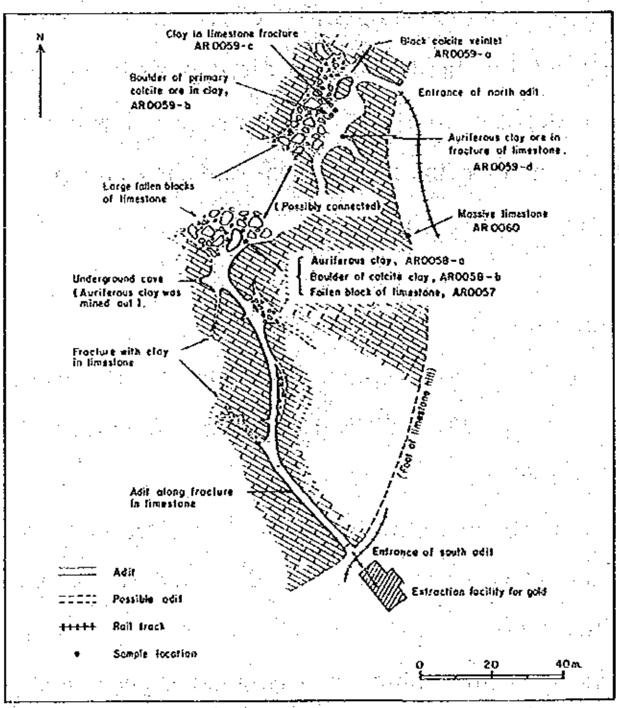

Fig. II-15 Mine Workings, Nam Loong B Ore Deposit

3–1–20 Jambusan East Ore Deposit

Several flooded old mine workings of the Jambusan East ore deposit are located about 2 km east of Jambusan, along the northern side of the Ah Onn Road. The deposit had been mined discontinuously for antimony and gold by many companies from the late 1800's to 1970's.

The mine area is underlain by the Bau Limestone, the Pedawan Formation and a few small dikes of argillized dacite intruding into both formations. Limestone is exposed only in and around the old workings, and is overlain by mainly shale of the Pedawan Formation with a nearly horizontal and in places, moderately dipping contact. The Formation near the old mine workings is intensely silicified with numerous quartz veinlets.

The deposit occurs in the contact zone between limestone and shale as quartz veins with minor calcite in limestone and networks of mainly quartz veinlets in silicified shale. Many fragments of quartz and quartz-calcite vein, and breccia-like siliceous ore containing shale fragments in the mine waste near the workings may be observed. The general trend of the deposit is in the E–W direction as indicated by the alignment of the old workings. Some fragments of veins from the mine waste contain stibnite, arsenopyrite, pyrite and rare realgar. Two lump ore samples containing stibnite assayed trace to 0.40 g/t Au, trace to 0.43 g/t Ag and 8.08 to 14.61% Sb. Another three ore fragment samples gave 0.63 to 3.90 g/t Au and 2.3 to 3.0 g/t Ag.

The general features of the Jambusan East ore deposit is very similar to that of the West Batu Bekajang Lake ore deposit, although the former is indicated to contain less gold. Both deposits occur along the contact between limestone and shale and are characterized by extensive networks of mainly quartz veinlets in shale.

3–1–21 Tegora Ore Deposit

The Tegora ore deposit located 11 km south of Bau town, was mined for mercury by the Borneo Company from 1868 to 1909 with a production of about 363 kg of Hg, and later by the Japanese between 1942 and 1945.

The mine area is underlain predominantly by black shale and sandstone of the Pedawan Formation which strikes northeast and dips 80°–90° south. A dike and a small stock of dacite are found near the deposit.

