Mineral Investigations in Northeastern Thailand

GEOLOGICAL SURVEY PROFESSIONAL PAPER 618

Prepared on behalf of the United Nations Development Programme Project of the Mekong Committee in cooperation with Royal Thai Department of Mineral Resources

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By HERBERT S. JACOBSON *and* CHARLES T. PIERSON, U.S. GEOLOGICAL SURVEY, THAWISAK DANUSAWAD, THAWAT JAPAKASETR, BOONMAI INTHUPUTI, CHARLIE SIRIRATANAMONGKOL, SANER PRAPASSORNKUL, *and* NARIN PHOLPHAN, ROYAL THAI DEPARTMENT OF MINERAL RESOURCES

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CONTENTS

	Page
Abstract	1
Introduction	1
Scope of report	1
Previous investigations	1
Background and objectives of present investigation	3
Methods of operation	3
Geochemical and geophysical field procedures	4
Traverse-line preparation	4
Geochemical soil surveys	4
Magnetic surveys	4
Electrical surveys	5
Resistivity	5
Self-potential	5
Electromagnetic	5
Induced polarization	6
Acknowledgments	6
Geography	6
Topography	6
Climate and vegetation	8
Proposed Pa Mong dam	8
Regional geology	8
Sedimentary and metamorphic rocks	8
Devonian or older rocks	8
Devonian and lower Carboniferous rocks	9
Carboniferous and Lower Permian rocks	9
Triassic to Cretaceous rocks (Khorat Series)	9
Quaternary alluvium and laterite	10
Igneous rocks	10
Structure	10
Metamorphism	11
Mineral deposits	11
Regional magnetic information	11
Aeromagnetic surveys	11
Magnetic interpretation	11
Geochemical reconnaissance	13
Sampling and analysis	13
Geochemical background	13
Geochemical anomalies	13
Mineral prospects	15
Base-metal prospects	15
Copper-lead-zinc deposits	15
Phu Han-Phu Sang prospect	15
Phu Hin Lek Fai area	16
Phu Thong Daeng deposit	16
Phu Poon-Phu Pa Phai prospect	16
Lead-zinc deposits	16
Phu Khum 1 (Ban Khok Mon) prospect	16
Phu Khum 2 (Ban Nong Ya Sai) prospect	16
Iron prospects	17
Phu Lek (Chiengkarn) deposit	17
Phu Yang deposit	17
Phu Hia deposit	17
Phu Ang deposit	17
Mineral prospects—Continued	
Manganese prospects	17
Gold prospects	18
Nonmetallic prospects	18
Limestone	18
Barite	18
Anhydrite-gypsum	18
Salt	18
Economic development potential	18
Mineral reserves	18
Copper	19
Iron	19
Nonmetallic mineral deposits	19
Recommendations for future work	19
Description of mineral prospects and deposits	20
Base metals	20
Phu Han-Phu Sang prospect	20
Phu Lek (Ban Na Muang prospect)	22
Tagua and Phu Suan prospects	22
Huai Hob prospect	22
Ban Khok Na Dok Kham prospect	22
Phu Sam Rua prospect	23
Phu Tham Sua prospect	23
Phu Hin Lek Fai area	23
Phu Hin Lek Fai deposit	23
Geology	23
Geochemical survey	25
Geophysical surveys	25
Phu Hin Lek Fai North prospect	25
Tonnage and grade	25
Conclusions and recommendations	29
Rong Rae and Khok Peng prospects	29
Phu Thong Daeng copper deposit	29
Geology	29
Geochemical and geophysical surveys	30
Tonnage and grade	30
Conclusions and recommendations	30
Phu Poon-Phu Pa Phai prospect	30
Phu Baw Lek prospect	32
Non Khok Kaw prospect	32
Phu Khum 1 (Ban Khok Mon) prospect	35
Phu Khum 2 (Ban Nong Ya Sai) prospect	36
Ban Huai Phuk prospect	38
Khum Thong prospect	38
Iron	40
Pone Bak Thek prospect	40
Phu Lek (Chiengkarn) deposit	40
Phu Yang deposit	40
Geology	44
Magnetic survey	44
Tonnage and grade	44
Conclusions and recommendations	46
Phu Hia deposit	46

Recommendations for future work—Continued
Iron—Continued — Page
Phu Kaeo Yai prospect — 47
Phu Lek (Ban That) prospect — 47
Ban Sup prospect — 50
Phu Lek (Ban Mak Bit) prospect — 50
Ban Rei Tham prospect — 50
Phu Noi prospect — 50
Phu Luak prospect — 50
Phu Ang deposit — 53
Geological and geophysical studies — 53
Geology — 54
Magnetic survey — 56
Tonnage and grade — 56
Conclusions and recommendations — 57
Pa Pao prospect — 57
Phu Fai Mai prospect — 57
Phu Khok-Phu Khum Thong prospect — 58
Phu Din Baw Eelert prospect — 58
Phu Phun prospect — 58
Other iron prospects — 58
Manganese — 58
Huai Muang mine — 59
Phu Lon mine — 60
Huai Khok Kha mine — 61
Huai Kan prospect — 61
Prakit prospect — 62
Ban Dong Mak Fai prospect — 62
Huai Tad mine — 62
Deposits southeast of Chiengkarn — 63
Phu Hin Lek Fai prospect — 63
Phu Tham Mup mine — 63
Deposits in the Ban Chiang Klom area — 63
Huai Nam Kam and Huai Tab Chang prospects — 63
Huai Pla Kang prospect — 63
Gold — 63
Ban Phia prospect — 63
Ban Kham Duang prospect — 64
Limestone — 65
Pha Baen limestone (cement-grade) deposit — 65
Barite — 66
Ban Huai Phot prospect — 66
Ban Tin Pha prospect — 66
Baw Hin Khao deposit — 66
Anhydrite-gypsum — 68
Loei deposit — 68
Wang Saphung deposit — 68
Salt — 70
Chaiyaphum deposit — 70
Geologic logs of diamond-drill holes — 71
Base-metal prospects and deposits — 71
Phu Hin Lek Fai diamond-drill hole 1 — 71
Geologic logs at diamond-drill holes—Continued
Base-metal prospects and deposits—Continued — Page
Phu Hin Lek Fai diamond-drill hole 2 — 71
Phu Hin Lek Fai diamond-drill hole 3 — 71
Phu Thong Daeng diamond-drill holes 1–3 — 72
Phu Khum 1 (Ban Khok Mon) diamond-drill hole 1 — 72
Phu Khum 1 (Ban Khok Mon) diamond-drill hole 2 — 73
Phu Khum 1 (Ban Khok Mon) diamond-drill hole 3 — 73
Phu Khum 1 (Ban Khok Mon) diamond-drill hole 4 — 73
Phu Khum 2 (Ban Nong Ya Sai) diamond-drill hole 1 — 73
Iron deposits — 74
Phu Lek (Chiengkarn) diamond-drill hole 1 — 74
Phu Yang drill holes 1–10 — 74
Phu Hia diamond-drill hole 1 — 76
Phu Hia diamond-drill holes 2–4 — 76
Phu Ang drill holes 1–22 — 77
Wang Saphung anhydrite-gypsum deposit — 82
Wang Saphung gypsum drill holes 1 and 2 — 82
Chaiyaphum salt deposit — 83
Chaiyaphum holes 1–5 — 83
Chemical analyses — 84
Base-metal deposits — 84
Phu Hin Lek Fai base-metal deposit, drill holes 1 and 2 — 84
Phu Thong Daeng copper deposit, drill holes 1–3 and Phu Khok trench 1 — 85
Iron deposits — 85
Phu Yang iron deposit, drill holes 1–10 — 85
Phu Hia iron deposit, drill holes 1–4 — 86
Phu Ang iron deposit, drill holes 2–12, 14–22 — 87
Pha Baen limestone deposit — 89
Wang Saphung anhydrite-gypsum deposit, drill holes 1 and 2 — 89
Chaiyaphum salt deposit — 90
Composition of composite drill-core samples — 90
Analysis of core samples — 90
Semiquantitative spectrographic analyses — 91
Petrographic analyses — 92
Intrusive rocks (Permian or Triassic) — 92
Undifferentiated intrusive rocks — 92
Volcanic rocks (Triassic) — 92
Mineral-deposit host rocks and wallrocks — 93
Phu Hin Lek Fai base-metal deposit — 93
Phu Thong Daeng copper deposit — 94
Phu Ang iron deposit — 94
Phu Yang iron deposit — 94
Other prospects — 95
References cited — 96

ILLUSTRATIONS

[Plates are in pocket]

PLATE 1. Geologic map of the Loei-Chiengkarn area.
2. Aeromagnetic map of the Loei-Chiengkarn area.
3. Maps and section of the Phu Hin Lek Fai base-metal deposit.
4. Maps and section of the Phu Thong Daeng base-metal prospect.
5. Maps and sections of the Phu Khum 1 (Ban Khok Mon) base-metal prospect.
6. Maps of the Khu Khum 2 (Ban Nong Ya Sai) base-metal prospect.
7. Maps and sections of the Phu Yang iron deposit.
8. Maps and sections of the Phu Hia iron deposit.
9. Geologic map and sections and magnetic map of the Phu Ang iron deposit.
10. Maps of manganese mines and prospects northeast of Chiengkarn.
11. Map and sections of the Chaiyaphum rock salt deposit.

Page

FIGURE 1. Index map of Thailand showing areas investigated 2
2. Geologic map of northeast Thailand 7
3. Reconnaissance geochemical map of the Loei River basin 14
4. Geological and geochemical map of the Phu Han-Phu Sang base-metal prospect 21
5. Map showing summary of electromagnetic surveys at the Phu Hin Lek Fai deposit 26
6. Electromagnetic profiles over the Phu Hin Lek Fai base-metal deposit 27
7. Geologic map of the Phu Hin Lek Fai North prospect showing copper content in soil and electromagnetic conductor axes 28
8. Cross section of the Phu Thong Daeng copper deposit 31
9. Geo'ogic map of the Phu Poon-Phu Pa Phai base-metal prospect 33
10. Geochemical map of the Phu Poon-Phu Pa Phai base-metal prospect 34
11. Geochemical map of the Non Khok Kaw base-metal prospect 35
12. Geophysical map of the Phu Khum 1 (Ban Khok Mon) base-metal prospect 37
13. Cross section of the Phu Khum 2 (Ban Nong Ya Sai) base-metal prospect 39
14. Geologic map of the Phu Lek (Chiengkarn) iron deposit 41
15. Cross section of the Phu Lek (Chiengkarn) iron deposit 42
16. Magnetic map of the Phu Lek (Chiengkarn) iron deposit 43
17. Geologic map of the Phu Lek (Ban That) iron prospect 48
18. Magnetic map of the Phu Lek (Ban That) iron prospect 49
19. Geologic map of the Phu Luak iron prospect 51
20. Magnetic map of the Phu Luak iron prospect 52
21. Map showing location of drill holes in the Ban Kam Duang area 64
22. Geologic map and sections of the Baw Hin Khao barite deposit 67
23. Vertical section through the Wang Saphung anhydrite-gypsum deposit 69

TABLES

Page

TABLE 1. Stratigraphy of northeastern Thailand 9
2. Aeromagnetic anomalies in the Loei-Chiengkarn area 12
3. Geochemical stream-sediment anomalies in the Loei River basin 13
4. Mineralogical anomalies in panned stream-sediment concentrates from principal streams 15
5. Summary of mineral reserves 19
6. Summary of iron and sulfur analyses of Phu Yang drill-hole samples 45
7. Summary of tonnage and grade, Phu Yang iron deposit 46
8. Test-pit data, Phu Ang iron deposit 54
9. Summary of tonnage and grade, Phu Ang iron deposit 56
10. Summary of data used for calculating proven and probable ore, Phu Ang iron deposit 57
11. Summary of drilling data, Ban Kham Duang gold prospect 65
12. Summary of analyses of Wang Saphung gypsum intersections 68

MINERAL INVESTIGATIONS IN NORTHEASTERN THAILAND

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ABSTRACT

Fifty-eight mineral prospects (copper, lead, zinc, iron, manganese, gold, limestone (cement grade), barite, gypsum, and salt) were investigated by geological, geophysical, and geochemical surveys and by pitting, exploratory mining, and diamond drilling from January 1963 to May 1966. Fifty-six of the prospects are in the Loei-Chiengkarn area of northeast Thailand where regional geological, aeromagnetic, and geochemical studies were also performed: the other two prospects are on the Khorat Plateau.

