DP/UN/BUR-72-002/9

BURMA

RESTRICTED

GEOLOGICAL SURVEY AND EXPLORATION

Project findings and recommendations

UNITED NATIONS

DP/UN/BUR-72-002/9

United Nations Development Programme

GEOLOGICAL SURVEY AND EXPLORATION

BURMA

Project findings and recommendations

Prepared for the Government of The Socialist Republic of the Union of Burma
by the United Nations
acting as executing agency for
the United Nations Development Programme

UNITED NATIONS
New York, 1978

Notes

Abbreviations used:

DGSE	-	Department of Geological Survey and Exploration
E.M.	-	Electromagnetic
I.P.	-	Induced polarization
ppm	-	parts per million

As of 1 February 1978, the rate of exchange was 7.11 Kyats to the US dollar.

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PREFACE

This report on the findings and recommendations of the project "Geological Survey and Exploration" in Burma covers the work of a team of Burmese and international experts under the direction of J.V. Huhta, United Nations Project Manager, and U Kyi Soe, Government Project Co-Director.

ABSTRACT

From January 1974 to June 1978 the Government of Burma, in co-operation with the United Nations and assisted by the UNDP, undertook a programme of regional geochemical exploration geologic mapping, follow-up investigation of anomalies, training and laboratory support fo the Department of Geological Survey and Mineral Exploration. More than 45,000 sq km were surveyed, 17 targets identified and investigated in detail and three prospects drilled to determine type and extent of copper mineralization. Geologic mapping led to major changes in an understanding of the structural geology of Burma. Two programmes of follow-up mineral exploration are recommended.

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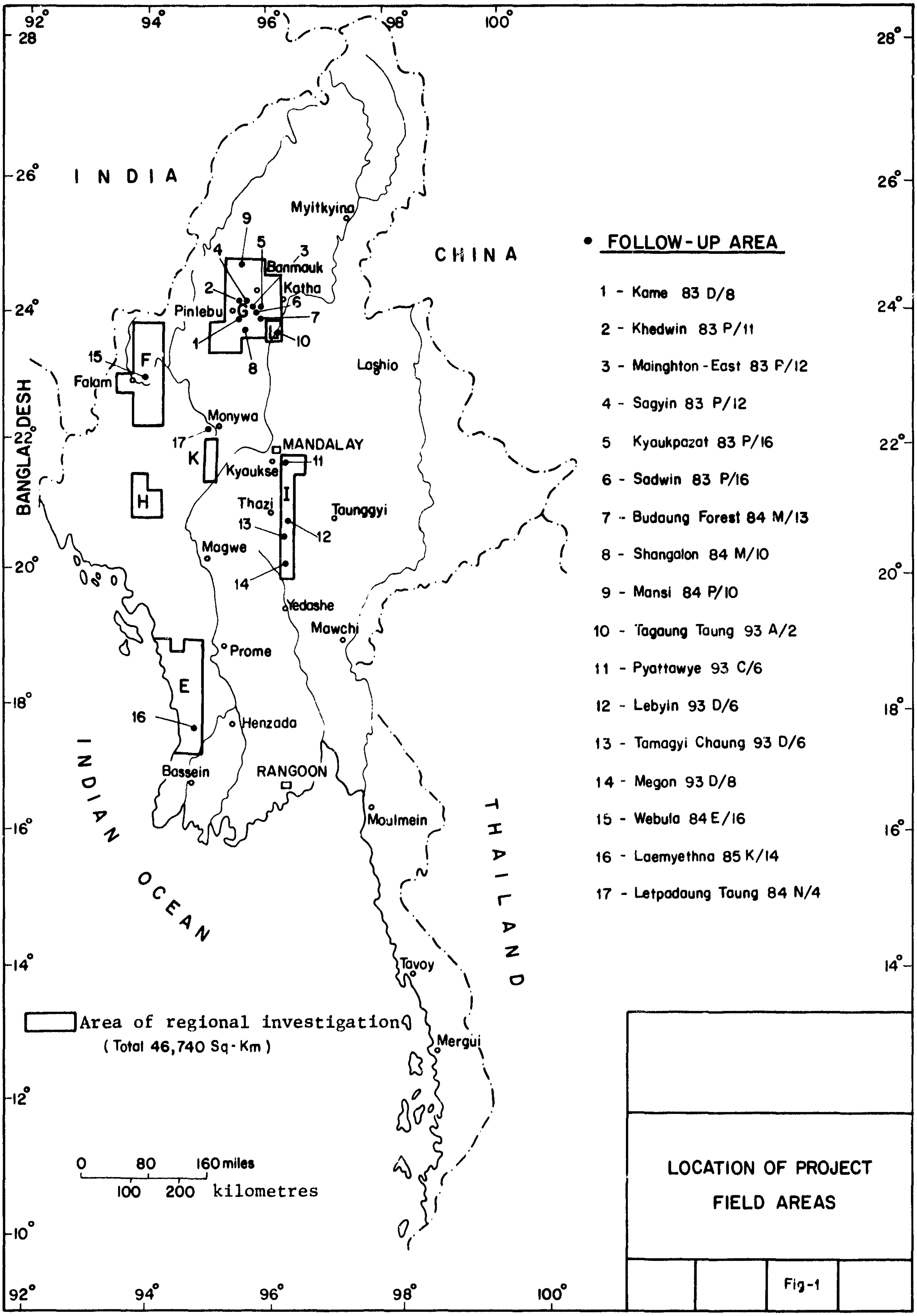
INDIA
CHINA
BANGLADESH
INDIAN OCEAN
THAILAND
Myitkyina
Banmauk
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Lashio
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Area of regional investigation
(Total 46,740 Sq-Km)
0 80 160 miles
100 200 kilometres
LOCATION OF PROJECT FIELD AREAS
Fig-1

INTRODUCTION

Project background

1. The Government of the Socialist Republic of the Union of Burma requested in June 1972 the assistance of the United Nations Development Programme (UNDP) to support the recently formed Directorate of Geological Survey and Exploration (DGSE), now the Department of Geological Survey and Mineral Exploration of the Ministry of Mines. Responsibility for geologic mapping and mineral exploration was transferred to the DGSE from the former Mineral Development Corporation. The UNDP assistance was needed owing to the shortage of experienced personnel, of expertise in various specialized fields, and almost complete lack of modern equipment and spare parts.

2. The request was approved by the Governing Council of the United Nations Development Programme in August 1973, the project document signed on 2 November 1973 and the project, entitled "Geological Survey and Exploration" (BUR-72-002) became operational in January 1974. Owing to delays in expert appointment and arrival of equipment the systematic field work started only in October 1974. A revised project document was approved in June 1975 to include additional activities for strengthening the laboratory and library facilities of the DGSE. The Project was originally planned for three and half years, but it was later extended to June 1978.

3. Before the field work started it became obvious that some major areas included in the original project document had insufficient security and substitutions were necessary. Unfortunately many of the new areas had much lower mineral potential than the original ones, for example the replacement of the Tenasserim Region by Chin Hills-Arakan Yoma.

4. In addition to the above activities the project was responsible for the geologic control and administration for the project"Pre-investment Drilling and Training" (BUR-72-001) which was completed on 31 December 1977. From 1 January 1978 the BUR-72-001 drilling programme at Letpadaung Taung and equipment were the responsibility of the present project.

Financial contributions

5. In the revised project document of 1 June 1975 the UNDP allocation was increased from $US 1,410,400 to $US 1,948,880; the Government contribution in cash was Kyats 1,729,000 and services in kind were estimated at Kyats 5,613,250. Owing to the financial crisis in 1976 the UNDP contribution was cut to $US 1,888,752 (as of April 1977). The United Nations acted as executing agency for the UNDP.

Objectives

Development objective

6. The development objective of the project was to increase the matallic mineral production of Burma, which had greatly declined; minerals were required not only for export to generate foreign exchange earnings, but also for domestic use to create new employment and provide raw material for existing or new industries. This objective was to be reached by assisting the co-operating agency DGSE in basic geologic mapping and modern exploration techniques, and training the Burmese staff in these aspects.

Immediate objective

7. The main objective, strengthening the Department's overall capability as a national geologic survey institute, was achieved through the following project activities:

(a) Introducing extensive regional geologic mapping and geochemical exploration which at the end of the project had covered 46,740 sq km of Burma;

(b) Carrying out integrated detailed investigations of 17 follow-up targets by utilizing all applicable modern exploration techniques such as geochemical methods, electric, magnetic and radioactive geophysical surveys, diamond drilling, chemical laboratory support and computer-based data handling and storage;

(c) Improving instrumentation, imparting the latest know-how in mineralogical, chemical and geochemical laboratory techniques, assisting in airborne geophysical surveys, and establishing a research library sufficient to support field studies.

Table 1 summarizes project activities through April 1978; the location of specific project areas is shown in figure 1.

Project documentation

8. The major activities of the project will be presented in six technical reports, one memorandum and one special report listed in Annex 1. Much data is stored in project progress reports, internal reports, technical memoranda, and field instructions prepared by the project staff and supported by a large number of maps, laboratory information and other illustrative material. This information and collected stream-sediment, rock and soil samples were deposited with the DGSE. The large amount of geochemical data were put into machine-readable form and are stored on magnetic tapes with the Universities Computer Centre in Rangoon.

Table 1. Summary of project activities (through April 1978)

Regional geologic mapping and geochemical reconnaissance		46,740	sq km
Stream sediments (number of samples)		19,380	
Petrographic examinations		425	
Age determinations:	K/Ar	16	
	Lead isotope	10	
	Paleontologic	42	
Follow-up targets		17	
Soil samples		5,560	
Topographic survey		289.2	line km
Geophysical survey:	I.P.	12,169	stations
	Resistivity	14,673	stations
	S.P.	5,741	stations
	Turam	4,704	stations
	Magnetic	11,937	stations
	Radiometric	12,138	stations
Samples analyzed, average 8 elements per sample (core samples included)		30,346	
Diamond drilling:	Letpadaung Taung	9,696.0 m (31,813 feet)	
	Shangalon	2,677.5 m (8,785 feet)	
	Lebyin	520.3 m (1,707 feet)	

I. PROJECT ACTIVITIES

A. Regional geochemical exploration

9. The purpose of regional geochemical sampling was to help decide which parts of a large investigated area had the best mineral potential and which parts could be eliminated as relatively unfavourable. The most promising areas were then surveyed in more detail to determine whether an intensive follow-up exploration programme was required. In only exceptional cases will a regional geochemical survey precisely locate specific mineralization; its main purpose is to indicate zones of higher mineral potential that should be covered by further exploration.

