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Base metal exploration in Sabah

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Abstract: A programme for base metal exploration is being carried since late 1980 in selected parts of Sabah by the Geological Survey with assistance from the Federal Institute of Geosciences and Natural Resources of the Federal Republic of Germany.

Joint project activities started with the screening and re-assessment of existing prospecting data and a multi-element re-analysis of about 30,000 drainage, base-of-slope and soil samples from earlier reconnaissance prospecting campaigns covering a total of about 9,500 sq. kms. of Sabah territory.

This first phase led to the delineation of several target areas warranting further investigation at different working stages.

In anticipation of particular model types of mineralization likely to occur within the given range of geological environments prevailing in the country special emphasis was given to the investigation of

(i) base metals drainage anomalies in areas with widespread manifestation of Late Tertiary acidic intrusive/sub-volcanic activity to the east and south of Mount Kinabalu.

(ii) lead-zinc anomalies related to acidic volcanics and volcaniclastic series of the Late Tertiary to Quaternary calc-alkaline volcanic belt of Semporna Peninsula, and

(iii) copper-zinc anomalies related to the pillow-lava stage of the Late Cretaceous to Early Tertiary ophiolite assemblages in Central Sabah.

The follow-up investigations carried out from 1981 to 1983 resulted in the detection of widespread cross-cutting and fissure-filling stockwork mineralization of galena, sphalerite and chalcopyrite related to the waning stages of the Pliocene felsic volcanism of Gunung Wullersdorf/Semporna Peninsula and led to the discovery of Cyprus-type massive sulphide occurrences related to basaltic pillow-lavas and associated volcano-sedimentary sequences of the Chert-Spilite Formation in the Bidu-Bidu Hills/NE Sabah.

Whereas Gunung Wullersdorf area was considered to offer little prospects for economic base metals concentrations and prospecting work was halted in early 1983, exploration in the Bidu-Bidu Hills comprising in particular pulse-electromagnetic surveys and shallow diamond drilling by portable Winkie drill are being continued.

INTRODUCTION

Apart from a short-lived boom immediately after the discovery of the Mamut porphyry copper deposit in 1964 (Kirk, 1967; Kosaka & Wakita, 1978), mineral exploration in Sabah by the private sector was in decline during the period from 1960 to 1980.

In an attempt to stimulate mineral exploration in the country the Geological Survey, initially assisted by the United Nations Special Fund, decided to carry out basic prospecting programmes covering extensive areas of the Labuk and Karamuak

Valleys, the Mount Kinabalu area, and the Upper Segama Valley by combined drainage and base-of-slope reconnaissance sampling.

In 1977 a request for technical assistance was made to the Federal Republic of Germany and a programme for the "Investigation of mineral resources in Sabah" was jointly prepared in 1978 by geologists of the Geological Survey of Malaysia, Sabah and the Federal Institute for Geosciences and Natural Resources. A Project Agreement was concluded by the two Governments in late 1979 and the implementation of the joint programme started ten months later in September, 1980.

PREVIOUS ACTIVITY IN MINERAL EXPLORATION

Exploration ventures in Sabah data back to the 19th century. Mineral investigation during the early period by individuals and groups of people was based on chance finds and was predominantly restricted to prospecting for alluvial gold in the Segama Valley (Fitch, 1955).

Concerted efforts in mineral prospecting started only in the late 1950's. Between 1960 and 1968 up to four foreign companies were prospecting in Sabah for metals such as chromium copper, lead, zinc and gold (Collenette, 1964, 1965). About 400 km^2 of licence area were prospected by the end of 1969. Although many new mineral occurrences were discovered and several prospects of copper and chromite were examined in detail, the final appraisal indicated in all cases, that economic mining was not feasible.

The investigation of Sabah's mineral potential had a major boost during the United Nations Natural Resources Survey (1963–1965) when 2,600 km^2 of the Labuk and Karamuak Valleys in Central Sabah and 980 km^2 to the east of Mount Kinabalu (fig. 1) were covered by reconaissance drainage and base-of-slope surveys. During the survey about 23,000 samples were collected and subsequently analysed for copper and nickel. Numerous geochemical anomalies were detected.

The most significant anomalies in the Kinabalu area and in the Bidu-Bidu Hills were selected for further detailed investigation comprising closer-spaced drainage and base-of-slope sampling, ridge-and-spur and grid soil sampling, followed by ground geophysical surveys, trenching, and pitting all of which led to the discovery of the Mamut porphyry copper prospect and to the detection of several copper showings in the Bangau-Bangau and Upper Sualog Valleys of the Bidu-Bidu Hills.

The copper showings in the Bidu-Bidu Hills however were later considered to be of little economic interest (Woolf, 1965; Cooper *et al.*, 1965; Winkler, 1966) and investigations were discontinued in 1965 when the United Nations Labuk Valley Project ended.