The base-metal prospects are in volcanic and carbonate rocks. Four prospects were tested by diamond drilling; disseminated copper deposits were found at two prospects and local lead-zinc mineralization at the other two. The two copper deposits have estimated proven and probable reserves of 16 million tons, containing about 1 percent copper, and possible reserves of 62 million tons.

The iron prospects are mostly metasomatic, at contacts of granodiorite with sedimentary and volcanic rocks. Four of the iron prospects were tested by diamond drilling; proven, probable, and possible reserves of about 27 million tons containing 52 percent iron were developed, predominantly in two deposits.

Twelve manganese and two gold prospects were investigated; all are small or low grade.

Deposits of barite, gypsum, and limestone (cement grade) were examined in the Loei-Chiengkarn area, and salt was studied at Chaiyaphum. Reserves of about 5.5 million tons of barite, half a million tons of gypsum, 12 million tons of limestone (cement grade), and 2,000 million tons of salt were estimated to be present.

Economic development of these deposits must await recommended economic feasibility studies and additional geologic work, including diamond drilling.

INTRODUCTION

SCOPE OF REPORT

This report is a synthesis and interpretation of geological, geophysical, and geochemical studies, as well as test drilling and exploratory work in the Loei-Chiengkarn,[1] Chaiyaphum, and Ban Kam Duang areas (fig. 1) of northeast Thailand during the period January 12, 1963, to May 15, 1966, under the United Nations Special Fund Project "Laos and Thailand: Survey of minerals and mineral processing industries in the lower Mekong basin."

The report incorporates investigations conducted by a U.S. Geological Survey field team working under contract with the United Nations, the Executing Agency for the project, and in cooperation with the Royal Thai Department of Mineral Resources. It also includes coordinated studies by a United Kingdom Overseas Geological Surveys-Royal Thai Department of Mineral Resources field team sponsored by the Colombo Plan.[2]

PREVIOUS INVESTIGATIONS

Geological investigations in northeastern Thailand began with the reconnaissance by Wallace M. Lee in the Khorat Plateau and by R. Bourret in the Pak Lay area of Laos, which included part of the Loei area in Thailand (Bourret, 1925). More than two decades later, Vija Sethaput, Saman Buravas, Jamchet Charaljavanaphet, and Nitipat Jalichandra, of the Royal Thai Department of Mineral Resources, and Glen F. Brown, William D. Johnston, Jr., and George C. Taylor, of the U.S. Geological Survey, jointly prepared a summarized description of the regional geology and mineral deposits of Thailand (Brown and others, 1951).

Several later investigations obtained additional information on the geology and resources of northeastern Thailand. A comprehensive study of the ground-water resources of the Khorat Plateau, including an extensive drilling program, was undertaken jointly by the Royal Thai Department of Mineral Resources and the U.S. Agency for International Development (LaMoreaux and others, 1958; Haworth and others, 1964). This program, supplemented by stratigraphic studies undertaken

[1] "Chiengkarn" is the spelling used by the United Nations. According to transliteration of the Thai name, the spelling should be "Chiang Khan." This report adopts "Chiengkarn" as the spelling.

[2] The results of this work were described in the following unpublished reports available in the files of the Royal Thai Department of Mineral Resources:

Bleackley, D., and Workman, D. R., 1964, Report on a geochemical reconnaissance survey in the Loei-Chiengkarn area of Thailand: London, Overseas Geol. Surveys, 72 p.

Bleackley, D., Stephens, A. E., Cratchley, C. R., Workman, D. R., Newman, D., Cogger, N., Sanevong, P., Thanvaranchorn, P., Intrakhao, B., and Chaungpaisal, S., 1965, The regional geology of the Loei-Chiengkarn area of Thailand and detailed investigations of the Phu Khum lead-zinc mineral prospects: London, Overseas Geol. Surveys, 67 p.

FIGURE 1.—Index map of Thailand showing areas investigated.

jointly by the Royal Thai Department of Mineral Resources and the U.S. Geological Survey, resulted in the first regional synthesis of data on salt resources underlying the Khorat Plateau.[3]

During the same period, mineral prospects, including those known at that time in the Loei-Chiengkarn area, were studied by Vija Sethaput, Saman Buravas, Amorn Methikul, and others of the Royal Thai Department of Mineral Resources, and by Louis Gardner and Roscoe Smith, of the U.S. Geological Survey, under the auspices of the U.S. Agency for International Development and the Government of Thailand. To support these investigations, an aeromagnetic survey was conducted by the Aero Service Corp.[4] A team from the German Krupp Rohstoffe Co.[5] examined several iron prospects.

This report is not an exhaustive summary of all mineral resources in northeastern Thailand; it gives comprehensive information on the mineral prospects investigated and recommendations for possible future investigations.

BACKGROUND AND OBJECTIVES OF PRESENT INVESTIGATION

The present investigation was based on reports of mineral prospects at Ban Kam Duang and in the Loei-Chiengkarn area by Amorn Methikul [6] and on reports of salt in the Khorat Plateau by Haworth and others (1964). In addition, the Krupp Rohstoffe Co.[7] had investigated several iron prospects, and the Aero Service Corp.[8] conducted an aeromagnetic survey in the Loei-Chiengkarn area in 1958. The aeromagnetic survey was sponsored by the U.S. Agency for International Development upon recommendation by the U.S. Geological Survey.

A request for the present mineral survey was made by the committee for Coordination of Investigations of the Lower Mekong Basin (Mekong Committee), an autonomous agency formed by Cambodia, Laos, Thailand, and the Republic of Vietnam, working under the aegis of the United Nations Commission for Asia and the Far East. The mineral survey became a United Nations Special Fund project through the signing of a Plan of Operation in 1961 by the Mekong Committee members, by the United Nations Special Fund, and by the United Nations. The United Nations subsequently contracted the U.S. Geological Survey to conduct a mineral survey in Thailand in cooperation with the Royal Thai Department of Mineral Resources.

The U.S. Geological Survey field party consisted of the following personnel: C. T. Pierson, senior mining geologist and party chief; H. S. Jacobson, economic geologist; and E. J. Young (1963), Louis Gonzalez (1964), and E. W. Raisanen (1964–66), drillers.

The Royal Thai Department of Mineral Resources field party consisted on an average of about 30 staff members supplemented by about 80 local laborers. The U.S. Geological Survey field party provided training for the junior members of the Thai field party.

The present investigation consisted of mineral exploration of the Loei-Chiengkarn area (pl. 1) and examination of 58 mineral prospects in northeastern Thailand, most of which are in the vicinity of Loei. The existence of 24 of these prospects was known before the start of the investigation.

The general aims of the investigation were:

1. To investigate the mineral deposits of northeastern Thailand as a guide to possible future establishment of industries based on minerals present in the area.
2. To assist in the potential development of the Mekong River basin, giving priority to minerals that relate to the immediate needs of the basin.
3. To train Thai Department of Mineral Resources personnel.

More specifically, the United Nations Special Fund Plan of Operation for the project listed the mineral commodities and following areas to be investigated:

1. Rock salt in the Khorat Plateau "west of a line Udorn-Chaiyaphum."
2. Iron, manganese, and barite in the Loei-Chiengkarn area.
3. Minerals in places where flooding may occur after the proposed erection of the Pa Mong dam.

METHODS OF OPERATION

Transportation.—Field operations were highly dependent on transportation facilities, which, in turn, were controlled by the seasonal monsoon rains. All reconnaissance work was conducted in the dry season from December to May when secondary roads are accessible. Detailed investigations were carried out throughout the year from a series of camps supplied by oxcart or boat. At some camps the vehicular travel season was extended by construction of more roads.

[3] Gardner, L. S., Haworth, H. F., and Na Chiengmai, P., Salt resources of Thailand: Unpub. rept. in files of Royal Thai Dept. Mineral Resources.

[4] See footnote 8.

[5] See footnote 7.

[6] Methikul, Amorn, 1955, Report of investigation on geology and mineral resources from Loei-Udorn-Nong Khai: Thailand Geol. Survey Rept. 219 (unpub. rept. in files of Royal Thai Dept. Mineral Resources).

[7] Krupp Rohstoffe Co., 1959, Raw material survey iron and steel industry, Thailand: Expedition 1957–58 Main Rept. (unpub. rept. in files of Royal Thai Dept. Mineral Resources).

[8] Agocs, W. B., and Curtis, C. E., 1959, Interpretation airborne magnetometer-scintillation counter survey in Chiang Khan-Loei, Na Khon Sawan, and Chachoengsao areas of Thailand: Unpub. rept. in files of Royal Thai Dept. Mineral Resources.

Prospecting methods.—The prospecting methods that led to the 34 mineral discoveries were:

1. Village mineral reconnaissance: systematic visits to villages in the area to locate mineral outcrops or boulders known to the local residents, followed by preliminary geologic inspection of mineral prospects.
2. Aeromagnetic surveys [9] used to locate magnetic iron deposits and base-metal deposits with associated magnetite.
3. Geochemical stream-sediment reconnaissance survey of the Loei River basin.
4. Geological reconnaissance.

Detailed investigations of mineral prospects.—The techniques used in the investigations included nearly all methods of modern mineral exploration and followed the concept of integrated mineral exploration, which is the use af all applicable techniques needed for a thorough appraisal of the mineral showings.

The methods used to evaluate the individual mineral prospects were:

1. Preliminary geologic examination.
2. Detailed topographic and geologic mapping.
3. Geophysical surveys including magnetic, electromagnetic, resistivity, and induced polarization.
4. Geochemical soil surveys.
5. Pitting, trenching, and mining.
6. Diamond drilling (4,963 m drilled at 54 sites).