10. The geochemical sampling and geologic mapping, which was based on 1 inch to 1 mile (scale 1:63,360) topographic maps, were done simultaneously using the same field teams. The sampling density ranged from 0.4 to 0.8 samples per square kilometre in areas of interesting geology to one sample per seven square kilometres in areas of non-favourable geology or alluvial plains.

11. The fine-grained non-organic silt collected from mid-stream of creeks or from small islands in bigger streams or rivers was used as sampling material. This material is considered to give the best representative information of the upstream geochemistry. Float and bedrock geology, pH conditions and characteristics of collected material were noted in the field and the sites plotted on 1 inch to 1 mile scale topographic maps. The dried samples were sieved through 80-mesh and sent to Rangoon for routine analysis of copper, lead, zinc, silver and molybdenum. Additional elements were analyzed depending on geology and expected mineralization. The analytical results were presented and the anomalies outlined on the base maps of the same scale as the regional geology.

B. Regional geologic mapping

12. Simultaneous regional geologic mapping and geochemical exploration proved to be efficient and is recommended for use in other areas with similar logistics, physiographic and geologic conditions. The mapping, closely supervised by the Project Chief Geologist, was done by Burmese teams of two to four geologists per map sheet (700 sq km). A geologist was assigned responsibility in the field for geologic mapping of a given area; however, extensive amounts of mapping and geologic observations were done by other supervising and traverse geologists whose additional duty was to complete the geochemical sampling.

13. Photogeologic interpretation formed an important part of the geologic mapping although the regional photogeologic mapping programme was cancelled. The aerial photographs used by the Project were mainly on an approximate scale of 1:50,000 although in some selected areas 1:20,000-scale photographs were available. Stereoscopic photo-interpretation and compilation on the base maps was done by the project mapping geologists. Landsat images were commonly used to identify major features supporting the photogeologic mapping.

14. In the field the geology was mapped on a scale 1 inch to 1 mile but the final maps were drawn at scales of 1:100,000 or 1 inch to 4 miles (1:253,440) depending on the complexity of geology and intensity of mapping.

C. Follow-up investigations

15. The regional survey was followed by semi-detailed or detailed investigations of areas where geochemical anomalies, promising geology, previously known mineralization, mining or prospecting activities were found. The normal procedure in the semi-detailed survey was to collect additional stream sediment, base of slope, bank or random soil samples, and to elaborate geologic mapping. Only in exceptional cases were any geophysical methods used either in semi-detailed or regional work.

16. An integrated follow-up survey was next done in the areas where the results were still encouraging. In a normal sequence it included all or part of the combined methods described below. The programme was stopped at any level if the results wer not encouraging enough to justify further activity.

(a) Topographic mapping: The areas selected for follow-up studies were first topographically surveyed to prepare a base map sufficiently detailed for presentation of all exploration results. The survey was based on a grid line system: lines were normally cut 100-200 m apart; they were topographically surveyed and landmark features between the lines were either measured or estimated; air photographs were also used to support the mapping. The final maps were drawn on scales from 1:1,000 to 1:10,000 and results of different methods presented on identical base maps.

(b) Geologic mapping: In detailed investigations the geologic mapping formed the basis of an integrated programme that included geochemical and geophysical methods, and diamond drilling. It was done along the same grid lines as topographic and other surveys, but all outcrops in between were also mapped and their locations measured and estimated. Wherever applicable the mapping included: (i) lithology, (ii) structure, (iii) alteration and mineralization, (iv) possible oxidation, (v) leached capping geology and (vi) morphologic features. Residual and alluvial floats were also used to support the mapping. To illustrate interpretation as compared to actual observations all outcrops or observation points were marked on the geologic maps.

(c) Geochemical investigations: Normal soil was the most common sampling material in follow-up geochemistry, although heavy-mineral fractions, stream sediments, rocks, and bank crest or base-of-slope soils were occasionally used to support the standard soil sampling. In most cases, the soils were collected along the grid lines from a depth of about 15-30 cm, except in areas of contamination, where deeper sampling was used. The samples were analyzed either for the metals sought in each area or for some pathfinder elements if easier to analyze, or geochemically more suitable. The analytical data were statistically treated and different anomaly levels calculated and contoured on the maps. Trenches and pits were often sunk into selected anomaly peaks and systematically channel- or chip-sampled to try to locate the actual anomaly sources.

(d) Geophysical investigations: The project was well equipped with various kinds of modern geophysical instrumentation, and combined geophysical methods were used in most follow-up surveys.

Magnetic measurements and radiometric survey were used to differentiate rock types, and to define geologic contacts and tectonic lines in the areas of poor rock exposure. The radiometric method was also used to determine if any anomalies were due to potassic alteration in porphyry systems.

The electrical self-potential (S.P.) survey was performed as a prelude to an induced polarization (I.P.) survey which was used as the major method to detect sulphide mineralization. Simultaneous resistivity measurements helped in finding large conducting deposits or alteration zones, calculating thickness of residual soil cover and locating buried gravel deposits. Electromagnetic (E.M.) Turam surveys were carried out to detect highly conductive massive sulphide zones or veins.

(e) Diamond drilling: The original drilling capacity of the project was only two units; one Boyles BBS-15 (capacity 400 m) and one Winkie GW-15 (capacity 50 m). However, as this was not enough to complete the large shangalon drilling programme, an additional BBS-15 rig was obtained from the BUR-71-516 project. A new BBS-25 machine (capacity 700 m) was delivered to the project at the end of 1977 and was subsequently used at Letpadaung Taung together with the three Sprague and Henwood 142C machines, which were transferred to the project at the end of December 1977 from the project "Pre-investment Drilling and Training" (BUR-72-001).

After completion of the Shangalon drilling in May 1977, the BBS-15 machines were moved to stibnite mineralizations at Lebyin and the Winkie, equipped with a reduction gear, was sent to test gold-bearing gravel deposits at Mansi.

The six larger machines are equipped with the wireline system which was used throughout, except in Lebyin where conventional drilling was used owing to an extremely hard host rock of silicified breccia. Table 2 describes some drilling statistics of Letpadaung Taung for the year April 1977 through March 1978.

Table 2. Diamond drilling in Letpadaung Taung, April 1977 to March 1978

Drilling performance

	Drilling (feet)	Average per bit (feet)
Rotary	1269	80
NWL	6594	77
BWL	5463	68
AWL	3010 15,067	70
Reaming shells	-	180

	Drilling (feet)	Average per bit (feet)
Total drilling	16336	-
Total salaries and wages	$US 35,737	($US 1.00 = Kyats 7.11)
Fuel, oil and lubricants	$US 4,595	

D. Laboratory support, data handling and drafting

(a) Laboratory support

17. All analytical work was done by the geochemical laboratory of the DGSE. The laboratory was assisted by the project which provided equipment, laboratory supplies, chemicals, supervision, local training and fellowship studies abroad. The analyses were originally done in Rangoon but in October 1977 a second Atomic Absorption Spectrograph (AAS) laboratory was organized and equipped in Letpadaung Taung to handle the large number of core, rock and soil samples from the area.

18. Copper, lead, zinc, antimony, silver and gold determinations were carried out by atomic absorption, mercury by MAS-50 Mercury Analyser, molybdenum by colorimetric and arsenic by the Gutzeit colorimetric method. Selected samples were analyzed for 25 trace elements (Au, As, Mn, Sb, Ga, Cr, Ba, Ti, Ag, Nb, Mo, Y, Cd, Sc, Zr, Ni, La, Co, B, Pb, Sn, W, Bi, Be, and Cu) by using semi-quantitative spectrographic scanning.

19. The reliability of the analytical results was checked by both the DGSE Laboratory and a commercial laboratory abroad. Statistical analyses of duplicate determinations showed that the results are sufficiently accurate and the reproductibility of the analytical data is quite satisfactory for exploration purposes. The Petrological and Mineralogical Laboratories of the DGSE were used for thin section, polished section and mineralogical studies.

(b) Data handling and drafting

20. The geochemical data were treated statistically either by simple graphical methods or, in the case of regional geochemical surveys and when a large amount of soil analyses were involved, by more sophisticated computer treatment. In both cases the cumulative distribution of elements was calculated and plotted on logarithmic probability paper. The trace element distribution in areas of non-mineralized geology was assumed to be log-normal and yielded a straight-line plot. Any excess of anomalous values causes a positive skewness of the otherwise straight frequency line; this inflexion point was normally selected as a threshold and the anomaly steps were set according to standard deviations. The anomalous zones in regional survey, and contours on selected anomaly levels in detailed work, were plotted on final geochemical maps. All geochemical information was punched on IBM cards and stored on magnetic tape.

21. Geophysical field data were reduced in the field to a format suitable for interpretation, and presented as profiles, maps of isolines and electrical depth soundings. Interpretation of all data was done by standard methods, and some data were selected for a trial-and-error interpretation method. Results of interpretation (position, size and shape of anomaly sources) were plotted on the maps or profiles, together with combined data from more than one method, where useful. Drafting work was done by 4 draftsmen who were seconded to the project from the DGSE.

E. Training

22. Implementation of the followship component was unsatisfactory and fell much behind schedule. Out of the 128 allocated man-months only 59 were utilized, as of April 1978, and five study programmes were yet to start. The main reasons for the delay were; the Government's decision, after many programmes had already been arranged, not to accept university training courses but only "practical" ones; failures by the candidates to pass the exceptionally strict Australian language test; the inflexibility of rules and regulations to change programme, study country or schedule; and difficulties in finding suitable study courses in acceptable countries.

23. By contrast, the completed fellowship studies were successful. After finishing the courses the fellows returned to the DGSE, or to the project, and their contribution to the project, and their contribution to the project was of great importance and of high professional standard.

24. Local training continued throughout the project. During the monsoon seasons (June - October) the experts gave lectures and courses in various subjects of economic geology, geochemistry and geophysics. On-the-job training during field work was the most important part of the training. Emphasis was laid on teaching the national professional personnel to organize and execute with minimum supervision a full exploration sequence from regional geologic-geochemical survey to diamond drilling and ore-reserve calculations.

F. Assistance to the project "Pre-investment Drilling and Training" (BUR-72-001)

25. The original target areas which were allocated to the project "Pre-investment Drilling and Training" (BUR-72-001) were found to be unsuitable for various reasons, and the present project was, in early 1974, requested to study alternative areas for the drilling programme. Consequently it was found that the Letpadaung Taung (Monywa) porphyry copper prospect was the most suitable and the area was recommended and accepted by the Tripartite review in June 1974 as the only target for the proposed drilling project.