Reconnaissance prospecting by the Geological Survey was subsequently extended to new target areas (fig. 1). From 1966 to 1969 approximately 5,500 km^2 of the Upper Segama-Darvel Bay area, 2,000 km^2 of Semporna Peninsula, and 280 km^2 of the Marudu Bay area were covered by reconnaissance drainage and bank sampling.

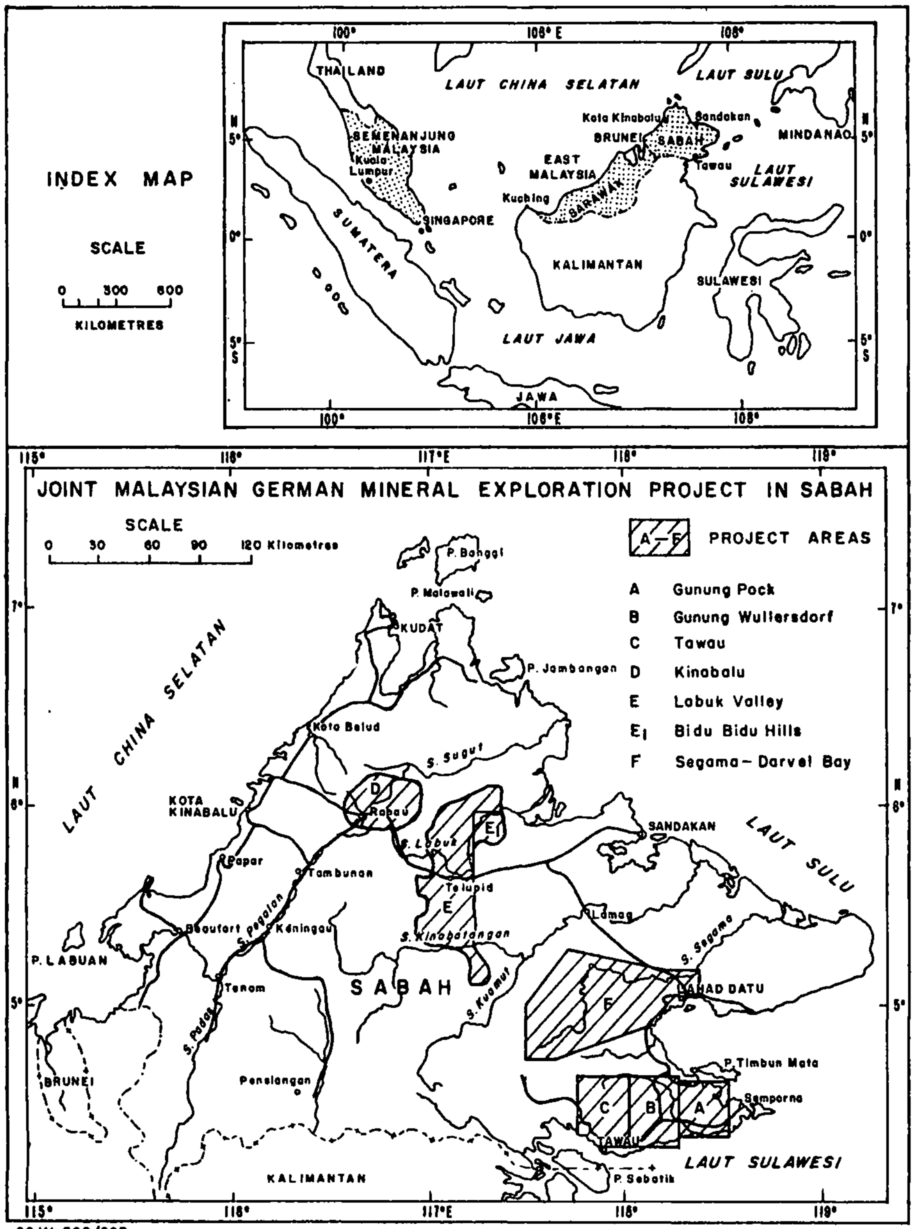

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Fig. 1. Location Map of Project Areas.

During these prospecting campaigns a total of about 16,000 samples were collected and analysed for copper and some for nickel, lead and zinc.

A number of copper anomalies were discovered in the area of Gunung Pock and Gunung Wullersdorf, Semporna Peninsula (Sullang, 1968; Wong, 1969; Lee, 1971) and in several catchment areas of the Segama Valley (Leong, 1974).

The results of the reconnaissance surveys and subsequent intermittent drainage and soil follow-up surveys in Gunung Pock and Gunung Wulersdorf areas remained however rather unsatisfactory and inclusive (Wong, 1972; Lee, 1971, Lim, 1980) due to lack of laboratory facilities for multi-element analysis and lack of expertise in data interpretation.