GEOCHEMICAL AND GEOPHYSICAL FIELD PROCEDURES

TRAVERSE-LINE PREPARATION

Geochemical and geophysical surveys were all performed along previously prepared traverse lines required by the thick tropical vegetation that covers most of the terrain. Lines were prepared by a four- to six-man crew that cut straight lines and placed stakes generally at 50-m intervals. Line preparation progressed at the rate of 600–1,000 m per crew day. The lines were subsequently surveyed by compass, hand level, and tape or by theodolite and stadia or tape. Baselines were surveyed with a theodolite.

GEOCHEMICAL SOIL SURVEYS

Sampling and analysis.—Soil samples were taken along the traverse lines at 25- or 50-m intervals at depths of about 10 cm. Some samples were analyzed in the field without screening to determine the approximate citrate-extractable total heavy-metal (Cu, Pb, Zn) content to rapidly delimit the areal extent of geochemical anomalies. Subsequently, most samples were screened to −80 mesh and analyzed for their total copper, lead, and zinc, using standard U.S. Geological Survey procedures (Ward and others, 1963), or similar procedures used by Geochemical Prospecting Research Center, Imperial College, London. Samples were analyzed either in Loei or Bangkok, Thailand, or in London, England. Analysis of geochemical reconnaissance samples and samples from the Phu Khum 1 and 2 prospects was done by the United Kingdom Overseas Geological Surveys and the Royal Thai Department of Mineral Resources. Most other samples were analyzed by the Royal Thai Department of Mineral Resources.

Data compilation and interpretation.—The analytical data were compiled on maps (see, for example, pl. 3*B*, 3*D*), and geochemical concentration contour lines were drawn. Most of the geochemical maps in this report show only the contour lines (for example, pls. 5*B*, 6*B*), but not the analytical data, which are held in the files of the Royal Thai Department of Mineral Resources, Bangkok, and the United Kingdom Overseas Geological Surveys, London. Contour lines that best fit each particular set of data were chosen, and wider spaced contours were used where the soil was more metalliferous.

MAGNETIC SURVEYS

The vertical component of the earth's magnetic field was measured with a Jalander magnetometer which is a "fluxgate type" instrument with maximum sensitivity of 10 gammas. In the field the effective limit of sensitivity was ±20–30 gammas. During the first surveys, diurnal magnetic variation was measured at a base station with an Askania magnetometer and was found to be less than the effective sensitivity of the Jalander instrument. No corrections of diurnal magnetic change were therefore applied to the data.

Magnetic measurements were usually made at 10-m intervals along traverse lines. Where large magnetic gradients were present, measurements were commonly made at 5-m intervals and occasionally at 2.5-m intervals. In reconnaissance, traverse measurements were made at 25-m or 50-m intervals.

Data reduction.—Because boulders of magnetic iron minerals are common, causing large changes in magnetic measurements over short distances, the magnetic intensity data was smoothed, using either of two standard procedures:

1. Plotting magnetic profiles visually with a curve to obtain the best fit.

[9] An aeromagnetic survey by Aero Service Corp. was performed in 1958, and a detailed aeromagnetic survey by Hunting Surveys, Ltd., was carried out in 1965.

2. Smoothing the data mathematically to obtain a running average of every three consecutive magnetic measurements.

Subsequently, the "smoothed" magnetic values for each station were plotted (such as in fig. 20) and magnetic contours drawn. Only the contours are shown in most of the magnetic maps in this report. The original data are in the files of the Royal Thai Department of Mineral Resources, Bangkok.

Interpretation.—Most of the magnetic surveys performed showed erratic magnetic patterns largely related to fields of magnetic boulders despite the attempted data smoothing. Only qualitative magnetic interpretations were therefore possible in most cases, and interpretation was confined to determining the maximum area of possible subsurface magnetic bodies, based on the principal inflection points in the magnetic profiles.

Quantitative interpretation was possible at the Phu Yang iron deposit because fewer boulders of iron ore were present, owing to the steep slopes of the Phu Yang Mountain, The magnetic pattern (pl. *7B*) indicated the possible presence of a shallow-dipping tabular body. Using a model of a dipping slab of magnetite, theoretical magnetic profiles were calculated and matched to two of the observed profiles. A reasonably good correlation was obtained. In addition, the pole depths for positive and negative magnetic poles were calculated for many of the profiles. These calculations indicated that the tabular magnetic body becomes thinner at its east and west ends. The lenticular-dipping tabular shape was subsequently confirmed by drilling.

ELECTRICAL SURVEYS

RESISTIVITY

Ground resistivity was measured in two areas (B 8, B 10) in an attempt to detect conductors related to base-metal minerals. Resistivity measurements were made at 25-m intervals along the traverse lines with an ABEM Terrameter instrument, using a Wenner electrode configuration. The apparent resistivity values were plotted, and resistivity contours were drawn (pls. *3C*, *4C*). The low resistivities were interpreted as the result of acid water in porous bedrock near sulfide mineralization (pl. *3C*) or to water saturation of alluvial sediments (pl. *4C*).

SELF-POTENTIAL

Self-potential measurements were made at two base-metal prospects (B 14 and B 15) by C. R. Cratchley[10] where sulfides are known to be oxidized close to the surface. Voltage was measured with a Pye potentiometer and nonpolarizing copper-copper sulfate electrodes. The voltage measurements were plotted, and self-potential contour maps were prepared. The observed self-potential anomalies were generally oval in shape, and the major axis of the oval was drawn (pl. *6D;* fig. 12). The maximum potential difference of most of the anomalies was a few tens of millivolts, with one exception: the anomaly represented by its axis trending north-northeast from drill hole 1 in figure 12, which had a maximum potential difference of 300 millivolts near the drill hole.

The drill hole (pl. 5*C*) indicated that the anomaly was caused by pyrite mineralization.

ELECTROMAGNETIC

Electromagnetic surveys were performed at many of the base-metal prospects and at two of the manganese prospects. Three different methods and five different instruments were employed. Most of the work was done with the horizontal loop method using two coils separated by a 50-m or 75-m cable. "Slingram" and "EM gun" instruments were used for most of these surveys. Most of the surveys failed to detect conductors in known mineralized areas because the depth of oxidation as subsequently determined by diamond drilling was greater than the detection limit of the two-coil system (assuming that the detection depth limit is approximately equal to half the coil separation). At two prospects (B 14, B 15) where sulfide mineralization is present close to the surface, however, effective use was made of this method to detect conductors. Electromagnetic measurements were made using a 75-m coil separation at two frequencies (440 and 1,760 cycles per second). The EM quadrature values for the 1,760-cycle data were plotted and contoured, and the axes of the conductive zones shown on the contour map were drawn. (The axes are shown on plate 6*D* and in fig. 12.) Diamond drilling showed some of the conductors (pl. 5; fig. 12) to be related to sulfide mineralization, whereas others were interpreted as being related to faults.[11]

A series of "Afmag" electromagnetic traverses were performed at two base-metal deposits (B 8, B 10) after negative results had been obtained with a two-coil electromagnetic system. At one deposit (B 8) a conductor was detected, but at the other (B 10) no conductors were found. The earth's natural electromagnetic field strength was adequate for daytime operation in Thailand in the months of April and May. No measurements were made in other months.

A long-wire "Turam" electromagnetic system was used at four prospects (B 8A, B 8B, B 14, B 15), using frequencies of 220 and 660 cycles per second. At the Phu Hin Lek Fai deposit (B 8A), for example, a wire 3 km long was laid out in a north-south direction, and the

[10] See footnote 2, p. 1, Beackley and others, 1965.

[11] See footnote 2, p. 1, Beackley and others, 1965.

electromagnetic field was measured with sensing coils 20 m apart along east-west traverse lines. The measured phase differences and reduced amplitude ratio were plotted on profiles (fig. 6). The peaks of phase difference curves representing the conductor axes were then drawn on the plan map (fig. 5). As shown in figure 6, these axes represent broad conductive zones. Diamond drilling (pl. 3) showed that the conductive zones are probably electrolytic near surface conductors. The rather poor conductivity of the conductors is indicated by the stronger response at the 660-cycle frequency. Similar procedures were applied at the Phu Hin Lek Fai North prospect (fig. 7). The results of Turam electromagnetic surveys at the two other prospects (B 14, B 15) (Overseas Geol. Surveys and Thai Dept. Mineral Resources, 1966) are not included in this report.

INDUCED POLARIZATION

Induced-polarization measurements were made in areas B 8A, B 14, and B 15 (Overseas Geol. Surveys and Thai Dept. Mineral Resources, 1966). Measurements were made using 50-m dipoles, and metal-conduction factors [12] were calculated and plotted. Metal-conduction factors were then contoured, and areas of high or anomalous values were outlined. These induced-polarization anomalies are shown on plate *6D* and in figures 5 and 12. The presence of disseminated sulfide mineralization has been confirmed by diamond drilling in all three areas.

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GEOGRAPHY

TOPOGRAPHY

Northeastern Thailand is a geographic and physiographic unit having an area of about 170,000 square kilometers; it consists of the Khorat Plateau and its western fringe (fig. 2). The Khorat Plateau is a broad nearly flat saucer-shaped basin, formed by Mesozoic sedimentary rocks of the Kohrat Series. It is divided into two subsidiary basins by the central ridge of the Phu Phan Mountains. Elevations of the plateau range from 130 to 200 m above sea level, and locally the mountains reach an elevation of about 700 m.

[12] Metal-conduction factors are obtained by substracting measured direct-current conductivity from measured alternating-current conductivity.