26. Before the project BUR-72-001 became

operational the present project performed geophysical and geochemical surveys in Letpadaung Taung to outline the proposed drilling area and prepare the drilling programme. At the same time the project supervised the camp building and took care of delivery and storage of arriving equipment.

27. After the drilling project ended at the end of December 1977 the present project took over operational and financial control of the Letpadaung Taung work. The technical details of the work are summarized later in this report.

II. MAIN RESULTS

A. Regional Geologic Mapping

28. Results of the regional geologic mapping over 46,740 sq km are described below. When combined with earlier information on the geology and Landsat and photo-interpretation by Project geologists, these results led to fundamental changes in the structural map and new concepts of metallogenesis in Burma. The structural belts defined as a result of this work are here summarized to provide a framework for understanding the geology and also the regional setting for some of the mineral deposits (figure 2).

1. Eastern Highlands

29. The Eastern Highlands (EH Belt of figure 2) comprise the Shan Plateau, Tenasserim Ranges and Mergui Shelf. In the Shan Plateau, Precambrian greywackes, from which minor placer gold deposits are derived, are overlain by local quartzite and silicic (acidic) volcanic rocks of Cambrian age which include the possibly stratiform volcanogenic lead-zinc-silver deposits of the Bawdwin Mine. Thick carbonates and shale, including small but numerous deposits of lead-zinc-barytes stratabound in limestone, pass up into shale, quartzite and carbonates. Thick Carboniferous to Lower Permian greywacke and pebbly mudstone described for the first time in Upper Burma, are the host rocks to all the later tin-bearing granites; they are overlain by the "Plateau Limestone". Late Mesozoic sediments including coal and volcanic rocks are preserved in the Shan Scarps thrust zone and lie unconformably on older rocks; they are overlain with a major unconformity by red conglomerate.

30. In the Mogok Belt along the Western margin of the Plateau, pre-Mesozoic rocks were metamorphosed to schist, banded gneiss, augen gneiss, quartzite and marble.

31. Granite in the eastern part of the Plateau is probably of Upper Triassic age, continuous with that containing tin, wolfram and fluorite in northern Thailand and the Main Range in Malaysia.

32. Along the western margin of the Highlands, granitic plutons intrude the metamorphic rocks and Carboniferous sediments to the east. Foliated plutons, restricted to the metamorphic belt, are mostly unmineralized. Tungsten and tin deposits are mostly associated with granite of Palaeocene age intruding Carboniferous host rocks; within the Project Area this granite is possibly genetically related to a major belt of eastward-directed thrusts in the Shan Scarps zone to the east. Minor alluvial gold is derived from diorite intruding the Jurassic rocks, and stibnite mineralization within Jurassic carbonaceous mudstone is possibly related to the same intrusions.

33. The Tenasserim Ranges and Mergui Shelf consist largely of Carboniferous to Lower Permian greywacke and mudstone, overlain by the 'Plateau Limestone' locally preserved in synclines. Tin and tungsten-bearing plutons are continuous with those of the western margin of the Plateau to north and peninsular Thailand to the south.

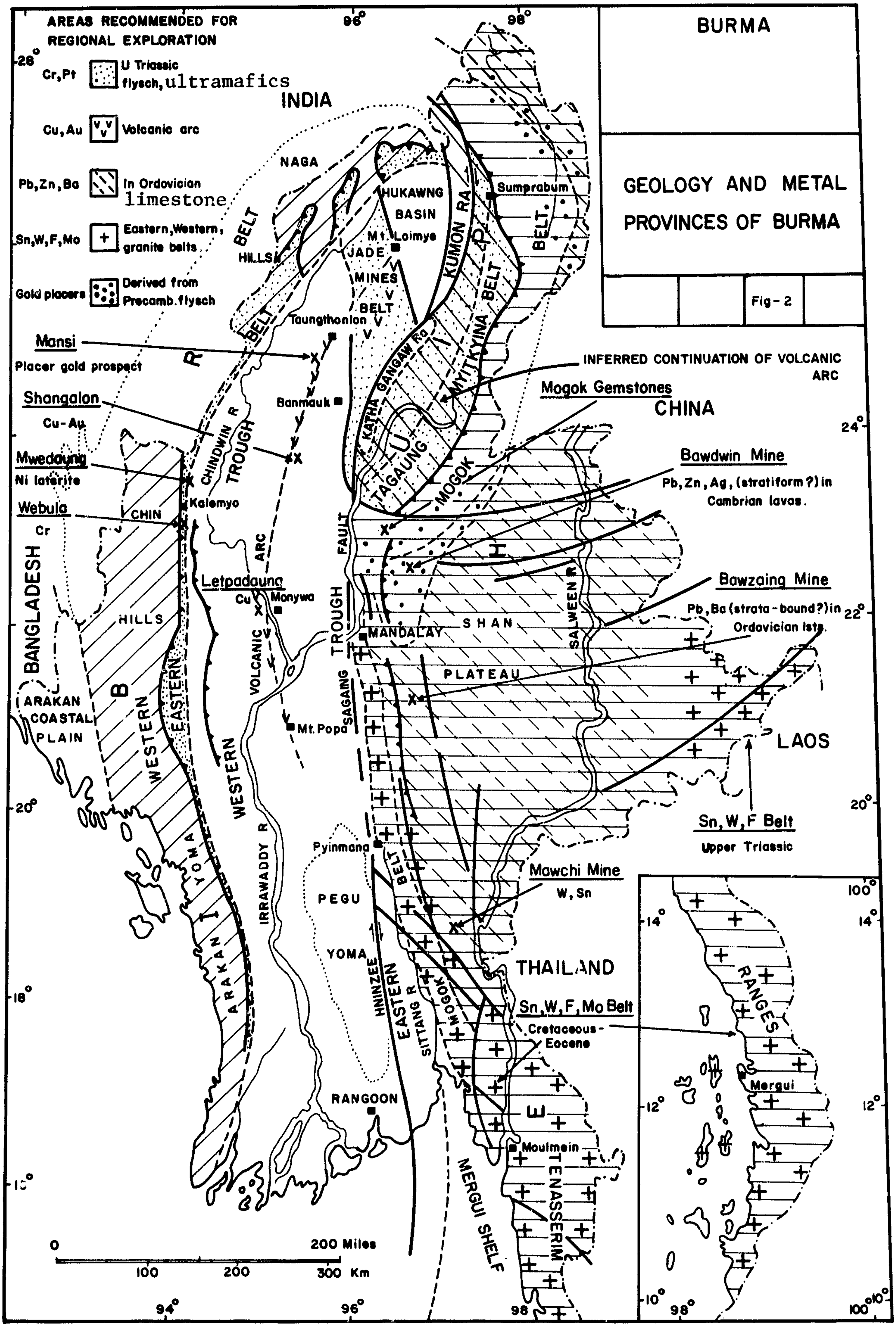
2. Central Lowlands

(a) Western and Eastern Troughs

34. The Western Trough consists of a synclinal succession of Upper Cretaceous to Eocene marine and non-marine locally coal-bearing sediments up to 10,000 m thick, overlain by a thick Oligocene to Pliocene succession in which the oil and gas fields occur. The younger sediments extend into the Eastern Trough as a non-marine succession.

(b) Volcanic Arc

35. The Volcanic Arc is defined by the Late Cenozoic volcanoes of Mt. Popa, the Monywa craters, and Taungtholon. Older volcanic and plutonic rocks are present at Mt. Loimye, in the Pinlebu-Banmauk area, near Monywa, and in the Salingyi-Shinmataung area. In the Pinlebu-Banmauk area sedimentary rocks are overlain by submarine andesite, local dacite and thick clastic sediments and intruded by a batholith of an early Late Cretaceous age. Overlying sediments are locally intruded by Oligocene plutons and overlain by the Oligocene to Miocene succession of the Western and Eastern Troughs. In the Salingyi-Shinmataung area, pillow lavas overlying buried metamorphic basement are intruded by mid-Cretaceous granite, diorite and gabbro. The mapping here and in the Pinlebu-Banmauk area clearly demonstrates for the first time the presence of a major volcanic arc in Burma



AREAS RECOMMENDED FOR REGIONAL EXPLORATION
Cr,Pt U Triassic flysch, ultramafics
Cu,Au Volcanic arc
Pb,Zn,Ba In Ordovician limestone
Sn,W,F,Mo Eastern, Western, granite belts
Gold placers Derived from Precamb. flysch
BURMA
GEOLOGY AND METAL PROVINCES OF BURMA
Fig-2
INDIA
NAGA
HILLS
BELT
HUKAWNG BASIN
Mt. Loimye
JADE MINES BELT
KUMON RA
MYITKYINA BELT
Sumprabum
Taungthonlon
Mansi
Placer gold prospect
INFERRED CONTINUATION OF VOLCANIC ARC
Mogok Gemstones
CHINA
Banmauk
Shangalon
Cu-Au
Mwedaung
Ni laterite
Webula
Cr
KATHA GANGAW Ra
TAGAUNG
MOGOK
CHINDWIN R
TROUGH
Kalemyo
CHIN
Bawdwin Mine
Pb, Zn, Ag, (stratiform?) in Cambrian lavas.
FAULT
ARC
BANGLADESH
Letpadaung
Cu
Monywa
Bawzaing Mine
Pb, Ba (strata-bound?) in Ordovician lsts.
MANDALAY
SHAN
PLATEAU
SALWEEN R
HILLS
ARAKAN COASTAL PLAIN
WESTERN
EASTERN
VOLCANIC
SAGAING
Mt. Popa
LAOS
Sn, W, F Belt
Upper Triassic
IRRAWADDY R
Pyinmana
PEGU
YOMA
Mawchi Mine
W, Sn
THAILAND
ARAKAN YOMA
HNINZEE
EASTERN
SITTANG R
MOGOK
BELT
Sn, W, F, Mo Belt
Cretaceous-Eocene
RANGES
Mergui
RANGOON
Moulmein
TENASSERIM
MERGUI SHELF
0 200 Miles
100 200 300 Km
94° 96° 98° 100° 28° 24° 22° 20° 18° 16° 14° 12° 10°

throughout the Cretaceous. Porphyry-type copper mineralization at Shangalon in the Pinlebu-Banmauk area is of probable Late Cretaceous age, appreciably older than the major porphyry deposits of Pliocene age at Monywa. Small placer gold deposits are derived from plutons of Mid-Cretaceous age and younger, and from Tertiary conglomerate. Boulders of jadeite are mined from conglomerate of late Tertiary age.

(c) Jade Mines Belt

36. This uplifted block comprises meta-sedimentary rocks with local glaucophane schist and jadeite dykes, overlain by mid-Cretaceous limestone with serpentinite sills and intruded by granitic rock. It continues southwards as a narrow structural belt east of the Pinlebu-Baumauk area, and northwards into the Naga Metamorphic Complex of the Indoburman Ranges.