The deposit occurs as fissure-fillings in a chimney-shaped pocket in a NE–SW trending brecciated zone of black shale and sandstone. Ore minerals are composed mainly of cinnabar and pyrite with a small amount of realgar and native mercury. The cinnabar occurs chiefly as coatings on the surfaces of fractures in breccia of the host rock. A sample collected from a mineralized outcrop gave the following contents:

Hg(%)	Au(g/t)	Ag(g/t)	Sb(%)	As(%)	Cu(%)	Pb(%)	Zn(%)
2.31	tr	tr	0.06	0.78	0.01	tr	tr

Under microscopic observation, a polished section of the analyzed sample contains euhedral crystals of pyrite and irregular, anhedral cinnabar filling interstices between quartz grains. Some of pyrite have been altered to limonite.

3–1–22 Gading Ore Deposit

The deposit is situated about 14 km south-southwest of Bau town, and it was mined for mercury together with the Tegora ore deposit.

The geological setting of the Gading ore deposit is almost the same as that of the Tegora deposit. The deposit occurs in a sheared zone with a northeast strike and a 70° southerly dip. It extends about 50 m along strike. The main ore minerals are cinnabar with arealgar and pyrite. These occur mainly in quartz veins.

From microscopic observation, the polished section of a sample is observed to consist mainly of pyrite and cinnabar, with subordinate kermesite and native arsenic in quartz gangue. Pyrite occurs usually as euhedral crystals but spherical aggregates of colloform pyrite, framboidal pyrite and aggregates of long tabular pyrite crystals are also observed. Kermesite and native arsenic are usually associated with cinnabar which occurs in the interstices of the gangue mineral.

3–1–23 G. Ropih Prospect

This prospect is located on the southwestern slope of G. Ropih, about 4 km southwest of Bau town.

Cu-Mo mineralization associated with abundant networks of quartz veinlets occurs in a quartz porphyry stock which forms G. Ropih. The stock with a diameter of about 1 km, intruded the Bau limestone and is intensely and extensively altered, and deeply weathered. Some mineralized outcrops and numerous mineralized floats were however, encountered in the southern part of the stock during detailed geological mapping along the geochemical soil sampling lines (Fig. II–16).

The mineralized outcrops and floats are composed mainly of pyrite, chalcopyrite and malachite, and a small amount of molybdenite in a network of abundant quartz veinlets which are mostly less than 5 mm in thickness. Pyrite and chalcopyrite occur as fine disseminations in quartz veinlets and in the quartz porphyry itself which is commonly so highly silicified and argillized that the original texture of the rock has been obliterated. Malachite occurs in some floats and outcrops, partially staining the rock green. Molybdenite occurs as sparse disseminations with pyrite in quartz veinlets. Some of the molybdenite form aggregates of fine-grained crystals.

The quartz porphyry has been subjected to intense silicification, chloritization, sericitization and kaolinitization. Silicification in particular is well-developed in the southern part where it is observed mainly as networks of quartz veinlets. Extensive chloritization and weak K-alteration are also recognizable in this part. Kaolinitization and sericitization occur commonly in the north central part of the stock.