RE-ASSESSMENT OF EARLIER PROSPECTING DATA —SELECTION OF TARGET AREAS

The project was started in September, 1980 with the updating of the Geological Survey's existing laboratory facilities in Kota Kinabalu. The screening and re-assessment of pre-existing prospecting data, and the multi-element re-analysis of about 30,000 drainage, base-of-slope and soil samples collected during earlier reconnaissance prospecting campaigns of the Geological Survey and the United Nations Labuk Valley Project was carried out. The samples were systematically re-analysed for a range of 7 to 10 elements (Cu, Zn, Pb, Ni, Co, Cr, Fe, Mn, As, Mo) by atomic absorption spectrometry and colorimetric methods.

The interpretation of analytical data was based on statistical parameters derived from cumulative frequency plots as described by Lepeltier (1969) and Sinclair (1974). In cases where lithological changes were reflected by significant changes in element distribution patterns the survey areas were systematically divided into subareas. Univariate statistical treatment of the analytical data was subsequently done subarea by subarea. The results obtained were presented on metal distribution maps by means of appropriate symbols taking into consideration as far as applicable the lithology-related partitioning of geochemical data.

This re-assessment programme led to the delineation of a number of target areas which were considered to warrant further investigation (Hoppe *et al.*, 1981, 1981 a, 1981 b, Lim *et al.*, 1981; Lee & Weber, 1982; Weber & Yan, 1983 a, 1983 b). However in view of limited funds and personnel only a few of these target areas could be examined in detail and project activities were concentrated on selected metals in particular geological environments which were likely to offer the best opportunities for successful prospecting. The following anomaly groups were given priority during the follow-up prospecting programme:

a. Base metals drainage anomalies in areas of Late Tertiary acidic intrusive and subvolcanic activity to the east and south of Mount Kinabalu (Mamut-type porphyry copper mineralization),

b. Lead-zinc-copper anomalies related to acidic volcanics and volcaniclastic series of the Late Tertiary to Quaternary calc-alkaline volcanic belt of Semporna Peninsula (massive sulphide mineralization of Kuroko kinship), and

c. Copper-zinc anomalies related to the pillow-lava stage of the Late Cretaceous to Early Tertiary ophiolite assemblages in Central Sabah (Cyprus-type massive sulphides).

SELECTED RESULTS OF CURRENT INVESTIGATIONS

Gunung Kinabalu area

Gunung Kinabalu area is built up by a thick pile of Cretaceous to early Miocene eugeosynclinal sediments of the Northwest Borneo Geosyncline (Haile, 1969) into which several large and numerous smaller bodies of an Alpine-type ophiolite assemblage were tectonically emplaced. This complex which is interpreted as polymict melange of the Eocene Northwest Borneo subduction zone by Hamilton (1979) following Middle to Upper Miocene orogenic activity was intruded by the Kinabalu adamellite batholith and its numerous apophyses, including the Mamut porphyries.

The results of the appraisal of pre-existing prospecting data from Mount Kinabalu area are largely consistent with the picture obtained during the UNDP survey in 1965. The known geochemical anomalies were confirmed as shown by the Mamut copper deposit which was initially reflected by a very impressive drainage train of anomalous copper, zinc and lead content up to 15 km downstream of the outcropping mineralization. Several new drainage anomalies of zinc and lead were also outlined. Follow-up work however evidenced their limited extent and showed that they are apparently not related to significant mineralization.

Semporna Peninsula

Semporna Peninsula is predominantly built up of Miocene marine sediments and volcaniclastic rocks of the Kalumpang Formation and of Pliocene to Quaternary volcanic and related hypabyssal intrusive rocks. The volcanic rocks form the calcalkalic basalt-andesite-dacite association which is the south-westerly extension of the volcanic belt of the Philippines extending from Mindanao through the Sulu Archipelago towards central Kalimantan and eastern Sarawak.

The screening and re-assessment of earlier reconnaissance prospecting data from an area of 2,000 km^2 (figure 1) and subsequent limited follow-up investigations in selected areas resulted in the detection of extensive drainage and base-of-slope anomalies of lead, zinc, and to a lesser degree copper in the areas of Gunung Pock and Gunung Wullersdorf (Hoppe *et al.*, 1981; 1981 a). The geochemical anomalies appeared to be related to widespread base metals mineralization whose host rocks are either that of altered andesitic and dacitic lava close to the contact with a subvolcanic intrusion of granodioritic composition in Gunung Pock area or that of a complex consisting of volcaniclastic sedimentary sequences, dacitic lavas and pyroclastics in Gunung Wullersdorf area.