(d) Hukawng Basin

37. The Hukawng Basin is the northernmost unit of the Central Lowlands; exposed rocks are 'molasse' sediments probably of Oligocene-Pliocene age overlying rocks of Late Cretaceous to Eocene age.

3. Indoburman Ranges

38. Project Mapping shows that the Indoburman Ranges (IBR BELT of figure 2) can be divided into an Eastern and Western Belt. The Eastern Belt comprises a thick turbidite succession of Late Triassic age locally metamorphosed to biotite schist and greenschist. The succession is tightly folded and includes a major east-facing nappe. In the east these rocks are overlain locally by pillow lavas; Mid-Cretaceous limestone lies unconformably on the Triassic rocks and pillow lavas and is itself overlain by the Western Trough succession.

39. The Western Belt comprises Upper Cretaceous to Eocene turbidite, mudstone and micritic limestone with major olistostromes and slumps with exotics derived from Triassic and younger rocks to the east. It mostly shows broad upright folds but in the western Arakan is isoclinally folded and repeated by thrusts. The mapping indicates that this belt is underlain by rock of Triassic age and perhaps older, and that contrary to numerous published speculations, the Indoburman Ranges do not include tectonically emplaced sediments of the Bengal Fan to the west.

4. Upper Irrawaddy Province

40. The Upper Irrawaddy Province (UIP BELT of figure 2) includes the Katha-Gangaw and Kumon Ranges and the Tagaung-Myitkyina Belt. The Katha-Gangaw Range consists of metamorphic rocks, mostly schist and interbedded quartzite with minor amphibolite, and showing structures indicating overthrusting to the east. The Kumon Range consists of Upper Cretaceous to Lower Tertiary clastic sediments. In the Tagaung-Myitkyina Belt meta-sedimentary rocks, overlain by mid-Cretaceous limestone with associated serpentinite sills, are intruded by plutons and probably overlain locally by volcanic rock.

5. Major faults

41. Keng Thrust; Mapping in the Indoburman Ranges (IBR BELT of figure 2) shows that a westward directed over-thrust forms the boundary between the Eastern and Western Belts of the Indoburman Ranges.

42. Thrusts in Western Trough: In the western part of the trough, mapping and photo-geologic interpretation indicates the presence of post-middle-Eocene westward-directed overthrusts distributed en echelon, probably with a component of strike-slip movement. These thrusts had not been recognized before despite numerous geologic investigations accompanying oil exploration.

43. Shan Scarps Thrusts and High-angle Faults; Mapping in the Shan Scarps, east of the Plateau margin, indicates a major zone of post-Early Cretaceous eastward-directed overthrusts forming an imbricate zone more than 150 km long. High-angle faults of probable Oligocene age cut the earlier Shan Scarps Thrusts. The high-angle faults possibly pass northwards into westward-directed overthrusts visible on Landsat imagery.

44. Hninzee-Sagaing Fault System: Landsat and geologic interpretation indicates that this is a major rise-thrust intracontinental fault system with at least 300 km of post-Oligocene right-lateral movement. The Hninzee-Sagaing Fault continues northward as the Mogaung Fault.

6. Regional implications

45. A major, not previously recognized, Late Triassic to Early Jurassic orogenic event occurred in Burma. The large ultramafic bodies and associated chromite and jadeite deposits are probably of this age, although mid-Cretaceous serpentinite sills are also present. The earliest metamorphism in and west of the Mogok Belt probably took place during the Early Jurassic, with later metamorphism within the Belt during the early Tertiary.

46. The pre-Miocene rocks of the Volcanic Arc of the Central Lowlands are offset at least 300 km along the Hninzee-Sagaing Fault. Their offset northward continuation beyond Mt. Loimye probably extends through the Tagaung-Myitkyina Belt, which should contain rocks favourable for porphyry copper, gold, and pyritic stratiform sulphide mineralization.

47. The structural belts defined above can

readily be interpreted in a plate tectonic framework, aiding understanding of the revolution of the politically inaccessible Eastern Himalayas and much of western Southeast Asia, and resulting in significant modifications to structural and metallogenic maps of the region.

48. The mapping results in selected areas of the Chin and Arakan Hills emphasize the extremely low mineral potential of the entire Indoburman Ranges. The Ranges together with the Western Trough and Pegu Yomas, offer little prospect of economic mineralization other than petroleum and coal.

B. Regional geochemical exploration

49. The geochemical reconnaissance was carried out simultaneously with the regional geologic mapping. The geochemical results were useful not only in locating anomalous patterns but also in supporting the geologic mapping in the areas of few outcrops and assisting in outlining differnet metallogenic zones.

50. The reconnaissance survey resulted in finding 13 significant anomalies including those caused by known mineralization. Ten of these anomalies were selected for further work and later studied by the project team. Additionally , the regional sampling revealed large areas of exceptionally low background values; these areas are considered to have no practical mineral potential and thus can be omitted from future exploration activities (large areas of Arakan Yoma, Salinbyi-Shinmataung and Chin Hills, for example). The multi-element analyses of collected samples (up to 8 elements were analyzed) helped to predict mineral combinations expected in the anomalous areas and to plan effectively the detailed exploration.

51. The anomalous areas detected by the project geochemical reconnaissance survey and the geologic evidence are listed below:

1. Pinlebu-Banmauk area (14,700 sq km, 7,200 stream-sediment samples)

(a) Kame (No: 1, copper anomaly); weak rock alteration and pyritization, in diorite and dacite, and placer gold.

(b) Mainghton-East Area (No: 3, copper anomaly); pyritization in and around granodiorite intrusions; rare copper staining.

(c) Sagyin (No: 4, lead-zinc-arsenic anomaly); cerussite veinlets and quartz-veins with sporadic sulphides in the vicinity of salt springs;

(d) Budaung Forest (No: 7, copper, nickel anomaly); ultramafic and volcanic rock in areas of otherwise sedimentary lithology.

These four anomalies (a, b, c and d) were chosen for follow-up work. (Technical Report No: 6).

(e) Shangalon Prospect (No: 8, copper-molybdenum anomaly); the most distinctive regional copper anomaly extending over about 130 sq km. Regional copper threshold for igneous environment set at 90 ppm was exceeded in Shangalon by 39 values. Geologic evidence included; hydrothermal alteration, sulphide showings, (pyrite, chalcopyrite, molybdenite), malachite, copper sulphate staining and placer gold. (Technical Report No: 1).

2. Shan Scarps area (6,250 sq km, 3,000 stream-sediment samples)

(a) Pyittawye (No: 11, lead anomaly); sulphide bearing (galena, tennantite) barite veins in Ordovician limestone, a favourable host rock for lead sulphides.

(b) Sabetaung (Map 93C/6, copper anomaly); quartz veins with tetrahedrite in Middle Ordovician limestone. Old underground excavation and diamond drilling.

(c) Myinbyan (Map 93C/10, lead anomaly); galena veins in biotite-garnet-schist. Old small-scale mine.

(d) Lebyin (No: 12, antimony anomaly); stibnite veins and dissemination in brecciated and silicified zone at a limestone-mudstone contact. Tribute mining district.

(e) Tamagyi Chaung (No: 13, lead anomaly); quartz-galena vein in gneissose schist, close to granite contact.

(f) Megon (No: 14, tungsten-tin-molybdenum-lead anomaly); quartz veins with wolframite and molybdenite at the contact zone of granite and meta-sediments. Tribute mining district.

Four of the anomalous zones (a, d, e and f) were selected for follow-up studies (Technical Report No: 6). In addition, a few minor anomalies without supporting geologic evidence were found in the area, and should be studied in future. They are: Chaungbya (Map Sheet 93D/7, lead), Letnge Sakan (93 D/7, tungsten), Myo Gyi (93C/7, copper in contact skarn). Only a weak lead anomaly was found at Paungdaw 93D/6, where the DGSE was carrying out diamond drilling.

3. Salingyi-Shinmataung area (1,990 sq km, 691 stream-sediment samples)

Stream-sediment reconnaissance survey carried out in Salingyi-Shinmataung area did not yield significant anomalies. Low copper, lead and zinc values predominate throughout the area. The few values exceeding threshold are either isolated or caused by lithologic units of the Salingyi Complex.

4. Chin Hills area (9,100 sq km, 1,275 stream-sediment samples)

Low sampling density was selected owing to the predominantly uniform flysch type of sedimentary environment which is considered to have a very low mineral potential.

The only anomalous values were of nickel and chromium which are caused by peridotite/serpentinite bodies in the eastern slopes of the Chin Hills (Webula massive No: 15). A prominent nickel anomaly also coincides with the previously investigated Mwe Taung garnierite deposit (Sheet 84I/3), where a diamond drilling programme was completed by the DGSE.

5. Southern Chin Hills (3,500 sq km, 582 stream-sediment samples)

No significant geochemical anomalies were delineated but the work continued(as of April 1978) and many of the samples collected during the subsequent field season remained to be analyzed.

The previously known Sidoktaya mineralization was visited by the project geologists who concluded that it has no economic importance.

6. Arakan Yoma (11,200 sq km, 2,800 stream-sediment samples)

The only significant anomaly in Arakan Yoma was a copper anomaly downstream from the known Lemyethna (No: 16) copper-bearing pyrite occurrence. The mineralization is located in a bottom part of a brecciated zone between basalt and flysch sediment.

High nickel and copper values elsewhere in Arakan Yoma represent only high background level of small ultramafic pods and scattered pockets of chromite.

C. Follow-up investigations

52. Detailed investigations by the Project involved altogether 17 targets, out of which 10 were selected mainly on geochemical bases and the remaining ones on geologic evidence or grounds of previous mining or prospecting activities. None of the prospects in which work was completed were found to be economic, but the up-to-date results of incomplete drilling at Letpadaung Taung were promising and work continued also in Lebyin, Mansi and Pyittawye areas (as of April 1978).

53. The Technical Reports No: 1 (Shangalon and Surroundings), No: 6 (Mineral Exploration in Selected Areas) and a special memorandum (Letpadaung Taung Copper Prospect) describe the project follow-up work in detail, for which reason the main results of these activities are only briefly described here. Recommendations concerning future work are given at the end of each target description.

1. Pinlebu-Banmauk area (G-area)

(a) Kame (No: 1)

54. Weak copper anomalies, pyritization, altered igneous and volcanic rocks and extensive placer gold workings were described here during the regional reconnaissance. These and the location along the geologic strike from the Shangalon mineralization indicated the possibility of similar kind of mineralization, especially because porphyry copper ones are known to occur in groups.