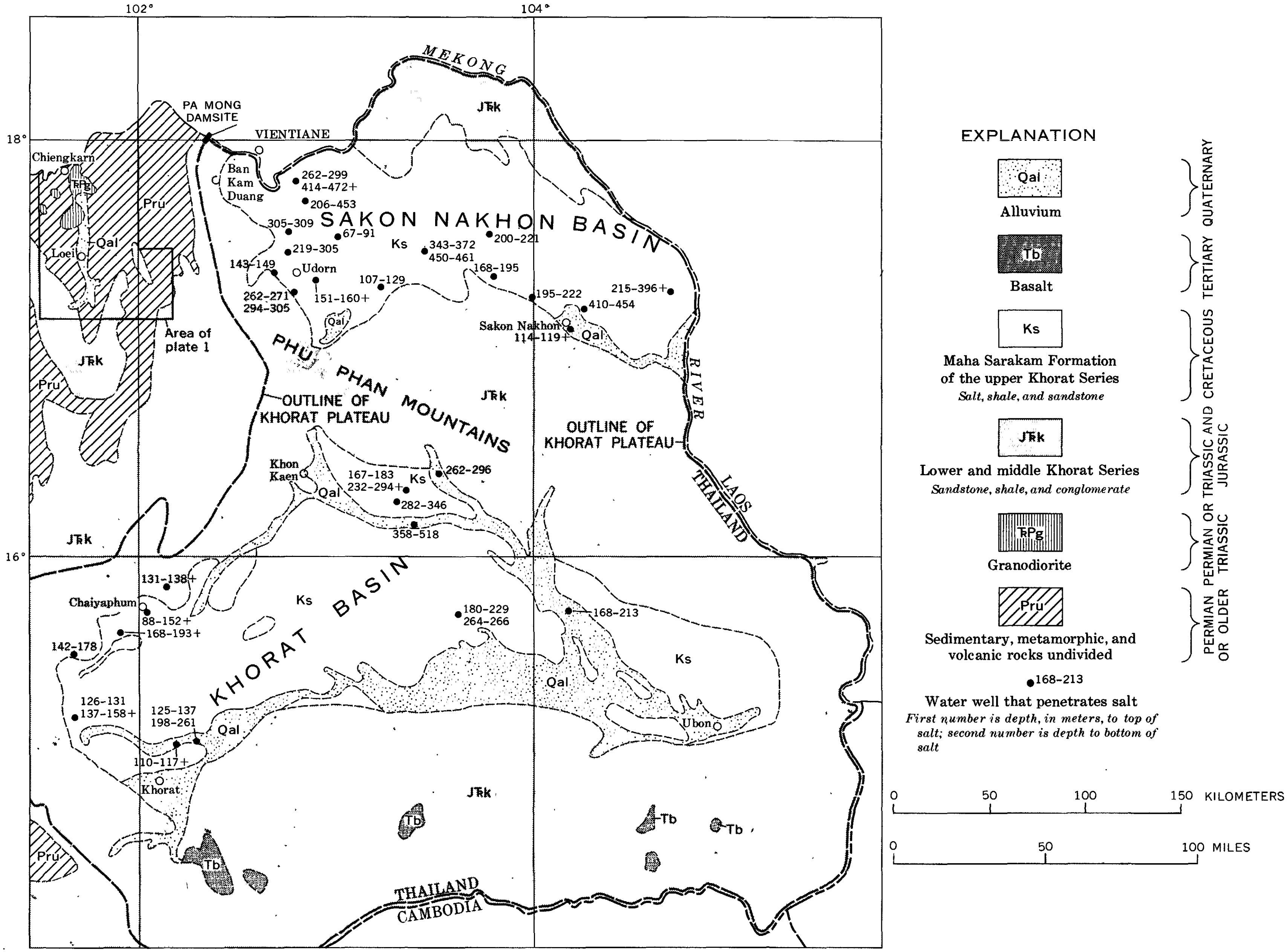


FIGURE 2.—Geologic map of northeast Thailand.

The western fringe of the Khorat Plateau is a transitional physiographic unit between the plateau and the Chao Phraya valley of central Thailand. It is an area of mature topography. Prominent isolated hills and mountains are composed of massive limestone, granodiorite intrusives commonly underlie areas of low relief, and flat-topped mountains are outliers of the Khorat Series. The area is actively undergoing erosion above an elevation of 300 m where rock outcrops are only slightly weathered, in contrast with the deep weathering known in many other areas of similar tropical climate.

The Loei-Chiengkarn area on the northwestern fringe of the Khorat Plateau contains the central north-trending valley of the Loei River (pl. 1) flanked by a mature mountain topography with relief ranging from less than 100 m to a maximum of more than 1,000 m (in the southwest corner of the area (pl. 1).

CLIMATE AND VEGETATION

Northeastern Thailand has a tropical climate characterized by a wet season and a dry season. During the wet season (May–October) heavy rains usually occur as afternoon and evening showers. Within the Loei-Chiengkarn area the mountain terrain has lower temperatures during the winter months and at the higher altitudes, morning fog in the valleys from January to March, and greater annual precipitation than on the Khorat Plateau.

The vegetation on the Khorat Plateau consists of fields of rice and open forest. Along the fringes of the plateau (as in the Loei-Chiengkarn area), vegetation includes tropical jungle forest at the lower altitudes, bamboo forest at higher altitudes, and second-growth thick brush on abandoned farmland. This vegetation and the soil cover hamper geologic observations.

PROPOSED PA MONG DAM

The proposed Pa Mong dam on the Mekong River about 30 km upstream from Vientiane (fig. 2) would provide low-cost electric power to the Loei-Chiengkarn area. It would raise the water level upstream from the dam to an altitude of about 230 m, creating a large lake and flooding the central valley of the Loei-Chiengkarn area (pl. 1) from the Mekong River south to the village of Ban That. Other smaller valleys near the Mekong River would also be flooded. Of the 58 prospects described in this report, only two are in the area that would be flooded. The effects of this flooding on the development of the mineral resources of the Loei-Chiengkarn area are listed below:

1. One very small iron prospect (Pone Bak Thek) would be flooded.
2. The Phu Lek (Chiengkarn) iron deposit would become a small island.
3. River-barge transport would become possible for some mineral products where the new lakeshore would come close to the mineral deposits (for example, the Phu Yang iron and Pha Baen limestone deposits).
4. River-barge transport might become feasible on the Loei River as far south as the town of Loei.

REGIONAL GEOLOGY

More than 95 percent of northeastern Thailand (fig. 2) is underlain by 4,800+ m thick (Haworth and others, 1964) Khorat Series (Triassic to Cretaceous) of generally flat lying conglomerate, sandstone, shale, and evaporites. These sedimentary rocks, which form the Khorat Plateau, are partly covered (fig. 2) by Tertiary volcanic flows and Quaternary alluvium. Pre-Triassic rocks are exposed along the western fringes of the Khorat Plateau and may also form the basement of the plateau. These are predominantly Devonian to Permian,[13] tightly folded sedimentary rocks cut by Permian or Triassic intrusive rocks; they serve as host rocks for most of the mineral deposits in the Loei-Chiengkarn area (pl. 1).

SEDIMENTARY AND METAMORPHIC ROCKS

The stratigraphy of Thailand is not yet well known, though significant progress has been made recently (Haworth and others, 1964; Kobayashi 1964; Ward and Bunnag, 1964; Bleackley and others, 1965.[14] Most of the rock formations known in Thailand are present in the Loei-Chiengkarn area (pl. 1, table 1).

DEVONIAN OR OLDER ROCKS

Along the east edge of the Loei-Chiengkarn area (pl. 1), possibly the oldest rocks of northeastern Thailand are exposed. The rocks are dominantly green quartzites, argillites, and phyllites and are tentatively correlated, on the basis of lithologic similarity alone, with the Cambrian(?) Phuket Series (Brown and others, 1951, p. 30) of south Thailand. They are also correlated with the "schistes cristallins indéterminés" to the north on the "Geologic Map of Vietnam, Cambodia and Laos" (Saurin, 1963). For the purpose of this report, these rocks are listed as "Devonian or older," inasmuch as no specific evidence of age is available.

[13] Previously (Brown and others, 1951), these rocks were placed in the Kanchanaburi Series (Silurian? to Carboniferous) and the Ratburi Limestone (Permian and Carboniferous). In this report the Kanchanaburi Series is restricted to the Carboniferous rocks and extended to include the Permian Ratburi Limestone.

[14] See footnote 2, p. 1.

TABLE 1.—*Stratigraphy of northeastern Thailand*

Age	Series		Rock unit	Character
Quaternary			Unnamed	Unconsolidated clay, sand, and gravel; laterite.
Tertiary			Unnamed	Basalt flows (only overlying. Khorat Series on Khorat Plateau).
Cretaceous	Khorat Series	Upper	Maha Sarakam Formation Khok Kruat Formation	Sandstone, siltstone, shale, salt, and anhydrite-gypsum. Sandstone, siltstone, and shale.
Jurassic	Khorat Series	Middle	Phu Phan Formation Sao Khua Formation Phra Wihan Formation	Massive sandstones with conglomeratic sandstone, siltstone, and shale.
Triassic	Khorat Series	Lower	Phu Khadung Formation Nam Phong Formation	Sandstone, siltstone, and conglomerate (including basal conglomerate).
			Unnamed	Andesite, rhyolite, tuff, agglomerate.
			Unnamed	Granodiorite and other intrusive rocks.
Permian	Kanchanaburi Series		Ratburi Limestone	Massive limestone with shale and sandstone.
Carboniferous	Kanchanaburi Series		Unnamed	Sandstone, siltstone, shale, tuff and limestone.
Devonian			Unnamed	Sandstone, quartzite, phyllitic shale, slate, and limestone.
Silurian and older			Unnamed	Argillite, quartzite, slate, phyllite, schist.

DEVONIAN AND LOWER CARBONIFEROUS ROCKS

A north-trending belt of rocks extending from just east of the town of Loei northward to the Mekong River is shown on plate 1. They are sedimentary and low-grade metamorphic rocks including phyllitic shale and sandstone, quartzite, slate, and limestone which were previously included in the Kanchanaburi Series (Brown and others, 1951). Paleontologic determinations indicate an early Carboniferous age for strata in the hills just east of Loei (Kobayashi, 1964) and a Devonian age at the Mekong River (Saurin, 1963). Most of the manganese and barite deposits in the Loei-Chiengkarn area are within these rocks.

CARBONIFEROUS AND LOWER PERMIAN ROCKS

Until recently the Carboniferous and Permian strata in Thailand were divided into the Kanchanaburi Series and the Ratburi Limestone (Brown and others, 1951; Haworth and others, 1964). The Kanchanaburi Series was described as Silurian(?) to lower Carboniferous shale and sandstone, locally containing interbedded limestone. This classification was based on the discovery of Carboniferous fossils from the Kanchanaburi Series and on Carboniferous and Permian fossils from the Ratburi Limestone (Brown and others, 1951, p. 32–36; Hamada, 1964; Kobayashi, 1964). However, because Permian fossils were found recently in the vicinity of Loei in sandstone, shale, and limestone beds previously included in the Kanchanaburi Series (Kobayashi and others, 1964, p. 7), we here extend the name Kanchanaburi Series to include Permian rocks and consider the Ratburi Limestone a unit of the Kanchanaburi Series. The Ratburi Limestone may be considered as a facies change of increased carbonate sedimentation within the Kanchanaburi Series.[15]

Most of the iron and base-metal prospects in the Loei-Chiengkarn area are within the Kanchanaburi Series as defined above.

TRIASSIC TO CRETACEOUS ROCKS (KHORAT SERIES)

The Khorat Series, which occupies most of northeastern Thailand, has been studied in considerable detail in recent years (LaMoreaux and others, 1959; Kobayashi, 1964; Haworth and others, 1964; Borax and Stewart, 1965), and has been subdivided into the following formations:

1. The Phu Khadung and Nam Phong Formations (lower Khorat Series—Triassic) are composed of red sandstone, siltstone, and conglomerate, which may be observed along the western fringe of the Khorat Plateau. Thickness at Phu Khadung is 2,465 m (Borax and Stewart, 1965, p. 4); fossil plants indicate a Rhaeto-Liassic age (Kobayashi, 1964, p. 9).
2. The Phu Phan, Sao Khua, and Phra Wihan Formations (middle Khorat Series—Jurassic) of red and gray massive sandstone and siltstone have a thickness of 500–950 m. The formations are well exposed on the Khorat Plateau (fig. 2) and along its western fringe, including the Loei-Chiengkarn area (pl. 1). Reptilian fossil teeth indicate a Jurassic age (Kobayashi and Fayami, 1963, p. 181–186).
3. The Khok Kruat Formation of sandstone, siltstone, and shale has been placed in the Upper Khorat Series (Borax and Stewart, 1965), but the age is uncertain.
4. The Maha Sarakam Formation (upper Khorat Series—Cretaceous) is the evaporite-bearing formation in the Sakon Nakhon and Khorat Basins within the Khorat Plateau (fig. 2). Surface exposures are rare, and principal observations are from well logs. The formation is at least 700 m thick and is composed of interfingering beds of evaporites (salt and gypsum) and shale and minor sandstone. Cretaceous age was established from fossils at one locality (Kobayashi, 1963, p. 35–39).