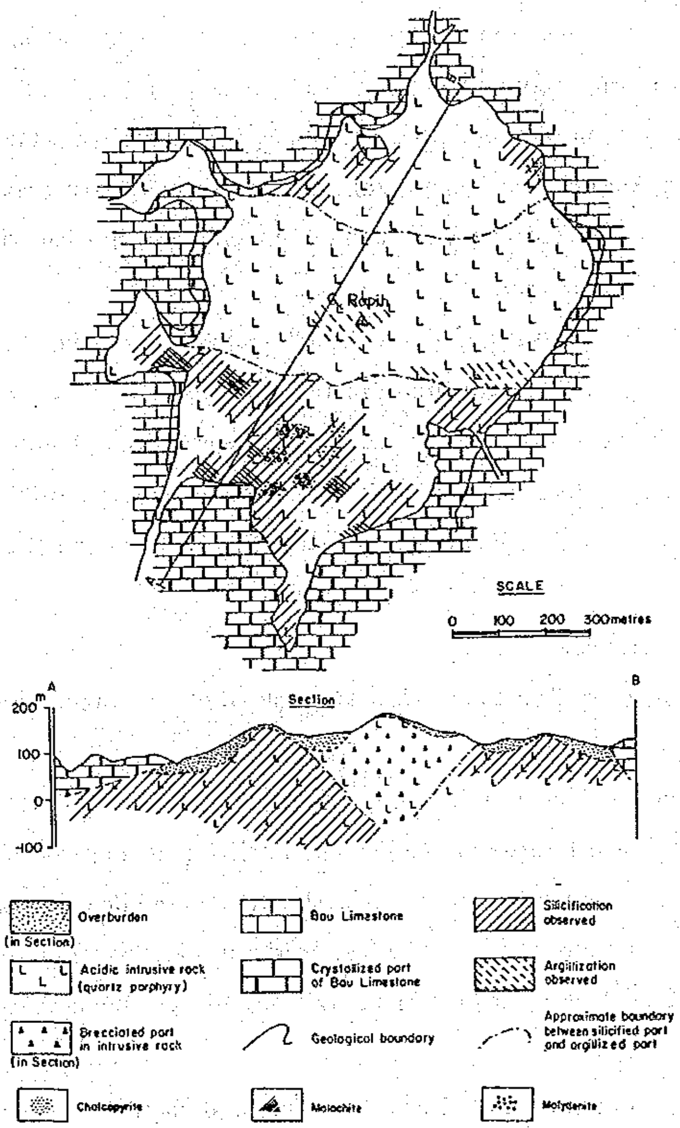

Fig. II-16 Geology of Gunung Ropih Prospect

Analytical results of 12 mineralized samples collected from the outcrops and floats show trace to 0.50 g/t Au, trace to 1.3 g/t Ag, 0.01 to 0.23% Cu and trace to 0.012% Mo.

The mineral assemblage, general features of alteration and geological setting, suggest that the Cu-Mo mineralization found in the area is of the porphyry copper type which is the first of its kind known in Sarawak. The Cu grade of this prospect indicated so far by exploration drilling and the floats and outcrops is relatively low. The discovery of the porphyry copper type mineralization in the Bau Mining District, however, is significant.

3–1–24 Gold mineralization, Sungai Sinyi and Sungai Matung Areas

Geochemical steam sediment and panned concentrate sampling undertaken during this project resulted in the delineation of the S. Sinyi and S. Matung areas which are indicated to have potenials for gold mineralization. The panned concentrate survey in particular indicated concentration of placer gold in the stream sediments from these areas, although no gold deposits and/or mine workings for gold have been previously reported in both areas.

During the Phase III work, detailed panned concentrate sampling of stream sediments and panning of crushed bedrock samples along S. Sinyi and S. Mud in the S. Sinyi area and S. Matung in the S. Matung area, were carried out in an effort to trace the primary source of the placer gold. In addition, 13 trenches with a total length of 120 m were also dug in the S. Matung area. The results of the panned concentrate survey and trenching indicate that the placer gold was derived from the Quaternary alluvial bank deposits of gravel, sand and clay. From the detailed geochemical soil survey which was also carried out in both areas however, possible primary sources of the alluvial gold may be delineated. The source of the alluvial gold in S. Sinyi was traced to a swampy area in the upper reaches of the river. A distinct anomaly for As and high Au values in soil occurs just SE of the swamp into which streams draining the anomalous area flow. It becomes obvious that this anomalous area is the most likely primary source of the alluvial gold found the Sungai Sinyi. The alluvial gold found in Sungai Mud most probably originated from this same primary source, the gold being carried there by the Sungai Sebuloh which drains the SE part of the anomaly. In the Sungai Matung area, a possible primary source is also detected by the geochemical soil survey to be in the upper reaches of Sungai Matung. This source if present however, is suggested to be of small extent.

3–1–25 Other Abandoned Old Mine Workings

Numerous old mine workings could not be investigated during the project period because