55. Consequently, detailed geologic and alteration mapping and stream sediment sampling of slightly over 100 sq km were carried out. The collected samples were analyzed for copper, lead, zinc, silver and molybdenum.

56. The only visible mineralization is pyritization in the middle part of the area, and a narrow quartz vein within the zone containing some oxidized copper sulphides. Placer workings are widespread and seem to be related to the igneous rock sources, particularly around altered dacite, adamellite and granodiorite contact zones.

57. The detailed mapping did not indicate any porphyry type of mineralization, characteristic hydrothermal alteration nor intensive fracturing. In addition, the few discovered geochemical anomalies were only of low intensity, limited in area and scattered. Consequently no further work is recommended in the Kame area.

(b) Khedwin (No: 2)

58. The previously known small copper showings did not cause any regional geochemical anomalies but were included in the project follow-up programme.

59. The only evidence of mineralization is a 10-cm wide chalcopyrite-bearing quartz vein in a weakly altered andesite exposure. Some disseminated sulphides close to the vein were observed in the host rock.

60. No more evidence of mineralization was found although the rocks in the area are fairly well exposed. The geochemical results showed no significant anomalous pattern. The mineralization is clearly non-economic and no more work is recommended.

(c) Mainghton-East (No: 3)

61. The Mainghton-East area was selected for

detailed study because of promising geology and anomalous copper values in stream sediments. The work included systematic base-of-slope soil sampling, detailed sediment sampling and geologic mapping on the scale of one inch to 1/2 mile (1:31,680). The mineralization is situated in one of the most rugged parts of the Pinlebu-Banmauk area where the average slope exceeds 1,250 feet per mile.

62. The lithology comprises silicic quartz-felspar porphyry and andesite intruded by stocks of granodiorite and diorite. Locally enriched disseminated pyrite is associated mainly with the intrusives although some insignificant massive pyrite veins occur in dacite at the northern part of the area.

63. The only alteration mapped in the area is minor silicification of pyritized dacite close to its intrusive contacts. The collected stream sediments and base-of-slope samples were analyzed for copper, lead, zinc, silver, molybdenum and arsenic. The fairly large anomalous area is clearly related to the well-exposed intrusive stocks and pyrite mineralization.

64. Although the follow-up survey confirmed the presence of sulphide mineralization (pyrite and scarce chalcopyrite) and the geology has some similarities with the Shangalon area, the mineralization, alteration and fracturing are less developed and the mineralization is non-economic.

(d) Sagyin (No: 4)

65. Scattered high lead and zinc anomalies and many mineral springs of chloride, sulphate, carbonate, arsenate and other brines were discovered during the regional survey.

66. Most of the Sagyin area is underlain by granodiorite with small diorite plutons in it. Dacite and andesite dykes and northeasterly trending quartz veins are widespread. The mineral springs are believed to be controlled by numerous deep-seated faults, but the origin of the brine is unknown and would be an interesting research problem.

67. Follow-up work by the project involved additional geologic mapping and collecting stream sediments over an area of about 35 sq km. The samples were analyzed for copper, lead, zinc and arsenic and semi-quantitatively scanned for 25 other elements.

68. No sulphide mineralization was found and the association between high lead, zinc and arsenic values in stream sediments and the mineral-spring activity is evident. It is supported by the observation that veinlets of cerrusite and occasional arsenates are found only in the vicinity of the springs. These veinlets are of no economic potential and only a research study to identify the source of the brines is considered worthwhile.

(e) Kyaukpazat (No: 5)

69. The original ore shoot, a gold containing chalcopyrite, pyrite and galena-bearing quartz-calcite veining, is considered to be related to a nearby diorite stock at the fault-controlled contact zone between andesite and a schistose and slaty formation. The underground working, operated from 1897 to 1903 by a German enterprise, is reported to have produced more than 200 kg of gold; operations ceased when the reserves were exhausted.

70. The project work at Kyaukpazat included: (i) detailed mapping of lithology, alteration and old workings, (ii) systematic geochemical channel- and chip-sampling, (iii) opening and sampling of the old galley, and (iv) digging and sampling several new pits and trenches. A few samples of remnants of sulphide-bearing quartz-calcite vein, collected from the pillars and walls of the old gallery, were the only ones to contain economic grade of gold but they do not represent minable ore reserves. Furthermore, the surrounding geology does not indicate mineralization, and the silicified and pyritized fracture zones close to the old mine were barren. Neither were high gold values found in numerous samples collected from the trenches and pits in the vicinity of the old gallery. Consequently no further exploration is recommended at present.

(f) Sadwin (No: 6)

71. The aims of the project activities were to study the known gold mineralization and to find its possible extension and to locate new occurrences in the vicinity. The Sadwin area had been intensively worked for placer gold deposits mainly at the turn of the century. The follow-up investigations included detailed geologic mapping and geochemical sediment sampling [illegible] sq km on scale 1:25,000, trenching and sel[illegible]ntial, magnetic and radiometric surveys over the known mineralization. Rock chips and channel samples were collected from all exposed quartz veins and trenches. The sediments were analyzed for copper, lead, zinc, silver, nickel, cobalt and the rock samples additionally for gold.

72. Most of the area is covered by a granodiorite pluton and only minor parts by andesite. The mineralization is formed by two groupings of pyriterich quartz veins, both within the granodiorite complex. One of the 15 analysed veins showed higher gold values, but trenching and geophysical survey confirmed its limited extension. The top part of this vein had been previously worked by the villagers, but it is possible that the gold, which was extracted only from the soft weathered part, was enriched by the

so-called "wind gap" effect, which concentrates placer gold into saddle parts of ridges. It is concluded that no additional work is justified at Sadwin area.

(g) Budaung Forest (No: 7)

73. Anomalous copper and nickel values were discovered during the regional exploration at the eastern edge of the Pinlebu-Banmauk area. It was therefore decided to extend the regional survey eastward (total extension 350 sq km) and study in detail an area of 60 sq km around the original anomalies at Budaung Forest. The work involved detailed geologic mapping and sediment sampling.

74. The lithology consists mainly of an older sedimentary unit with sills of serpentinite and basalt and a younger one with clastic sediments. They are flanked in the east by a discontinuous belt of limestone and schist.

(h) Shangalon and surroundings (No: 8)

75. Technical Report No: 1 (Geological Mineralization of the Shangalon Copper Prospect and Surroundings) describes in detail the large-scale integrated exploration in the area and its results. Hence only the main points are summarized here.

76. The work, carried out between January 1975 and May 1977, involved geologic mapping, combined geo-electric, magnetic and radiometric surveys and geochemical soil sampling covering an area of more than 20 sq km. Diamond drilling involved 33 holes totalling 8,785 feet (2,700 m).

77. Further geologic mapping, sediment sampling over 260 sq km surrounding Shangalon and electric, magnetic and radioactive surveys extending 15 km southward from it was also carried out to check if other mineralization was present in the vicinity.

78. Seven major zones of alteration and mineralization were delineated at Shangalon proper. The most promising zones were drilled but found to contain only sub-economic grade of copper. In addition, smaller higher-grade vein-type showings were tested for possible small reserves, but the results were not encouraging.

79. Estimates based on final drilling results indicate that a maximum of 9 million tons of ore containing 0.23 per cent copper, a trace of molybdenum and approximately 0.17 grams per ton of gold exists in Shangalon. The short high-grade sections intersected in several drill holes show no continuity and are economically insignificant.

80. The extensive exploration in the surrounding areas disclosed no geochemical, geophysical or geologic evidence of economic mineralization. Shangalon and the surroundings area are clearly non-economic even in the near future and no further work is recommended.

2. <u>G-area extension</u>

(a) Tagaung Taung (No: 10)

81. The Tagaung Taung area totalling 285 sq km was known to contain some nickel silicate (garnierite) deposits, chromite mineralization and showings of manganese and copper. It was studied in February-May 1976, when detailed geologic mapping (partly at a scale 1:2,000) and geochemical sediment, soil and rock-ship sampling were performed. The whole topographic sheet area (93A/2) was regionally mapped and geochemically surveyed during the 1977/78 field season. (Appendix to the Technical Report No: 2, under preparation as of April 1978.)

82. One large and two smaller circular ultramafic massifs of dunite, harzburgite, pyroxenite and serpentinite occur in the central part of the area. They are bordered by schist to the east and south-east, gritty sandstone to the north and younger pebbly sandstone and alluvium elsewhere. Coloured cherts (partly "gossanous") south-east of the schist complex are overlain by calcareous sandstone and younger sediments.

83. The area was previously studied by a Yugoslavian team, private consultants and by a DGSE team; the DGSE concentrated their work mainly on manganese showings.

84. Nickel silicates occur exclusively in the ultramafic massif, the only significant deposit being at Innet Lake where it forms a supergene alteration zone about 150 m by 350 m in areal extent.

85. Outcrops of chromite are restricted to small and scattered occurrences although compact chromite bolders are fairly common on the north-eastern slopes of the massif. No economic concentration of alluvial deposits are expected primarily because of dilution by the nearby Irrawaddy River alluvium.

86. Minor manganese mineralization as veins in chert had previously been reported in the area. Detailed geologic mapping and geochemical results of the project work proved that the manganese mineralization is isolated and has no economic extension.

87. Copper mineralization in float had previously been observed in a few creeks. The mineralization was traced to quartz veinlets or small quartz lenses in greenschist at the contact with chert where it forms a narrow and dis-continuous belt about 4 km long.

88. The average sampling density was 1.62 sediment samples per sq km, but the areas of special interest were sampled in more detail. The Innet Taung ni ˙el deposit was covered by systematic soil sampling.

89. The ultramafics, schist and cherts are mostly well exposed and the geologic mapping on scale 1:20,000 is considered sufficiently informative. The areas of geochemical anomaly and those surrounding known mineralization were mapped in detail and many rock-chip samples were collected and analyzed in support of the mapping.

90. Evaluation of the results indicates that the chromium and manganese mineralization in the area is only scattered and of no economic significance.

91. Geologic and geochemical evidence suggests that the scattered copper-bearing veinlets in greenschist do not form any concentration of economic interest. However, attention should be paid in future mapping to the area northeast of the greenschist-chert contact zone which may be favourable for copper sulphides.

92. The garnierite mineralization at Innet Taung is estimated to have reserves no more than 4 million tons containing between 0.6 and 2.0 per cent nickel. The formation is presently non-economic and no further exploration is justified.

(b) Mansi (No: 9)

93. The gold-bearing gravel deposits at Mansi are overlain by as much as 30 feet of thick alluvial sand and clay. They have been worked by local villagers for many generations, but production has been low owing to primitive working methods and low gold content.