[15] A. E. Stephens (unpub. rept., see footnote 2, p. 1) has proposed to replace the stratigraphic names "Kanchanaburi Series" and "Ratburi Limestone" with the terms "Argillite Series" and "Calcareous Series" within a Carboniferous and Permian stratigraphic unit yet to be named.

The salt investigated at Chaiyaphum is in this formation.

QUATERNARY ALLUVIUM AND LATERITE

Unconsolidated clay, sand, and gravel are present in many areas of the Khorat Plateau (fig. 2) and in the Loei area (pl. 1) as stream, flood-plain, and terrace deposits. In places, the stream gravels contain small amounts of placer gold.

A thin veneer of reddish lateritic soil, generally 1–3 m thick, extends over considerable areas in northeastern Thailand. It contains sparse nodular laterite pebbles, most of which are within a few centimeters of the surface. Well-developed laterite has been observed only in the Dong Ka See forest area, 16 km southeast of Loei, where it overlies limestone in thicknesses exceeding 3 m. Lateritic soil with few laterite nodules grades downward to an area of predominant laterite nodules with little soil at a depth of 3 m. Chemical analysis indicates that the laterite has an intermediate composition and is not an economic aluminum or iron resource.

IGNEOUS ROCKS

Granodiorite.—Granodiorite stocks in the Loei-Chiengkarn area are intrusive into Lower Permian and older sedimentary rocks of the area (pl. 1) and probably join a central batholith at depth. This view is supported by the discovery of intrusive rocks in drill holes in two iron prospects (Phu Ang and Phu Hia) where no surface igneous exposures are known. Local compositional variations of granodiorite stocks observed include granite, quartz diorite, quartz monzonite, and quartz latite. According to a potassium-argon age determination (R. Marvin, H. H. Mehnert, and W. Mountjoy, U.S. Geol. Survey, written commun., 1966), the granodiorite is 230 million years old (Permian or Triassic); the determination was made on a sample from Phu Kwai Ngoen, 8 km due east of Chiengkarn. The granodiorite was previously mapped as "older granite" (Brown and others, 1951, pl. 5). All the contact-metamrophic iron deposits and some base-metal prospects in the Loei-Chiengkarn area are closely related genetically to the granodiorite.

Other intrusive rocks undivided.—In the Loei-Chiengkarn area are numerous small stocks and dikes of variable composition; some of these are shown on plate 1. They include diabase, aplite, rhyodacite, latite, andesite porphyry, hornblende porphyry, and others. They intrude all the pre-Khorat Series rocks, but the number of epochs of intrusion represented and their ages are unknown. Some of these intrusive rocks contain magnetite and are the cause of some of the weaker aeromagnetic anomalies (pl. 2).

Andesite, rhyolite, tuff, and agglomerate.—Predominantly andesitic volcanic rocks are exposed in a southeastward-trending belt west and southwest of Loei (pl. 1). The volcanic rocks uncomformably overlie the Permian or Triassic intrusive rocks and are conformably overlain by the Khorat Series. The age of this unit was first recorded as Permian and Triassic (Bourret, 1925) because Permian fossils were found in limestone pebbles in an andesitic agglomerate. Later regional compliations (Brown and others, 1951; Haworth and and others, 1964) included these volcanic rocks with the Tertiary basalts, but evidence from the Loei-Chiengkarn area indicates and Early Triassic age. Four lead-zinc prospects were examined within these rocks.

Basalt.—Remnants of basalt flows overlying the Khorat Series are exposed on the Khorat Plateau south of the Khorat Basin (fig. 2) as hills rising above the floor of the plateau. They unconformably overlie the Middle Khorat Series and have not been observed overlying the Upper Khorat Series.

STRUCTURE

Folds.—The principal folding in northeastern Thailand involved all the Paleozoic rocks and probably occurred during Permian time. In the Loei-Chiengkarn area (pl. 1), rocks underlying the Khorat Series have been deformed into isoclinal folds and into tight folds whose axes trend nearly due north in the northern half of the area and swing toward the northwest in the southern half. The massive more competent Permian limestones, although conformable with the other rocks, are less tightly folded. This is illustrated by the area around the Phu Hin Lek Fai base-metal prospect (pls. 1 and 3*A*, B 8).

An older period of folding probably resulted in the deformation and regional metamorphism of Devonian and pre-Devonian rocks, but no specific evidence was observed during this investigation.

The rocks of the Khorat Plateau were warped into their present structural form in the Late Cretaceous or early Tertiary. The overall structure of the Plateau is that of a flat saucer with upturned edges. Within the plateau, a central northwest-trending anticlinal ridge divides the saucer into two subsidiary basins (fig. 2).

Faults.—Faults have been noted on photogeologic maps in the Loei-Chiengkarn area (pl. 1) but not in the Khorat Plateau. Plate 1 shows a group of north-trending faults east of the Loei River that follow local fold axes and bedding trends. A single prominent northwest-trending fault was observed along the Huai Nam Huai Creek (pl. 1), 16 km southwest of Loei. East-trending faults of small displacement are present at several of the base-metal prospects examined (pl. 6; fig. 9).

METAMORPHISM

Metamorphic effects are limited to the regional metamorphism of the Devonian and older rocks and to contact effects around the granodiorite intrusives. The regional metamorphism has formed slate, phyllite, argillite, and quartzite. Schist has also been reported (Saurin, 1963) but has not been observed by the authors. Thermal metamorphism at the intrusive contacts has formed slate, quartzite, hornfels, chert, marble, and garnet or epidote skarn, depending on the nature of the original sediments.

MINERAL DEPOSITS

Relationships between regional geology and mineral deposits have been observed which may help provide a basis for future mineral exploration. Already mentioned is the presence of manganese and barite deposits in the Devonian and lower Carboniferous rocks, of iron and base metals in the Carboniferous and Permian rocks, and of salt in the Upper Khorat Series.

The iron deposits are closely related to intrusive contacts; most of the deposits are within 1 km horizontally of such a contact (pl. 1). The base-metal prospects are also related to intrusive contacts, but they tend to be a greater distance from them.

The iron and base-metal prospects tend to form in tuffaceous beds within the Carboniferous and Permian rocks.

Finally, a rough mineral zoning has been observed in the Loei-Chiengkarn area.[16] Iron and copper tend to be present along the central north-south axis of the area parallel to the Loei River valley; lead and zinc tend to be present both east and west of the central zone (pl. 1).

REGIONAL MAGNETIC INFORMATION

AEROMAGNETIC SURVEYS

The aeromagnetic data for the Loei-Chiengkarn area was obtained from two sources:

1. An aeromagnetic survey made in 1958 by the Aero Service Corp.[17] and sponsored by the U.S. Agency for International Development. The Loei-Chiengkarn area was one of a group of areas flown in Thailand.
2. An aeromagnetic survey in August 1965 by Hunting Surveys, Ltd., for the United Nations provided a series of aeromagnetic maps without accompanying interpretation, according to contract specifications. The data provided by both aeromagnetic surveys have been compiled on the aeromagnetic map (pl. 2). Original records are in the Royal Thai Department of Mineral Resources Office, Bangkok.

Aero Service Corp. survey.—The Aero Service survey was flown before base maps for the area were available, and the aeromagnetic data were compiled on an uncontrolled aerial photomosaic. The position of Aero Service magnetic data on plate 2, therefore, cannot be exactly matched with the geologic map (pl. 1).

Flight lines for the Aero Service survey were spaced about 800 m apart in a N. 25°–30° W. direction, and mean terrain clearance was about 250 m. The southernmost part of the area covered in plate 2, around anomalies M, N, O, Q, and R was resurveyed by the more detailed Hunting aeromagnetic work and is shown on the plate as belonging to the area covered by the Hunting survey.

Hunting Surveys, Ltd., survey.—The Hunting survey in 1965 was done over areas where detailed airborne work was considered desirable, based on knowledge gained by the authors during the preceding 2½ years. Flight lines were eastwest because the strike of most magnetic iron prospects, as well as formation contacts and bedding, is northerly. To obtain maximum detail, flight-line spacing was 400 m and terrain clearance was 150 m. Doppler navigation and U.S. Army Map Service base maps were used. As a result, the position of the Hunting data on plate 2 coincides with the geologic map (pl. 1).

MAGNETIC INTERPRETATION

Interpretation of the aeromagnetic data was based on regional geology and on ground checks of all the high-amplitude aeromagnetic anomalies as well as of some of the weaker anomalies.

Magnetic patterns related to regional geology.—Comparison of the geologic map (pl. 1) and the magnetic map (pl. 2) shows several obvious correlations between geologic features and their magnetic expression:

1. Magnetite-bearing intrusives have caused magnetic anomalies having low magnetic gradients, a magnetic amplitude of a few hundred gammas, and a typical pattern of a magnetic low north of a positive high. Many of these anomalies are listed in table 2 and indicated on plate 2. Perhaps the best example is anomaly H, 15 km northeast of Loei.
2. Magnetite-bearing intrusives with associated contact-metasomatic magnetite deposits cause irregular magnetic anomalies having local high magnetic gradients and relief. These intrusive rocks have magnetic iron deposits at their contacts; for example, the large granodiorite stock southeast of Chiengkarn (pl. 1), which includes several local

[16] See footnote 2, p. 1.
[17] See footnote 5, p. 3

magnetic highs (pl. 2, anomalies A, B, C, D) and several iron prospects.

3. The roughly circular granodiorite intrusive centered 20 km north-northwest of Loei (pl. 1) has an associated aeromagnetic low (pl. 2) having the same shape as the intrusive.
4. The northwest-trending granodiorite intrusive centered 16 km southwest of Chiengkarn (pl. 1) may be correlated with magnetic anomaly E (pl. 2).
5. Sedimentary rocks have a featureless magnetic expression; for example, the Khorat Series in the south-central section of the area shown on the geologic map (pl. 1).
6. The northwestward-trending belt of volcanic rocks west and southwest of Loei adjoining the area of the Khorat Series (southwest corner, pl. 1) may be readily correlated with the irregular magnetic patterns of moderate magnetic relief in the same areas of plate 2, for example, anomaly V.
7. A major east-west fault may run from Loei to the Phu Hin Lek Fai base-metal deposit (pl. 1, B 8), as indicated by the linear magnetic grain due east of Loei (pl. 2).