The most outstanding anomalies, highest in density and contrast occur in the

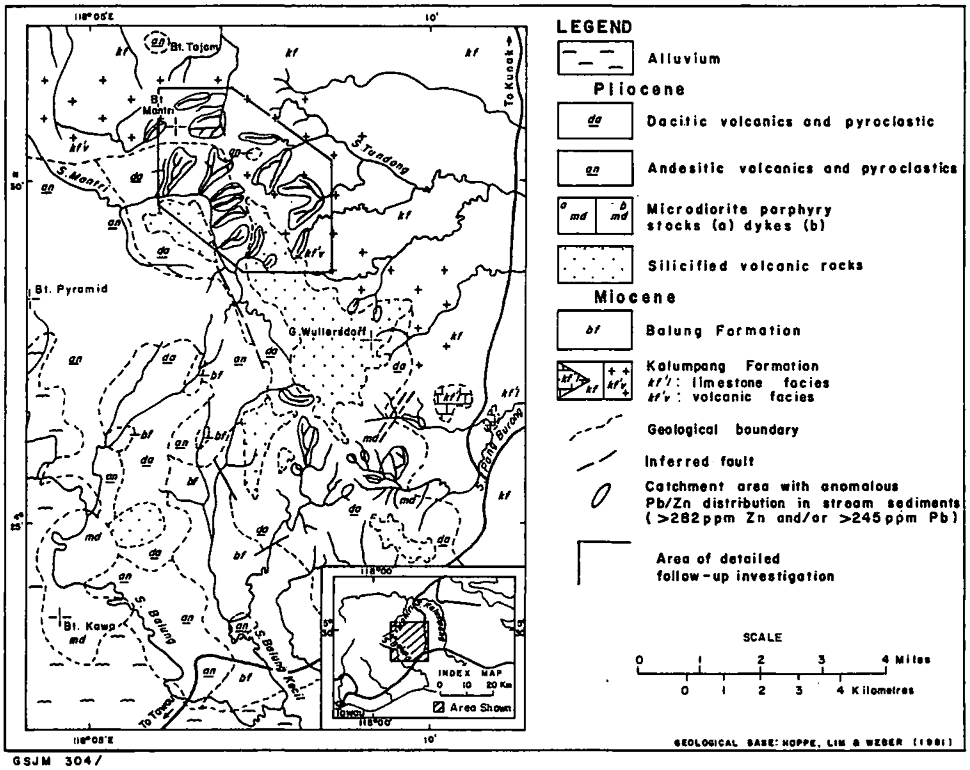

Fig. 2. Geological Sketch Map and Results of Geochemical Drainage Survey—Gunung Wullersdorf Area/Semporna Peninsula.

northern part of Gunung Wullersdorf area and were found to reflect base metals sulphide mineralization consisting of galena, sphalerite and subordinate chalcopyrite (fig. 2). The composition of the mineralization and its close spatial relationship with acidic volcanics and associated volcano-sedimentary sequences deposited in a variety of holomarine neritic environments indicated prospects for Kuroko-type sulphide mineralization. This led to the selection of an area of 24 km² extent covering the northern part of Gunung Wullersdorf and Bukit Mantri (fig. 2) for further follow-up investigation comprising

(i) detailed geological mapping and narrow-spaced drainage and base-of-slope sampling of selected catchment areas having an anomalous metal distribution,

(ii) a major ridge-and-spur soil sampling programme with compass traverses of 30 km aggregate length,

(iii) a grid soil survey covering 1.5 km² of the southeastern portion of Bukit Mantri,