94. The area was selected for detailed alluvial exploration because the geomorphology and topography of the Chaunggyi valley are considered favourable for large-volume gravel deposits. The work plan for the first field season, 1977/78, was not to determine the actual gold content but rather to find the source of the gold-bearing gravel and to outline the gravel reserves as to whether they would justify mechanized operations. Detailed geologic mapping, electronic depth sounding and auger drilling (3-inch diameter) were begun. In addition, all available information from the old workings and pits (some as deep as 50 feet) was recorded.

95. The geologic mapping, which continued as of April 1978, showed that the scarp-forming conglomerates to the west are the source of the gold; it suggests that at least two cycles of concentration have been involved.

96. Preliminary information, supported by approximately 25 auger holes and 12 electronic depth soundings, suggest that although the gravel beds are locally up to 18 feet thick, they do not form a large continuous blanket but are concentrated in two separate areas.

97. Estimates of gravel reserves were not available pending completion of auger drilling but the information available indicates that the reserves are of limited extent. It was tentatively concluded that mechanized water monitoring or dredging would be economic only if the gold grade were much higher than now predicted.

98. It is recommended (April 1978) that gold content be checked during the next field season, by sinking pits and drilling 8-inch auger holes, to obtain sufficient representative gravel to determine the grade. This work should be done only if the final results of drilling have proven that sufficient gravel is present.

3. Shan Scarps (I-area)

(a) Pyattawye (No: 11)

99. The Pyattawye area, underlain by Middle Ordovician limestone, was known to contain barytes veins and some sporadic galena, tetrahedrite and tennantite mineralization. Widespread lead anomalies were discovered during the regional reconnaissance and they were investigated by a brief follow-up survey in 1976/77. It involved detailed geologic mapping and sediment sampling of about 60 sq km; the sampling density was 4.1 samples per sq km. All samples were analyzed for lead, zinc, copper, silver, cobalt, barium, arsenic, antimony and molybdenum. The results showed that the known barytes veins coincide with higher lead, arsenic and copper values, and also resulted in discovery of two new significant lead anomalies.

100. The follow-up phase which still continued as of April 1978 involved soil sampling and detailed geologic mapping of these two anomalies. Recommendations for future work are presented in Technical Report No: 6.

(b) Lebyin area (No: 12)

101. The Lebyin area is an old mining district where copper and placer gold has been mined in the past and small-scale tribute mining of stibnite continues.

102. Three different kinds of mineralization were recognized in the area. They are: (i) copper sulphide bearing contact veins or replacement bodies, (ii) stibnite veins, small lenses and minor dissemination in silicified rock and (iii) barytes veins containing some galena. The practically exhausted placer gold deposits and the copper sulphide mineralization were associated with a diorite stock. The lead-bearing barytes are insignificant in both size and grade.

103. The first phase of follow-up activities included detailed sediment sampling of 114 sq km. The sampling density in the areas of more interest was up to 5 samples per sq km and the samples were analyzed for copper, lead, zinc, silver, antimony, arsenic, mercury, molybdenum, tungsten and tin.

104. The last phase which was still continuing as of April 1978 covered the area of possible stibnite mineralization and involves detailed geologic mapping on 1:2,500 scale, geophysical Turam survey, deep geochemical soil sampling, bulldozer trenching and diamond drilling of known stibnite occurrences. Nine holes totalling some 1,700 feet had been completed by April 1978. The results indicate that the stibnite mineralization is scattered and no reserves sufficient for modern mining techniques have been proved. However, some areas remained to be drilled, and work continued.

(c) Tamagyi Chaung (No: 13)

105. The strong lead anomalies discovered during the regional reconnaissance were briefly studied. The anomaly, limited to the Tamagyi drainage, is close to a calc-silicate and schist-gneiss contact zone geologically similar to the Phaungdaw mineralization about 15 km to the north.

106. The project work involved further sediment sampling of about 50 sq km (3.2 samples per sq km), detailed bank-and-ridge soil sampling and geologic mapping. Only one insignificant galena-bearing vein in situ and a few boulders containing galena were found, but the results were inconclusive. A geophysical survey (Turam EM) in the vicinity of the galena-bearing vein is, therefore, recommended.

(d) Megon (No: 14)

107. The area of the follow-up survey includes the Megon Mine where small-scale tribute mining for wolframite is still practised. The mineralization, mainly wolframite with sporadic concentrations of molybdenite, occurs as four parallel quartz veins which intrude the biotite granite of the tin-tungsten province of Burma.

108. Stream-sediment sampling, heavy-mineral panning and geologic mapping involved an area of more than 50 sq km; the sampling density reached 1.5 samples per sq km. All samples were analyzed for copper, lead, zinc, silver, tungsten, molybdenum, arsenic, boron, beryllium, tin, niobium and manganese.

109. The investigations suggest that no other sizeable tungsten deposits occur in the area covered by the programme. Nevertheless, the Megon mineralization belongs to a prominent tungsten belt which should be surveyed in detail when security conditions allow.

4. Chin Hills (E-area)

(a) Webula Massif (No: 15)

110. The regional survey revealed strong nickel, chromium and sporadic copper anomalies around the ultramafic Webula massif. Geologic mapping of 120 sq km was first completed on a scale of 1:10,000; followed by a base-of-slope and grid soil sampling and 1:2,000 scale geologic mapping of areas of special interest.

111. The geomorphological conditions in Webula are not favourable for formation of nickel silicate or laterite deposits, and the well-exposed and scattered chromite occurrences are too small to be of economic interest. The high copper values are associated with the chromite mineralization and do not represent any copper mineralization. No further work is recommended.

5. Arakan Yoma (E-area)

(a) Lemyethna (No: 16)

112. Only a brief follow-up visit was paid to the previously known mineralization at Lemyethna. The combined geologic observations and limited extension of stream-sediment anomalies confirmed earlier conclusions of a small occurrence in a strongly brecciated zone of basalt and conglomerate associated with flysch. The approximately 3-foot-thick lens-like massive pyrite mineralization locally contains green copper oxides and chalcanthite. It is exposed only in the bottom of a steep and narrow stream valley.

113. Further exploration is recommended and should include grid-based detailed geologic mapping, geophysical I.P., Turam and magnetic surveys, and soil sampling on a scale 1:5,000. (The area was included in the 1977/78 field programme but was cancelled because of lack of time and logistic difficulties.)

6. Letpadaung Taung (No: 17), Monywa

114. The Project gave geologic support and administrative assistance to the project "Pre-investment Drilling and Training" (BUR-72-001) until 31 December 1977 and assumed full control of its operations in Letpadaung Taung from that date. Details of these activities and geology of the mineralization will be described in a special memorandum which includes Dr. Sillitoe's report (1977) as an annex. Only the salient points are mentioned here.

115. Three separate copper deposits are recognized in the Monywa area. The twin deposits, Kyisindaung and Sabetaung, are located about 10 km north-west of Letpadaung Taung and were drilled earlier by a combined Burmese Government - Japanese team. The project study concerns only the Letpadaung Taung area. Details of exploration

efforts are shown in figure 3.

116. The previous exploration in Letpadaung Taung included small-scale diggings of oxide ore and a few test pits, S.P. survey and geologic mapping by a Yugoslav team, early diamond drilling in between 1957 and 1960 by the Government, reconnaissance I.P. by a Colombo Plan team and a large-scale integrated exploration campaign including geologic mapping and I.P. survey by a Japanese team in 1973/74. The project carried out additional I.P. work, geochemical soil sampling and Turam survey. The diamond drilling,which was started in May 1976, and geologic mapping of veinlike features continued as of April 1978.

117. Regionally the area is situated within the Burma Volcanic Arc of late Mesozoic and Cenozoic volcanic, intrusive and sedimentary rocks. The local lithology at Letpadaung Taung comprises mainly strongly altered andesitic to dacitic volcanic rocks (biotite porphyry), tuff, possible rhyolitic (silicified?) dykes (zones?) and hydrothermal breccia, all of late Cenozoic age. Many clearly post-mineral dykes were mapped on surface and in core, but in places the strong supergene alteration of softer non-fractured, non-mineralized and less-silicified zones of the biotite porphyry host rock effectively mask its origin.

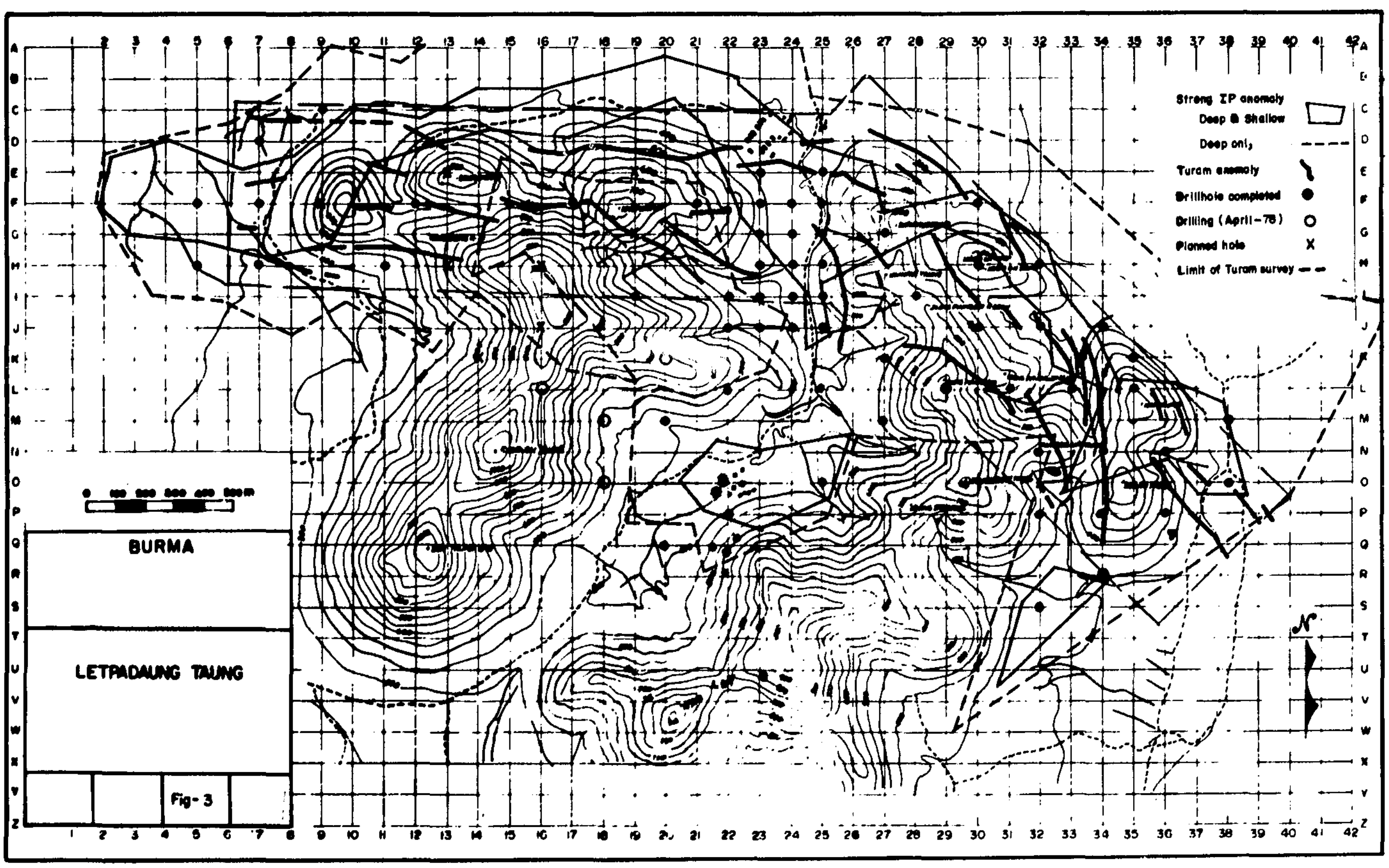
118. The degree of alteration is strongly fracture-controlled, and consequently the widespread zones with few or no fractures between the major veins are only slightly altered. Because of these zones, and existing post-mineralized dykes, reliable correlation of ore intersections between drill holes cannot be made and the drilling done is sufficient only to outline the mineralization and predict the tenor of the ore.