TABLE 2.—*Aeromagnetic anomalies in the Loei-Chiengkarn area*

[Locations of anomalies given on plate 2]

Anomaly	*Apparent cause*
A	Local magnetite enrichment in intrusive.
B	Phu Yang iron deposit.
C	Phu Hia iron deposit.
D	Phu Kaeo Yai iron prospect.
E	Granodiorite intrusive with magnetite.
F	Intrusive contact with magnetite.
G	Granodiorite intrusive: Local magnetite enrichment.
H	Granodiorite intrusive with magnetite.
I	Do.
J	Magnetite at Phu Hin Lek Fai base-metal prospect.
K	Small intrusive with magnetite.
L	Local magnetite enrichment in volcanic rocks.
M	Unknown (Phu Pa Phai).
N	Phu Luak iron prospect.
O	Magnetite at Phu Khum 2 base-metal prospect.
P	Limestone with minor magnetite.
Q	Small mafic igneous intrusive with magnetite.
R	Phu Ang iron deposit.
S	Intrusive dike with magnetite.
T	Intrusive andesite dike(?) with magnetite.
U	Small intrusive with magnetite.
V	Volcanic rocks with magnetite.

Magnetic anomalies related to mineral deposits.—Seven of the 22 anomalies listed in table 2 are related to mineral deposits; four of these anomalies resulted in new discoveries. The seven anomalies (B, C, D, J, N, O, R) are related to magnetic iron prospects (pl. 1, Phu Yang, Phu Hia, Phu Kaeo Yai, Phu Luak, and Phu Ang) or to base-metal prospects where massive magnetite is present locally, adjacent to the base-metal mineralization (pl. 1, Phu Hin Lek Fai and Phu Khum 2). All these anomalies are characterized by steep magnetic gradients, relatively high magnetic relief, and restricted surface area (pl. 2). Detailed ground magnetic surveys were conducted over each of these anomalies; they are described individually in relation to specific mineral prospects and deposits.

The principal difficulty encountered in magnetic interpretation of the anomalies is that some anomalies having the above characteristics are not related to mineral deposits (pl. 2, anomalies A, G, L). These anomalies are on high mountain ridges where aircraft terrain clearance was at a minimum and where magnetite is locally enriched in igneous rocks; therefore, they might be labeled "topographic anomalies."

Magnetic anomalies related to intrusive rocks.—In addition to the regional correlations between igneous rocks and magnetic patterns, many intrusive rocks in the Loei-Chiengkarn area have associated aeromagnetic anomalies (table 2). Some of these rock units cover considerable areas and are readily identified in regional geologic mapping (pl. 2, anomalies E, H, I), whereas others are small local stocks, dikes, or dike swarms which were detected from their magnetic expression and not previously known geologically (pl. 2, anomalies K, Q, S, T, U). Most of these anomalies have low magnetic relief and gentle magnetic gradients and may be correlated with different amounts of magnetite observed in the intrusive rock.

Other anomalies.—Anomaly F (pl. 2) lies at an intrusive contact and is probably caused by the magnetic contrast between the intrusive and the sedimentary rocks to the south. The anomaly was not checked on the ground, however, and iron minerals could be present.

Anomaly M (pl. 2) at Phu Pa Phai was investigated in detail on the ground because high-amplitude magnetic anomalies were observed locally on four flight lines (these details were obscured by contouring and are not apparent on pl. 2). The ground investigation indicated the presence of a weak vertical magnetic anomaly having a relief of about 500 gammas between two magnetic poles 1 km apart in a north-south direction. In the area of the anomaly, the only exposures are a few fragments of sedimentary rocks and white quartz. Inasmuch as the airborne magnetic survey measured the total-intensity field and the ground survey measured only the vertical field, we must conclude that the anomaly has a large horizontal component. The cause of the anomaly was not determined, but it could represent a totally concealed ore body.

Anomaly P is a weak but unusual anomaly. A field check showed that it is related to an area of carbonate rocks containing a small amount of magnetite.

Anomaly V is in an area of volcanic rocks and is probably due to variable magnetite concentrations observed in those rocks.

GEOCHEMICAL RECONNAISSANCE

SAMPLING AND ANALYSIS

A geochemical reconnaissance of the Loei River drainage basin was made[18] by sampling stream sediments wherever principal streams were readily accessible by road (fig. 3). Additional samples were taken from tributary creeks where they were readily accessible (not shown in fig. 3). Two types of samples were taken: fine-grained stream-sediment samples screened to −80 mesh in the field, and heavy-mineral concentrates obtained by panning stream gravel.

The heavy-mineral concentrates were examined under a binocular microscope, and the −80-mesh stream-sediment samples were analyzed chemically. Analysis for citrate-extractable heavy metals (copper, lead, and zinc) was performed in the field; subsequently, the samples were analyzed for total copper, lead, zinc, nickel, chromium, tin, molybdenum, and cobalt by the United Kingdom Overseas Geological Surveys Laboratory, London, England, and by the Royal Thai Department of Mineral Resources Laboratory, Bangkok.

The stream-sediment sampling was followed by geochemical soil sampling and analysis in selected anomalous areas. A total of nearly 900 stream-sediment and soil samples was taken.

GEOCHEMICAL BACKGROUND

The geochemical background was estimated from histograms showing a compilation of analytic results for 514 samples, but no other statistical analysis was performed.[19] The estimated geochemical backgrounds thus obtained are:

Element	*Parts per million*	*Element*	*Parts per million*
Arsenic	10	Nickel	30
Cobalt	15	Tin	7.5
Copper	50	Zinc	75
Chromium	100	Citrate-extractable total heavy metals (Cu, Pb, Zn)	12
Lead	25		
Molybdenum	2		

GEOCHEMICAL ANOMALIES

The sampling procedures led to two kinds of geochemical anomalies: chemical and mineralogical. The chemical anomalies are based on chemical analyses of −80-mesh stream-sediment samples; the mineralogical anomalies are based on microscopic examination of panned concentrates.

Chemical anomalies.—In this report we define an anomalous sample as one containing more than three times the geochemical background concentration[20] as listed above. The geochemical reconnaissance found 18 base-metal anomalies (table 3), half in principal streams and half in tributary creeks.

The anomalies (table 3*A*) in the principal streams (fig. 3) that contain the highest copper concentrations (B 8, B 9) were apparently caused by base-metal mineralization.

TABLE 3.—*Geochemical stream-sediment anomalies (in parts per million) in the Loei River basin*

[Samples are −80-mesh stream sediment]

Anomaly No. or location	Copper	Lead	Zinc	Probable cause of anomaly
A. Base-metal anomalies in principal streams (fig. 3)				
B 1	80	75	110	Intrusive.
B 2	60	90	140	Do.
B 3	30	75	180	Do.
B 4	75	88	225	Do.
B 5	25	112	175	Disseminated pyrite.
B 6	60	50	240	Near intrusive.
B 7	50	75	110	Intrusive.
B 8	225	55	125	Phu Hin Lek Fai deposit.
B 9	375	50	75	Ban Huai Phuk prospect.
B. Base-metal anomalies in tributary creeks (pl. 1)				
Drainage north and west of Phu Hin Lek Fai deposit (B 8).	125–450	25–37	75–160	Base-metal deposit.
Drainage west of Phu Poon prospect (B 11).	150	12	100	Base-metal prospect.
Creek, 1 km northeast of village of Ban Na Din Dam.	125–225	37–125	30–125	Unknown.
Drainage from Phu Tham Sua prospect (B 7).	75	10	290	Base-metal prospect.
Drainage west from Phu Khum 2 (Ban Nong Ya Sai) prospect (B 14).	50–190	112–1,500	50–300	Do.
Drainage south from Phu Khum 1 (Ban Khok Mon) prospect (B 15).	25–170	100–1,750	180–1,200	Do.
Creek, 4 km east-southeast of the village of Ban Na Din Dam.	40	300	30	Lateritic concentration.
Drainage east from Ban Khok Na Dok Kham prospect (B 5).	40	75	1,400	Base-metal prospect.
Creek, 3 km southeast of village of Ban Huai That.	35	150	75	Unknown.

Most of the other anomilies in this group lie in two areas: Ban Huai That area: anomalies B1–B3 (fig. 3) and Ban Phu Sawan area: anomalies B4–B7 (fig. 3). Both these areas were investigated in detail in 1965 by D. R. Workman by means of geological mapping and geochemical sampling, but no base-metal prospects were found[21]; the geochemical anomalies seemed to be related to intrusive rocks and intrusive contact zones The strongest zinc anomalies (B5–B6) in the Huai Tak creek seemed to be from zinc associated with disseminated pyrite mineralization in sedimentary rocks near an intrusive contact.

[19] See footnote 2, p. 1, Bleackley and Workman, 1964.

[20] Bleackley and Workman, 1964 (see footnote, p. 1) defined a geochemical anomaly in the Loei River basin as one containing only twice the background concentration.

[21] See footnote 2, p. 1, Bleackley and others, 1965.

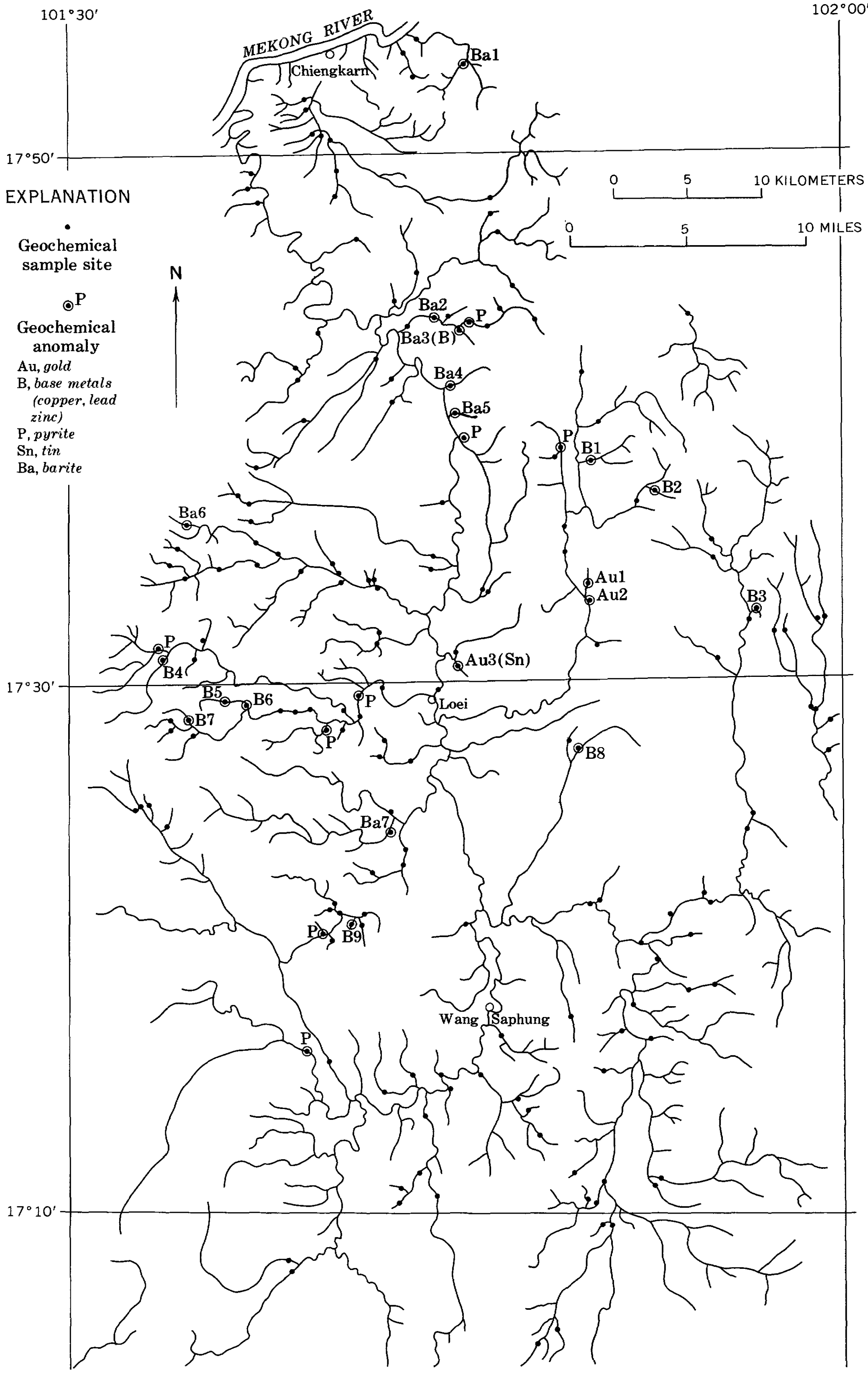


FIGURE 3.—Reconnaissance geochemical map of the Loei River drainage basin. Data from Bleackley and Workman (see footnote 2, p. 1).