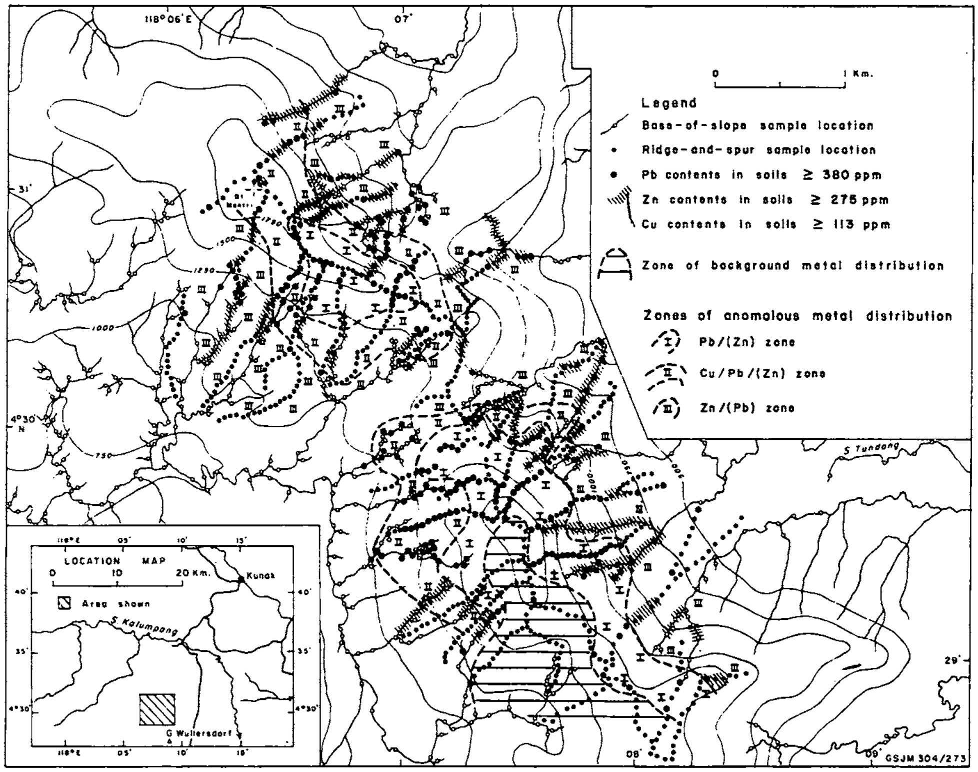

Fig. 3. Results of Geochemical Soil Survey Gunung Wullersdorf—Bukit Mantri Area.

(iv) detailed investigation and systematic sampling of the most promising mineral occurrences by means of a portable Winkie drill, and

(v) narrow-spaced grid soil sampling in the vicinity of outcropping mineralization.

The combined results of ridge-and-spur and base-of-slope sampling revealed the presence of two major zones of anomalous metal distribution in the survey area (fig. 3). The larger anomaly is predominantly related to volcaniclastic and argillaceous sedimentary sequences of the Kalumpang Formation, and occupies the central portion of the ridge which links Gunung Wullersdorf and Bukit Mantri. The second anomaly covers the southeastern portion of Bukit Mantri and is predominantly related to dacitic lava and pyroclastic rocks.. A common features of both anomalies is a conspicuous zonal distribution of the major elements. Zones of leak peak values extending over the ridge crest occupy the centre of the anomalies. They are surrounded by an inner halo of high copper, zinc and lead values and an outer halo with highly anomalous zinc.

Field observations on the composition of outcropping sulphide mineralization in the survey area suggest that the metal distribution patterns in the soils largely reflect the metal ratios of subjacent and adjacent base metals sulphide mineralization in the area (Markwich in Lim *et al.*, 1983). The extensive outer zinc halo is partly attributed to the effects of secondary dispersion.

The most common modes of occurrences of the sulphide mineralization in the area are:

(i) vein and fissure fillings intimately associated with quartz veins in a whole range of different host rocks of the Kalumpang Formation and the Gunung Wullersdorf-Bukit Mantri volcanic complex,

(ii) fine to coarse dissemination in dacitic lava associated with quartz fissuring and quartz fillings of vugs,

(iii) coarsely disseminated sulphide blebs in volcanic agglomerates and breccia containing abundant interstitial quartz.

Except for syngenetic or diagenetic pyrite generations ubiquitous in the felsic volcanics of the Wullersdorf-Mantri complex and in the dark shales of the Kalumpang Formation, all base metals sulphide mineralization observed so far must be considered as epigenetic (Lim *et al.*, 1983). Thus the initial concept of Kuroko—style mineralization was not confirmed. The essential features of the Pb-Zn-Cu sulphide mineralization in the Wullersdorf area are rather consistent with the concept of widespread, generally low-grade cross-cutting and fissure-filling stockwork mineralization (with transitions to dissemination) related to the waning stages of the Pliocene calc-alkaline felsic volcanism in the area (Markwich & Weber, in press).

The widespread and diffuse distribution of the mineralization, its partly disseminated nature, together with the well defined metal zoning observed in the area may however indicate the presence of deepseated porphyry copper mineralization whose outermost halo is exposed by the present relief (Markwich in Lim *et al.*, 1983).

Bidu-Bidu hills

Geological setting

The Bidu-Bidu Hills form a prominent mountain range in the Lower Labuk Valley of NE-Sabah covering an area of about 320 km² extent (fig. 1). They form one of several discrete ophiolite fragments located in a northwest to northnorthwest trending arc-shaped belt of discontinuous igneous and metamorphic rocks and Late Cretaceous to Neogene melange and broken formations which has been interpreted as an oroclinal structure providing continuity between the subduction complexes of northwest Borneo and of the Sulu Island Arc (Hamilton, 1979).