119. The leached capping ranges from 70 feet (21.5m), on the low land to 625 (192 m) feet under the highest hill peaks and adversely affects the stripping ratio.

120. Owing to the close association between the copper mineralization and strong pyrite concentration the area of strong I.P. and Turam anomalies was selected as a target for outline drilling. In general, the mineralization coincides with such intensive alteration features as alunite, advanced argillization, silicification, fracturing, brecciation and hematite capping. The drilling plan was later modified to include a few holes outside the strong geophysical anomaly.

121. The programme of outline drilling involves 75 holes out of which 62 (average 800 feet (245 m) were completed and four were being drilled as of April 1978.

122. The drilling results indicate that the Letpadaung Taung is a major porphyry-type copper mineralization. As noted earlier it is not yet possible to calculate the ore reserves, but it can be estimated that they might reach considerably more than 100 million tons with a tenor of 0.5-1.0 per cent copper. It is concluded that at least 90 more drill holes (totalling 22,000 m) are needed to prove the ore reserves.



III. ASSESSMENT

123. Field operations were originally intended to start during the 1973/74 field season, but had to be postponed owing to the late appointment of experts and delays in delivery of equipment. The latter part of the season was used mainly for preparatory work, and for selecting drilling targets for the proposed Pre-investment Drilling and Training Project. By the start of the first full field season, 1974/75, the poor security situation and other circumstances forced changes in project areas and cancellation of the photogeologic mapping programme of about 101,000 sq km (39,000 sq miles). The final programme of the project involved 46,740 sq km (18,050 sq miles) of regional geologic mapping and geochemical exploration, and led to follow-up investigation of 17 targets of which 3 involved extensive diamond drilling; in two of these area (Lebyin and Letpadaung Taung) the drilling continued as of April 1978.

124. The planned ground survey for radioactive minerals and participation in the DGSE airborne geophysical survey were cancelled because the Government would not permit the experts to join these activities.

A. Regional surveys

125. Altogether four field seasons from 1974/75 to 1977/78 were used to complete the programme. The regional geologic mapping by the project served not only the exploration purposes but led to major changes in the structural map of the whole country. This will be of value in selecting areas for future regional exploration, in aiding understanding of the regional setting of mineral deposits, and in identifying specific lithologic units, contacts and structures favourable for mineralization. It also indicated regions of negligible mineral potential for example, the flysch comprising most of the Chin Hills and Arakan Yoma where further exploration is not justified. The major structural modifications assisted in improved delimitation of metallogenic zones resulting in new zone boundaries, lithologic associations, and ages of mineralization supported by numerous potassium-aryon and paleontologic age determinations.

126. The regional geochemical reconnaissance results formed the base for planning further exploration. It was not expected to show precise locations of mineralization, but merely to indicate areas of higher mineral potential which should then be considered for detailed investigations. The multi-element analyses used by the project reduced the risk of overlooking smaller mineralizations; and in many cases the element associations were used to support the geologic mapping, especially in areas with few rock outcrops.

127. The project followed-up all the major reconnaissance anomalies, apart from these at which work was still in progress as of April 1978, but it is possible that some minor mineralization, which caused only insignificant or isolated anomalies, is present. These anomalies are recorded on the maps and should be followed-up in connection with possible future geologic activities in the vicinity.

128. However, all previously known mineral occurrences caused detectable reconnaissance anomalies, which suggests that the survey was reliable and that no near-surface body of ore of the analyzed elements was missed.

B. Follow-up investigations

129. Detailed follow-up investigations of 17 targets proved that 11 are non-economic and no further activities were recommended. More detailed exploration is needed in Tamagyi (No: 13) and Lemyethna (No: 16) although mineral potential is considered to be low. In Mansi (No: 9) the exploration of gold-bearing gravels continued, but the gravel reserves seem limited and divided into at least two separate zones. The gold content, although not confirmed, is believed to be low. In Pyattawye (No: 11) the final phase continued but no significant lead mineralization was reported. In Lebyin (No: 12) surface geologic mapping and diamond drilling, still in progress as of April 1978, suggest that the stibnite mineralization is scattered over a large area, and no economic concentration for mechanized mining has been proved.

130. In Letpadaung Taung (No: 17) a major porphyry copper mineralization of generally acceptable grade has been outlined by diamond drilling which was continuing. In addition to

the impressive porphyry copper potential the drilling, supported by a Turam E.M. survey, indicates that some of the massive pyrite veins, containing up to 10 per cent copper, might form high-grade deposits extensive enough for small-scale underground mining. A closer evaluation of the underground mine potential might become important if only low investment is planned or if excess thickness of the leached capping and other benefication problems prove that a large-scale open-cast mining of the whole deposit is uneconomic.

131. Further evaluation of Letpadaung Taung is included in the proposed programmes of the UNDP-supported projects "Mineral Exploration and Prospect Evaluation" and "Pre-feasibility Studies for Mineral Exploration". The programme includes development drilling, driving of two inclined tunnels, beneficiation tests and preliminary feasibility ("pre-feasibility") studies. As of April 1978, the formal position of the Government of Burma was not known; however, it was understood informally that other plans for follow-up work not involving UNDP were in prospect. Investment possibilities are clearly present, but cannot yet be specified.

C. Fellowship study and training

132. Implementation of the fellowship component was unsatisfactory. Early problems were encountered when the Government decided not to accept the proposed university training programmes but only practical ones. Later, the strict Australian language requirements, and the Government's decision not to permit language training in the study country, caused many cancellations of candidatures. More recently, the implementation was further jeopardised owing to the last-minute cancellations of already-approved candidates or delays in their departure. Additionally, no new or replacement nominations were made despite repeated enquiries by UNDP. In these circumstances the Project Manager recommended that all pending fellowship programmes, totalling 69 man-months, be cancelled.

133. The national field geologists received intensive on-the-job training, seminars and lectures in all practical aspects of a full exploration sequence. Their field performance was excellent, the work standard steadily improved and many of them became competent to carry out exploration programmes with minimum supervision.

134. In spite of the progress made in training by the Project, it cannot be over-emphasized that the professional competence of the technical staff of DGSE can neither be maintained nor improved without continual technical training of staff in modern exploration and mining methods. This should be combined with modern textbooks and journals made available to staff at all levels in the organization.

135. The project team feels that the DGSE would benefit if more of the senior geologists were to supervise systematic and large-scale exploration programmes in field, as this is where the strength of the organization lies. There is a tendency, however, for the more qualified people to perform administrative tasks at headquarters while field operations are run by less experienced junior geologists.

136. The project team is also concerned about what seems to be a random transfer of geologists from post to post. It is common that after a person is trained in certain aspects of exploration or familiarized with local geologic conditions, he is transferred to a new job which has no relation to his training or experience.

D. Administrative matters

137. As a whole, the administrative assistance and co-operation received from the DGSE was satisfactory but its ability to support the Project was noticeably decreased towards the end of the project.

138. One serious problem was the withdrawal for lengthy periods of professional national staff from the field without advising the project management. The matter was discussed in the final Tripartite review but the situation did not improve. The start of the present (1977-1978) field season was delayed by about a month when promotion and fellowship examinations were held in Rangoon at the end of November 1977 involving all but 4 of the national geologists. The situation was repeated when 8 key national geologists were re-called to Rangoon in February 1978 by the Ministry and spent one month in Rangoon waiting for an interview that was repeatedly postponed.

139. Another problem was the lack of communication between the DGSE and project team. During the joint drilling operations in Letpadaung Taung, an approved drilling plan was not followed by the DGSE and their drilling results were not made readily available to the project team.

IV. CONCLUSIONS AND RECOMMENDATIONS

140. The technical support by the DGSE was satisfactory and generous assistance and material help were received whenever feasible. The Project team worked in close relationship with many sections of the DGSE, especially with the Geochemical, Geological Mapping, Photogeological, Geophysical, Exploration, Mineralogical, Drilling and Administrative Sections. However, the most important support to the project was the enthusiasm and high general ability of the Burmese geologists and other technical staff assigned to the Project who carried out their field duties in often extremely adverse conditions. Without their work, it would have been impossible to complete the objective assigned.

141. A large-scale mineral exploration programme which comprised regional geologic mapping and geochemical reconnaissance of 46,740 sq km, integrated follow-up investigations of 17 targets, and diamond drilling of 12,900 metres was successfully completed. The fact that all previously known principal mineralizations caused significant geochemical anomalies demonstrates the reliability of the methods used.

142. The specific technical conclusions and detailed recommendations are presented in relevant technical reports listed in Annex No: 1 and also briefly in Chapter III MAIN RESULTS of this report; they are not repeated here.

143. It is concluded that reliable results in a regional survey can be obtained only through a systematic exploration sequence in large areas. Regional geologic mapping, observation of float distribution and collection of stream-sediment samples must be done simultaneously and by competent professional people. Geochemical data unsupported by adequate geologic background are of little value.