In contrast, six of the nine base-metal anomalies in tributary creeks (table *3B*) were related to base-metal prospects and led to the discovery of the Phu Khum 1 and 2 prospects.

Three additional anomalies were also investigated: (1) The anomaly 1 km northeast of the village of Ban Na Din Dam (table *3B*) is in an area of rice paddies; its cause is unknown. (2) The anomaly 4 km east-southeast of the same village is probably associated with lateritic concentration of the base metals in this extensive area of laterite (pl. 1). Other geochemical samples showed a high background in this area. (3) The anomaly 3 km southeast of the village of Ban Huai That was included in the detailed study of this area, but no base-metal prospect was found.

No geochemical anomalies of As, Co, Cr, Mo, Ni, or Sn were detected, but higher geochemical background values for cobalt, molybdenum, and tin were obtained in samples with anomalous base-metal values.

Mineralogical anomalies (table 4).—Native gold was found in two samples (fig. 3, Au 1–Au 2) from the vicinity of Ban Phia (pl. 1). Native gold was also observed in a sample (fig. 3, Au 3) from a stream 3 km northeast of Loei (fig. 3) together with grains of cassiterite. The source of both the gold and the tin is unknown. Barite was noted in seven panned concentrates from the principal streams (fig. 3). Large amounts of barite found in four samples (Ba 2–Ba 5) are apparently related to the Ban Tin Pha and Baw Hin Khao barite prospects (pl. 1). One anomaly (Ba 1) was apparently related to barite at the Phu Han base-metal prospect (pl. 1). The source of the barite at the remaining two anomalies (Ba 6, Ba 7) is unknown.

TABLE 4.—*Mineralogical anomalies in panned stream-sediment concentrates from principal streams*

[For location, see fig. 3]

Mineral	Anomaly	Concentration	Probable cause of anomaly
Native gold	Au 1–2	Trace	Ban Phia prospect.
Do	Au 3 [1]	do	Unknown.
Barite	Ba 1	Low	Barite at Phu Han.
Do	Ba 2–3	High	Ban Tin Pha barite prospect.
Do	Ba 4–5	do	Baw Hin Khao barite deposit.
Do	Ba 6	Low	Unknown.
Do	Ba 7	do	Do.

[1] Also cassiterite present.

MINERAL PROSPECTS

Mineral investigations were conducted at 58 prospects, 24 of which were previously known by the Royal Thai Department of Mineral Resources. An additional seven previously known prospects in the northeast corner of the Loei-Chiengkarn area (pl. 1) near the village of Pak Chom just south of the Mekong River were not investigated because of security problems. Of the 58 prospects investigated, 56 are in the Loei-Chiengkarn area (pl. 1) and 2 are on the Khorat Plateau (figs. 1, 2). They include 20 base-metal prospects, 17 iron, 12 manganese, 2 gold, and 7 nonmetallic prospects.

BASE-METAL PROSPECTS

COPPER-LEAD-ZINC DEPOSITS

The 12 copper-lead-zinc prospects are all in Devonian and lower Carboniferous rocks and in the Carboniferous and Permian Kanchanaburi Series (pl. 1), commonly in tuffaceous strata. Some are close to observed intrusive contacts but most are not. Alinement of the prospects is generally parallel to the regional north strike of the sedimentary rocks.

The combined effects of soil and vegetation cover, rock weathering, and hydrothermal alteration allowed only limited surface observations of these 12 prospects. At most prospects, only gossan boulders were observed at the surface, and the dimensions of the gossan boulder field, together with the strength and extent of any associated geochemical soil anomalies, were used as a guide to the probable size of the prospects. On this basis, six of these prospects have maximum dimensions of less than 100 m, one (B 13) has a maximum dimension of several hundred meters, and five (B 1, B 8A, B 8B, B 10, B 11) have maximum dimensions on the order of 1 km.

The gossan boulders consist of vuggy hematite, limonite, and other iron oxides and minor silica. The vugs are usually rounded, and limonite boxworks are generally absent, but cubic vugs after pyrite are present. Chemical analyses of the gossan typically show the presence of approximately 0.1 percent copper, 0.5 percent lead, and 2.0 percent zinc. Diamond drilling at two prospects (pls. 3, 4) indicated that the gossan boulders represent secondary surficial concentration of iron oxides probably derived mostly from disseminated pyrite mineralization rather than from weathering products of massive sulfide deposits.

The five prospects with the largest areas of gossan exposure and geochemical anomaly were studied in detail:

PHU HAN-PHU SANG PROSPECT

The Phu Han-Phu Sang prospect (pl. 1, B 1) is parallel to a granodiorite intrusive contact (pl. 1). It consists of an area of gossan pebbles and boulders in red soil about 1 km long. A geochemical soil survey indicates the presence of two areas of geochemical anomaly associated with the gossan. Geophysical (electromagnetic) work gave negative results, but an induced polarization survey is recommended to attempt to delineate the possible subsurface mineralization.

PHU HIN LEK FAI AREA

The Phu Hin Lek Fai Mountains contain the largest single area of sulfide mineralization observed in the Loei-Chiengkarn area (pl. 1). It is an area about 3 km. long and 1 km. wide where most of the rocks show evidence of hydrothermal alteration and iron oxide staining. Within this area two base-metal prospects were studied: the Phu Hin Lek Fai deposit and the Phu Hin Lek Fai North prospect (pl. 1, B 8A, B 8B).

The Phu Hin Lek Fai deposit (pl. 3) has principally disseminated copper mineralization in a north-striking steeply dipping sequence of tuffaceous and volcanic rocks. Zinc is also present, together with traces of lead and molybdenum. Geochemical soil surveys were made which showed broad areas of geochemical anomalies (pl. 3); resistivity, electromagnetic, and induced polarization surveys all gave anomalous indications.

The Phu Hin Lek Fai North prospect lies 2 km north of the Phu Hin Lek Fai deposit and has similar characteristics, as indicated by surface gossan exposures and geochemical and geophysical anomalies. Preliminary surveys were performed which indicated a north-south length of more than 900 m, but no diamond drilling was done.

Fifteen million tons of proven and probable reserves containing about 1 percent copper and 50 million tons of possible reserves of copper-bearing tuff and porphyry are estimated to be present in the Phu Hin Lek Fai area. Additional drilling being done by the Royal Thai Department of Mineral Resources may increase the reserves.

PHU THONG DAENG DEPOSIT

The Phu Thong Daeng deposit (pl. 1, B 10; pl. 4) is similar to the Phu Lek Fai in that it is a low-grade capper deposit in north-south-striking steeply dipping tuffaceous and volcanic rocks. At the surface, areas of gossan boulders and geochemical anomalies were observed, but no geophysical resistivity or electromagnetic anomalies were detected. The deposit consists of an upper zone about 800 m long, 140 m wide, and 60 m thick containing about 0.3 percent copper. This zone is underlain by a zone 45 m thick, containing proven and probable reserves of 1 million tons near drill holes 1 and 2; this zone contains about 1 percent copper and about 12 million tons of possible reserves.

PHU POON-PHU PA PHAI PROSPECT

The Phu Poon-Phu Pa Phai area (pl. 1, B 11) is nearly 2.5 km long. Most of the northern half (Phu Poon) is covered by boulders and outcrops of iron oxide-impregnated altered sedimentary rocks and gossan, but a geochemical anomaly is present only at the west edge of Phu Poon. The geological similarities of the area to the Phu Hin Lek Fai and Phu Thong Daeng areas, however, indicate the presence of possible base-metal mineralization which should be further investigated.

LEAD-ZINC DEPOSITS

The lead-zinc prospects are in the Lower Triassic volcanic rocks (B 3, B 4, B 9), in the Ratburi Limestone (B 14, B 15), and in limestone beds in the Kanchanaburi Series. In contrast with the copper-lead-zinc prospects, the eight prospects in this group all have some sulfide minerals exposed at the surface. In the volcanic rocks the sulfide exposure is a result of active erosion; in the limestone the exposure is a result of the relative stability of the limestone in the local weathering environment.

The prospects in the vocanic rocks consists of lenticular quartz veins filling fractures with associated sulfide minerals. The width of the veins is 1–210 cm (centimeters), and the maximum observed length is 100 m. Sulfide mineralization has formed irregular pods or disseminations of pyrite, galena, and sphalerite in the quartz; average lead content ranges from 1.2 to 3.5 percent, and average zinc content ranges from 1.3 to 4.4 percent.

The one prospect in a limestone bed of the Kanchanaburi Series (B 5) consits of a galena vein, 8 cm wide; but the two prospects in Ratburi Limestone (B 14, B 15) are extensive mineralized areas, as indicated by geochemical soil anomalies more than 1.5 km long and 0.5 km wide. These two prospects are more fully described below:

PHU KHUM 1 (BAN KHOK MON) PROSPECT

The Phu Khum 1 (Ban Khok Mon) prospect (pl. 1, B 14; pl. 5) contains sulfide mineralization along a contact between massive limestone and diorite porphyry with marginal intrusion breccia (Bleackley and others, 1965).[22] The contact is roughly circular and encloses an area nearly 1 km in diameter. Sulfide mineralization was indicated by geochemical and geophysical anomalies subsequently tested by four diamond-drill holes. Three meters of high-grade lead-zinc-silver mineralization was intersected by one drill hole. Disseminated pyrite with local traces of lead and zinc mineralization partially replacing limestone was found in the other three holes.

PHU KHUM 2 (BAN NONG YA SAI) PROSPECT

The Phu Khum 2 (Ban Nong Ya Sai) prospect (pl. 1, B 15) lies at a granodiorite-limestone contact (pl. 6). Local lead-zinc minerals were observed in the limestone at the surface, and a geochemical soil survey outlined a very strong lead-zinc anomaly 800 m long parallel to the intrusive contact. Geophysical self-potential, electro-

[22] See footnote 2, p. 1.

magnetic, and induced polarization anomalies were found locally within the areas of geochemical anomaly. One hole drilled to test the geochemical and geophysical anomalies intersected only traces of base metals. Additional drilling by the Royal Thai Department of Mineral Resources is in progress.