The Bidu-Bidu Ophiolite Complex forms an arcuate structure closing towards the southwest (fig. 4). Serpentinized ultrabasic rocks occupying the outer rim of the structure form the base of the ophiolite assemblage and are overlain by basic volcanic

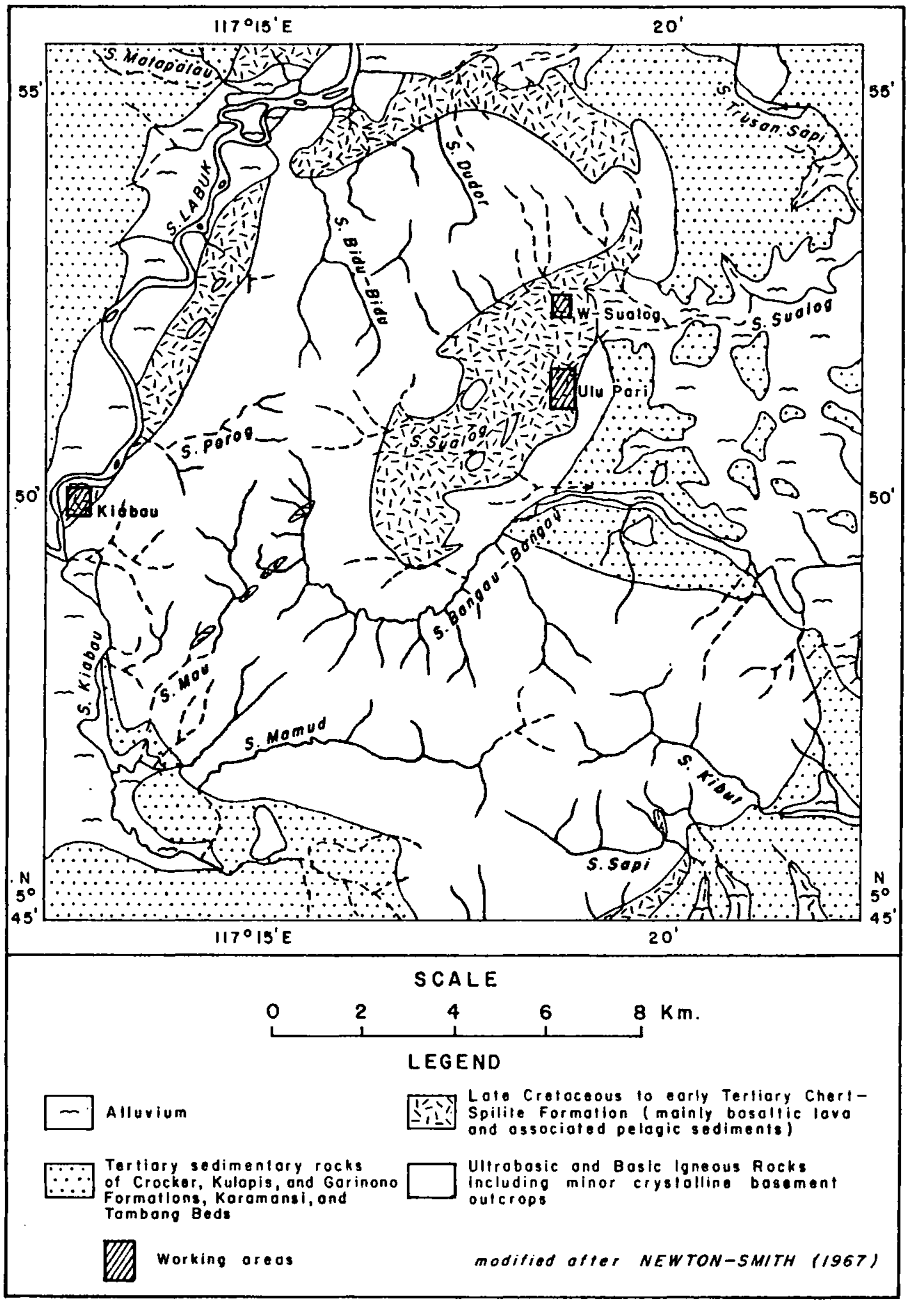

Fig. 4. Geological Sketch Map of the Bidu-Bidu Hills with Working Area Locations.

rocks and associated pelagic sediments. Rare gabbro outcrops apparently occur as infaulted blocks in the basic volcanic unit.

Arcuate zones of ultrabasic rocks extend from the main ultrabasic intrusion and almost completely surround a northeast trending zone occupied by a sequence of basic volcanic rocks with interlayered, finely banded shales forming the core of the arcuate structure.

Fitch, (1955, 1958) and Newton-Smith (1967) assigned these rocks to the Chert-Spilite Formation of late Cretaceous to early Tertiary age. The basic volcanics consist predominantly of intensely altered basaltic lava with abundant chlorite, epidote, secondary calcite and zeolites. As evidenced by the presence of pillow-structures, the lava is at least partly of submarine origin.

Results of earlier investigations

The United Nations Labuk Valley drainage survey conducted from 1963 to 1965 led to the discovery of a number of significant copper anomalies in three distinct areas of the Bidu-Bidu Hills: Bangau-Bangau Valley, Kiabau area and the Sualog Valley (fig. 4). Follow-up prospecting comprising ridge-and-spur and grid soil sampling, ground geophysical surveys, trenching, and pitting were carried out in the three areas leading to the following essential results.