144. Similarly, results of detailed investigations are reliable only when the work is carried out systematically and in sequence. Normally, it should start with detailed geologic mapping of a sufficiently large area, followed by geochemical soil survey and measurements by appropriate geophysical methods. Diamond drilling should depend on combined information from these methods. The whole study should be based on a topographically surveyed grid-line system and the results presented on maps having the same base.

145. The follow-up investigations, carried out in this way, led in most cases to the finding and outlining of the mineralized sources causing the anomalies, although none of the new discoveries proved to be economic under present economic conditions.

146. Consequently it is recommended that the DGSE continue the combined geologic mapping and exploration activities as started by the project team and as outlined above. Selection of the regional areas should be based on metallogenic zones shown in figure 2 and described in paragraphs 28 to 48 of this report and in the relevant Technical Reports. In particular, it must be emphasized that with exception of a small area near Taungthonlon and in the southern Chin Hills, Burma west of Long. 96°E has low potential for the discovery of new mineral deposits.

147. The project team encountered some problems in obtaining previous reports by the DGSE and action should be taken to improve the situation. It is recommended that responsibility of report writings be clearly assigned and that the reports be produced and properly distributed once the work is complete. The present distribution is not well-organized and, for example, some project reports sent to the DGSE did not reach many persons who could benefit from them.

148. Action should be taken to keep the technical personnel assigned to their field posts until the work programme is complete. The practise of rotating the technical staff without considering their training or experience is unsatisfactory and lowers the standard and output of work and the morale of the individuals concerned. As an example, a geologist who had been trained specifically to map post-mineral dykes in Letpadaung Taung was transferred to another post on completion of the training.

ANNEX 1

LIST OF PROJECT REPORTS

Title of report	Remarks
1. Geology and mineralization of the Shangalon Copper Prospect and Surroundings Part 1: Shangalon Part 2: Surroundings	Technical Report No: 1 (in preparation, June 1978)
2. Geology and exploration geochemistry of the Pinlebu-Banmauk area, Sagaing Division, northern Burma.	Technical Report No: 2 (in preparation, June 1978)
3. Geology and exploration geochemistry of the Shan Scarps area, east of Kyaukse, Thazi and Tatkon, central Burma.	Technical Report No: 3 (in preparation, June 1978)
4. Geology and exploration geochemistry of part of the northern and southern Chin Hills and the Arakan, western Burma.	Technical Report No: 4 (in preparation, June 1978)
5. Geology and exploration geochemistry of the Salingyi-Shinmataung area, central Burma.	Technical Report No: 5 (in preparation, June 1978)
6. Mineral exploration in selected areas.	Technical Report No: 6 (in preparation, June 1978)
7. Letpadaung Taung Copper Prospect.	Memorandum
8. A graphical method for the treatment of geochemical data. (by T.G. Davenport)	Internal Report
9. Geological mapping and exploration instructions for field personnel.	Special Report

ANNEX 2

PROJECT PERSONNEL

International staff	Nationality	Arrival date	Departure date	Total months served
		A. International staff		
J. V. Huhta Project Manager	Finland	Jan. 1974	June 1978	53
A.H.G. Mitchell Chief Geologist	United Kingdom	Jan. 1974	July 1978	55
P. Carrel Economic Geologist	France	Dec. 1974	Oct. 1976	24
F. Sumi Geophysicist	Yugoslavia	Oct. 1974	Mar. 1978	40
B. Zitek Chief Geochemist	Czechoslovakia	Feb. 1975	Mar. 1978	37
T. Davenport Field Geochemist	United Kingdom	Apr. 1975	Feb. 1976	12
F. Baumann Consultant	Canada	Mar. 1976	July 1976	4

B. Government staff

U Kyi Soe — Project Co-Director

Geologists

U Zaw Pe

U Danny Sein

U Khin Maung Aye

U Tin Hlaing

U Tin Maung Thein

Geologists (continued)

U Tin Swe

U Kyi Tun

U Soe Thi Ha

U Nyunt Htay

U Nyunt Swe

Annex 2 (continued)

Geologists (continued)

U Myint Swe
U Khin Maung Aye
U S. Lwin Than
U Ko Ko
U Aye San
U Kyaw Sein
U Tet Sein
U Sein Tun
U Tint Naung
U Kyaing Sein
U Saw Andrew Htwe
U Ohn Maung
U Ye Maung Tin
U Than Aung
U Htein Win
U Htein Lynn
U Tin Than
U Soe Kyi
U Aung Gyi
U Tin Hlaing
U Tin Maung Win
U Shyam
U Sein Aung Win
U Richard Shwe
U Kyaw Win
U Tint
U Myo Myint Swe
U Saw Naung
U Htay Win
U Thein Han
U Ko Ko
U Ba Kyi

Geochemists

U Shwe Gaung Lay
U Kyaw Soe
Daw Khin Khin Win
Daw Thit Thit Hla
Daw Myat Myat Sein

Geophysicists

U Tin Myint Oo
U Win Myint
U Nyunt Sein
U Tauk Tut
U Thein Htun
U Mya Thaung
U Khin Maung Htay
U Kyaw Soe

Drilling Engineer

U Ba Soe

Draftsmen

U Tun Aye
U Tun Shin
U Khin Pyone
U Tin Wan
U Khin Sein
U Hla Than
U Hla Tun
U Maung Maung Nyo

ANNEX 3

UNITED NATIONS FELLOWSHIP AWARDS

Nominee/Post	Study	Place of study	Duration
U Kyi Soe Project Co-Director	Geological survey organization	Geological Surveys and Institutes of IRAN, TURKEY, UNITED KINGDOM, FEDERAL REPUBLIC OF GERMANY, GERMAN DEMOCRATIC REPUBLIC AND CANADA.	Oct 73 - Feb 74
- do -	Study tour	Seminar, PHILLIPPINES	July 1977
U Sein Myint Director General	Geological survey organization	Geological Survey, FINLAND.	Sept 74 - Oct 74
U Zaw Pe Geologist I	Geologic mapping	Geological Survey of MALAYSIA and Bureau of Mineral Resources, AUSTRALIA.	Feb 76 - Oct 76
U Than Naing Photogeologist II	Photogeology	University of Aston, United Kingdom.	Sept 74 - Aug 75
U Shwe Gaung Lay Chemist II	Analytical chemistry	Geological Survey, FINLAND.	Jan 76 - Jan 77
Daw Khin Khin Than Geologist V	Library and documentation	Geological Survey, FINLAND.	Aug 77 - Dec 77
Daw Thinn Thinn Phyu Geologist IV	Mineralogy	Geological Survey, FINLAND.	Aug 77 - (Jun 78)
U Nyunt Htay Geologist IV	Geochemistry	Bureau of Mines, PHILIPPINES.	Jan 77 - (Sept 78)
U Myo Mying Electronic Assistant II	Electronic engineering	CANADA	Jan 78 - Mar 78
U Tet Sein Geochemist IV	Geochemistry	US Geological Survey, United States of America	Mar 78 - (Dec 78)

ANNEX 4

MAJOR ITEMS OF EQUIPMENT PROVIDED BY UNDP

Description	Quantity
Vehicles	22
Vehicles (transferred from BUR-72-001)	3
Drill rigs with accessories	3
Drill rigs with accessories (from BUR-72-001)	3
Drill rigs with accessories (from BUR-71-516)	1
Mercury analyzer (MAS-50)	1
Induction furnace	1
Atomic absorption spectrophotometer AA-175B	1
Background corrector - AA5	1
Jaw crusher	1
Disc grinder	1
Ball mill	1
Magnetic separator	1
Super panner	2
Induced polarization system (I.P.)	1
Gamma-ray spectrometer	2
Flux-gate magnetometers	3
Proton magnetometer	1
Magnetic susceptibility meter	1
Turam EM system	1
Scintillometers	2
Oscilloscope	1
Polarizing microscopes	3
Transceivers	3
Mirror stereoscopes	4
Diazo printer	1
Ricoh copying machines	2
Kail reflecting project	1
Duplicator	1
Movie projector, 16-mm	1
Overhead projector	1

UNITED NATIONS NATIONS UNIES

POSTAL ADDRESS—ADRESSE POSTALE UNITED NATIONS, N.Y. 10017
CABLE ADDRESS—ADRESSE TELEGRAPHIQUE UNATIONS NEWYORK

REFERENCE: EC 132/226/2 BURMA (12)

I have the honour to refer to the project "Mineral Exploration" (BUR-72-002) undertaken in Burma with the assistance of the United Nations Development Programme, for which the United Nations served as executing agency, and to transmit a technical report of the United Nations entitled "Geology and Mineralization of the Shangalon Copper Prospect and Surroundings" (DP/UN/BUR-72-002/10).

The reports deals specifically with the work performed by the United Nations and national government personnel during the period January 1975 to May 1977 at the Shangalon copper prospect. Details are provided of the geologic, geochemical, geophysical and diamond drilling activities which were conducted in order to evaluate the prospect and reach conclusions on its economic potential.

Although the anomalies disclosed at Shangalon during the systematic regional geochemical reconnaissance and geologic mapping of the Banmauk-Kawlin G-area in date 1974 indicated a promising target for further examination, the results embodied in this report only indicate sub-economic grades of mineralization and do not justify further exploration for the present in the main prospect area or in its immediate surroundings.

These conclusions were reached as a result of extensive field work involving geologic mapping, combined geoelectric, magnetic and radiometric surveys, geochemical soil sampling and diamond drilling over an area of approximately 20 sq km, in addition to the chemical analysis of over 16,700 samples. A total of 33 holes were drilled during the programme, aggregating 8,785 feet.

Estimations, based on drilling results, indicate a maximum potential tonnage of 9 million tons grading 0.23 per cent, 0.17 grams per ton of gold and trace quantities of molybdenum. Even these low grades, however, are contained in small sections and all not continuous throughout the prospect. Thus, in considering any future mining operation that might be based on these unproven reserves, account would have to be taken of the dilution effect, with further lowering of the mining grade.

We should appreciate your informing us, through the Office of the Resident Representative of the United Nations Development Programme, of your comments on the report.

This report represents technical contributions prepared with the co-operation of the United Nations Development Programme. In conformity with the agreement governing such co-operation, the report should be available for utilization by all interested parties. We should, therefore, appreciate your Government's agreement to the derestriction of the report so that it may be placed on open file and made available to all interested parties. Your Government's concurrence to derestriction will be assumed, unless you inform us, within six months of the date of this letter, that you wish the report to remain restricted.

Accept, Sir, the assurances of my highest consideration.

Findley Burns, Jr.
Director of Operations
Department of Technical Co-operation
for Development