Bangau Bangau Valley

The major copper anomalies in the Bangau Bangau Valley were found to be related to small, structurally controlled vein-type to lenticular pyrrhotite-chalcopyrite bodies in strongly sheared and brecciated serpentinite. The economic potential of the area was considered to be low and further investigation was not recommended (Woolf, 1965).

Kiabau

The combined results of geological, geochemical and geophysical surveys in this area were considered to be indicative of subeconomic vein-type and disseminated copper mineralisation in intensely sheared and brecciated ultrabasic rocks and at the contact between these rocks and spilitic lavas and microgabbros (Woolf, 1965; Winkler, 1966).

Sualog Valley

Geochemical follow-up prospecting work in the Sualog Valley resulted in several new findings of copper mineralization which were reported to be related:

(i) to zones of brecciation and faulting in basic volcanics (SW-Sualog),

(ii) to faulted contacts between spilitic lavas and pene-contemporaneous mudstone series (W-Sualog; Ulu Pari), and

(iii) to contacts between mudstone and brecciated serpentinite (NE-Sualog) (Woolf, 1965; Woolf *et al.,* 1966).

Electromagnetic and self-potential surveys covering areas of highly anomalous copper distribution in soils at West-Sualog led to the detection of two major EM anomalies correlative with substantial SP lows which were interpreted to represent subjacent sulphide mineralization of 30–50% sulphide contents closely related to fracture zones (Winkler, 1966).

Woolf (1965) on the basis of outcrop and trench information inferred a structural control of the mineralization and associated the latter with the gabbro intrusions in the area.

Present investigations

The re-assessment of pre-existing prospecting data from the Bidu-Bidu Hills area led to a new interpretation with respect to the significance of the known copper showings and the mineral prospects of the area (Lee & Weber, in press). The geological environment, the mode of occurrence, and the physical features of the sulphide mineralization observed in the area together with geochemical and geophysical evidence were found to be consistent with the model of Cyprus-type massive sulphide mineralization related to the pillow-lava stage (Chert-Spilite-Formation) in the Bidu-Bidu ophiolite assemblage. With this model type of mineralization in mind, diamond drilling in accordance with earlier proposals by Winkler (1966) was considered the best approach to test the type, grade, and "stratigraphic" position of the suspected mineralization below one of the major conductive trends in the West-Sualog area.

Diamond drilling using portable Winkie drill in late 1982 in fact confirmed the presence of massive cupriferous sulphide mineralization of Cyprus kinship. This was a major break-through. The discovery substantially enhanced the mineral prospects of all those areas where geochemical anomalies and indications of sulphide mineralization occur in close areal relationship with pillow-lavas and associated pelagic sediments of the Chert-Spilite-Formation and led to the selection of several target areas, for further investigation.

Follow-up investigations in 1982–1983, comprising extensive geophysical surveys, geochemical grid soil surveys combined with detailed geological mapping, and further drilling were essentially concentrated in the three most promising areas: West-Sualog, Kiabau and Ulu Pari (fig. 4). The following chapters give a summary of results obtained.

Results of drilling

Exploratory diamond drilling by portable Winkie drill in 1982–1983 was carried out in West-Sualog with drill locations sited along a north-south axis following the longitudinal extent of one of the major EM conductors.

The first two drill holes under a cover of deeply weathered and altered basic volcanic rocks penetrated an apparently continuous sequence of 52 m and 26 m respectively of massive sulphides. They bottomed in chloritized and partly silicified basic volcanics with quartz veining and cross-cutting sulphide mineralization. The third drill hole under 15 m of chocolate-brown, highly sheared silty shales continuously intersected massive sulphide mineralization down to a depth of 30 metres.

The textures and composition of the massive sulphides intersected in the drill holes or observed in surface exposures are extremely heterogeneous. The most common types of sulphides encountered are:

(i) dark grey to brownish, fine-grained, sooty and friable sulphide aggregates ("sandy ore"),

(ii) colloform, delicately banded, cavernous to compact "massive ore",

(iii) subangular lumps of cavernous to massive pyrite in a fine-grained sandy sulphide matrix ("brecciated ore"), and

(iv) fine-grained, dark bluish, sooty ore, rich in secondary copper sulphides and commonly confined to the upper zone of the sulphide body.

The sulphide mineralogy consists mainly of iron sulphides, predominantly pyrite. Chalcopyrite, bornite, covellite, and chalcocite are the main copper minerals observed. Abundant covellite, some bornite, and rare chalcocite produced by supergene processes occur predominantly in the upper zone of the sulphide body, giving rise to its dark bluish sooty appearance.

Assay results

Due to heterogeneous composition and generally high porosity of the massive sulphides together with the smaller diameter core barrel (EX) of the Winkie drill, core recovery within the mineralized sections never exceeded 30%. The assay results of core samples partly complemented by analytical results from sludge samples can therefore only give an approximate indication of the grade. Copper contents of continuous samples from splitted core runs of the first two drill holes in West-Sualog range from 1% to 26% and from 1% to 10% respectively. The highest copper contents of the first drill hole occur in the upper 10 m section of the sulphide body where supergene enrichment has raised the average grade to 18% Cu (15% Cu in sludge samples).

Zinc values in the core samples range from 200 to 9,000 ppm, cobalt contents from 600 to 9,000 ppm. Silver and gold values are highly variable ranging from 1.5 to 49 ppm Ag and from 0.5 to 18.5 ppm Au.

Geological setting of the sulphide mineralization

Exposures of massive sulphide mineralization have been found in the target areas of West-Sualog and Kiabau (fig. 4). Detailed geological mapping at both locations revealed their close areal relationship with outcrops of reddish to chocolate brown shales ranging in thickness from a few metres to several tens of metres and their association with highly altered, strikingly red-coloured lavas.

Although contacts are often obscured by fault gouges, evidence derived from outcrops and drill information suggests that the sulphide bodies are sandwiched between underlying volcanic rocks and overlying shale (Muff *et al.*, in press).

Disseminated pyrite mineralization, sulphide veinlets and stringers with quartz gangue were observed in lava outcrops in proximity to the massive sulphide bodies and at the bottom of one of the drill holes. These features are interpreted as an indication of stockwork type mineralization commonly underlying massive sulphide mineralization.

Results of geophysical surveys

During 1983 a total of 46 line kilometres of pulse-electromagnetic (PEM) measurements partly combined with dipole-dipole or gradient array IP measurements were carried out in West-Sualog, Kiabau, and Ulu Pari. In West-Sualog, the PEM survey confirmed the presence of two strong electromagnetic conductors and provided a more precise localization and better definition of their form, size, trend and quality. The sulphide bodies reflected by the PEM anomalies were defined as approximately N-S trending, steeply dipping "plates". The IP results suggest that the massive sulphides are laterally bordered by a zone of disseminated mineralization (Grissemann & Yan, in press).

At Kiabau and Ulu Pari the geophysical survey led to the detection of new electromagnetic conductors, again interpreted as steeply dipping plates with a longitudinal extent of 150 m and 400 m respectively. The PEM anomaly in the southern part of the Kiabau area has almost the same quality (conductivity-thickness) as the West-Sualog conductors, whereas the conductor in the northern part of the Ulu Pari area although still of good quality is significantly weaker (Grissemann *et al.,* 1984).

The new PEM anomalies were detected in rock sequences which were found characteristically associated with the massive sulphides in West-Sualog. Altered red basaltic lava with intercalations of brown shales occur at Kiabau while a sequence of brown shales with tuff beds close to the contact with altered and brecciated basalt at Ulu Pari.

The nature of both anomalies needs to be verified by drilling. Numerous gossan blocks and outcropping massive sulphide mineralization in the vicinity of the Kiabau anomaly however strongly suggest that as in West-Sualog, the PEM conductor reflects subjacent massive sulphides (Grissemann & Yan, in press). At Ulu Pari, due to the high conductivity of the rock sequence hosting the inferred conductor, the interpretation is less certain and additional PEM measurements with reduced transmitter—receiver coil spacing are required prior to drill investigation.

CONCLUSIONS

The joint Malaysian German mineral exploration programme was successful in detecting new geochemical anomalies and mineral occurrences in three main geological settings. Due to various constraints however, only the most promising copper/zinc anomalies related to the Bidu-Bidu Hills ophiolite assemblages were pursued to the exploratory drilling stage.

The investigation of massive sulphide mineralization at the West-Sualog prospect revealed a whole range of striking similarities with the synvolcanic cupriferous sulphide deposits described from Cyprus (Searle, 1972; Constantinou & Govett, 1973; Constantinou, 1980). Analogies are particularly conspicuous with respect to the regional geological association of the sulphide bodies, and the textural features and mineralogic composition of the sulphide bodies (Lee & Weber, in press, Muff *et al.*, in press)

The discovery of Cyprus-type cupriferous sulphide mineralization the orebodies of which tend to occur in clusters, and the occurrence of numerous geochemical anomalies, promising geophysical anomalies, and widespread indications of sulphide mineralization in outcrops and stream float lead to the conclusion, that the West-Sualog massive sulphides are probably not isolated and similar occurrences can be expected elsewhere in the Bidu-Bidu Hills where the depositional environment was favourable (Lee & Weber, in press).

Future prospecting work for massive sulphide deposits in the Bidu-Bidu Hills and perhaps elsewhere in Sabah where copper mineralization is known to occur in Chert-Spilite environment should first be guided by the ore-controlling parameters established at the West-Sualog prospect (Muff *et al.*, in press).

After the identification of geological indicators known to be typically associated with the massive sulphide mineralization, pulse-electromagnetic surveys would be the best exploration tool to define drilling targets.

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