IRON PROSPECTS

Of the 17 iron prospects, 12 are magnetite contact-metasomatic deposits within 1 km of intrusive rocks exposed at the surface (pl. 1) or in drill holes. Among the remaining prospects, three are very localized deposits of hematite boulders (Fe 1, Fe 9, Fe 17) and two are deposits of lateritic iron boulders (Fe 7, Fe 13), consisting of sand and rock fragments cemented by iron oxides. In addition, small amounts of magnetite were noted at two of the base-metal prospects.

Iron oxides are resistant to chemical weathering in the tropical environment of the Loei-Chiengkarn area; the iron prospects are relatively well exposed, therefore, and are generally found on tops of mountains, hills, or ridges. Because of mechanical weathering, however, iron mineral outcrops are rare, and the surface expressions of the prospects are generally iron-mineral boulder fields. At and near the surface, the iron is in the form of hematite and magnetite with scattered cubic vugs after pyrite; whereas at depth, the mineralization is mostly magnetite with minor pyrite.

The approximate surface dimensions of the magnetite iron prospects were determined by preliminary geologic mapping of iron boulder fields and magnetic surveys, and all but four of the prospects had a maximum horizontal dimension of less than 150 m. Those four prospects were examined in detail:

PHU LEK (CHIENGKARN) DEPOSIT

The surface expression of the Phu Lek deposit (1 pl, Fe 2) consists of patches of hematite-magnetite boulders exposed along a strike length of 500 m. The boulders are mostly hematite, and only a rather weak magnetic anomaly is present. Trenching and drilling showed the presence of a northwest-dipping zone of iron mineralization 6.7 m thick. Proven and probable reserves are estimated to be 400,000 tons.

PHU YANG DEPOSIT

The Phu Yang deposit (Fe 3) is at the top of a mountain at an intrusive contact (pl. 1). The deposit is a tabular dipping lens (pl. 7) 330 m long, 200 m wide, and 45 m thick. The iron mineralization is in a surface hematite-magnetite zone of 1.5 million tons of proven and probable reserves having an average iron content in hematite-magnetite of 62.4 percent and in a lower magnetite-pyrite zone of 9.25 million tons of proven and probable reserves having an average iron content in magnetite of 45.9 percent. Possible reserves of 3.5 million tons are present. The deposit is amenable to open-pit mining, and the magnetite in the magnetite-pyrite zone can be separated by dry magnetic methods.

PHU HIA DEPOSIT

The Phu Hia deposit (pl. 1, Fe 4) is 5 km east of the Phu Yang deposit. It consists of two outcrops of high-grade magnetite mineralization 250 m apart (pl. 8) which are the surface expressions of at least two dipping tabular magnetite zones. The deposit was tested by four drill holes which indicate proven and probable reserves of 1.05 million tons and possible reserves of 0.5 million tons with an indicated grade of 62 percent iron.

PHU ANG DEPOSIT

The Phu Ang iron deposit (Fe 12) is in a hill 900 m long and 250 m wide, having a maximum relief of 50 m (pl. 1). The hill is underlain by anticlinal strata of the Kanchanaburi Series, including an upper unit consisting mainly of tuff and a lower unit of limestone, dolomite, and mudstone (pl. 9). The rocks have been intruded by a diorite(?) stock, resulting in the development of a contact-metasomatic iron deposit and local contact-metamorphic rocks.

The iron deposit consists of a surface blanket of hematite-magnetite boulders and outcrops averaging 3.3 m thick, underlain by a series of overlapping lenses of iron minerals alternating with layers of sedimentary rocks. The lenses have a thickness of 2–18 m. They are composed of hematite, magnetite, martite, and goethite in the weathered oxidized zone and of magnetite with pyrite in the unoxidized zone below a depth of 50 m.

The proven and probable reserves in the oxidized zone are 7.6 million tons containing 58.6 percent iron, and in the unoxidized zone are 3.3 million tons containing 43.0 percent iron in iron oxides and 6.7 percent pyrite. Additional possible reserves are 0.1 million tons.

MANGANESE PROSPECTS

Of the 12 manganese prospects examined, 11 are in north-striking steeply dipping beds of Devonian and lower Carboniferous quartzite, phyllite, and shale (pl. 10). The other prospect is in argillite in the Kanchanaburi Series. At all the prospects, manganese oxides have formed near the surface as pods, impregnations, and fracture fillings in brecciated or porous rocks, or as pods in surface alluvium. Locally, manganese oxides and rhodochrosite form narrow veins.

The prospects are all small and the manganese content is low. However, high-grade manganese oxides have been mined on a limited scale by manual labor. The hand-sorted product is battery-grade manganese, which commands a premium price. Additional manganese reserves at the prospects examined are small, because most of the ore has already been mined.

GOLD PROSPECTS

Placer gold prospects were examined at Ban Phia in the Loei-Chiengkarn area (pl. 1) and at Ban Kam Duang on the Khorat Plateau (fig. 2). At Ban Phia, traces of gold in the stream gravels were detected by panning, and at Ban Kam Duang, rotary drilling and sampling of 26 short holes detected traces of gold in three of the holes.

NONMETALLIC PROSPECTS

LIMESTONE

Cement-quality limestone was found on the Pha Baen hill (N 1) near the Mekong River, 9 km east of Chiengkarn (pl. 1). The limestone, of probable Devonian age, is a massive gently dipping bed underlain by shale. Proven and probable reserves are estimated at 12 million tons. Additional possible reserves were not determined, and other potential sources of cement-grade limestone were not investigated.

BARITE

Three barite prospects were examined, including the Baw Hin Khao deposit (pl. 1, N 4) which is an extensive barite replacement of a steeply dipping dolomite bed having a strike length of 1,200 m. Barite is present in all concentrations from scattered barite nodules in dolomite to massive barite. Trenching indicated an average width of massive barite of more than 5 m. In addition, barite boulders are commonly present in the soil near the barite outcrops. Proven and probable reserves are 2.5 million tons of barite, and possible reserves are more than 3 million tons. Barite also is present at the Phu Han-Phu Sang base-metal prospect.

ANHYDRITE-GYPSUM

Anhydrite with gypsum underlies the Loei River Valley (pl. 1) in two localities (N 5, N 6). Two drill holes at Wang Saphung (N 6) intersected a sequence of anhydrite, gypsum, and interbedded limestone, tuff (?), shale, and mudstone; the sequence is more than 215 m thick and includes four intervals of gypsum having a total thickness of 17.2 m. The rocks dip west at an undetermined angle. The upper gypsum bed should form a suboutcrop not too far east of drill hole 2. Proven and probable reserves of 500,000 tons of gypsum are calculated. Possible reserves may be large, but they were not estimated.

Anhydrite and gypsum are also present in the Khorat Plateau associated with the salt deposits.

SALT

Vast resources of salt are present in Sakan Nakhon and Khorat Basins in the Khorat Plateau (fig. 2) within the Cretaceous Maha Sarakam Formation. The investigations under this project were confined to detailed study and diamond drilling of one salt locality (Chaiyaphum) in the Khorat Plateau.

At Chaiyaphum (pl. 11), drilling showed the presence of a nearly flat-lying massive salt (halite) bed, averaging 103.2 m in thickness, overlain by 61.2 m of sand, clay, gypsum, and anhydrite. The salt contains stringers of gypsum (?) and anhydrite 1–10 mm thick. Chemical analysis shows average NaCl content of 97 percent and a $CaSO_4$ content of 3 percent. Proven and probable reserves are 660 million tons of salt, and possible reserves are an additional 1,500 million tons.

ECONOMIC DEVELOPMENT POTENTIAL

MINERAL RESERVES

In assessing the mineral deposits studied by this project, the reserves have been classified in proven, probable, and possible categories defined as follows: "Proven reserves" are those for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes, and for which the grade is computed from the results of detailed sampling. "Probable reserves" are those for which tonnage and grade are computed partly from specific measurements and samples and partly from projection for a reasonable distance on geologic evidence. "Possible reserves" are those for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements.

As noted previously, exposures of mineral deposits are poor in the areas of investigation; therefore, the estimation of reserves depends heavily on drilling. In the present investigations, only a limited number of holes were drilled at each mineral deposit (with two exceptions), with the result that only a small percentage of the reserves are classed as "proven reserves." In this report, the proven and probable reserves as defined above have therefore been combined into a single category, which is mainly "probable reserves."

Copper and iron reserves were determined in the Loei-Chiengkarn area, but significant amounts of other metals were not observed. The copper is in two deposits (table 5) with proven and probable reserves of 16 million tons containing about 1 percent copper and possible reserves of 62 million tons, and the iron is in four deposits (table 5) totaling 27.2 million tons, averaging 52 percent iron.

TABLE 5.—*Summary of mineral reserves*

Commodity	Deposit	Reserves (million of tons)			Average grade (percent)
		Proven and probable	Possible	Total	
Copper	Phu Hin Lek Fai area.	15	50	65	1 Cu
	Phu Thong Daeng	1	12	13	1 Cu
	Total	16	62	78	1 Cu
Iron	Phu Lek (Chiengkarn).	0.40	(1)	0.40	
	Phu Yang	10.75	3.50	14.25	48.5 Fe [2]
	Phu Hia	1.05	.50	1.55	62.0 Fe
	Phu Ang	10.90	.10	11.00	56.3 Fe
	Total	23.10	4.10	27.20	52.0 Fe
Barite	Baw Hin Khao	2.5	3.0	5.5	93 $BaSO_4$
Gypsum	Wang Saphung	.5	(1)	.5	96 $CaSO_4 \cdot 2H_2O$
Limestone (cement grade).	Pha Baen	12	(1)	12	97.3 $CaCO_3$
Salt	Chaiyaphum	660	1,500	2,160	96.8 NaCl

[1] Possible reserves not estimated.
[2] Percent iron in iron oxide minerals.

The investigations also indicated considerable reserves of high-grade nonmetallic minerals, including barite, gypsum, limestone, and salt (table 5).

COPPER

The two copper deposits (Phu Hin Lek Fai and Phu Thong Daeng) may represent the best opportunity for mining in the near future, but specific mine development (planning) must await additional drilling to determine tonnage and grade. Copper has sufficient market value to be considered for possible exploitation with the transportation facilities presently available in northeast Thailand.

IRON

Construction of the proposed Pa Mong dam would make barge transportation possible along the Mekong River and along part of the Loei River. This might make the development of the iron deposits feasible. Among the deposits studied, the Phu Yang and Phu Ang deposits have the best potential because of their relatively large reserves. Phu Yang is favored by being close to the Mekong River, and Phu Ang, by having a larger tonnage of high-grade mineral reserves.

NONMETALLIC MINERAL DEPOSITS

Economic development of nonmetallic deposits is dependent on the creation of markets, low-cost transportation facilities, power, and other factors. Among the deposits investigated, the cement-grade limestone at Pha Baen may represent the best opportunity for development because proposed construction of the Pa Mong dam will provide a potential market, and river transport can be used from Pha Baen to Pa Mong. Development of the salt deposit at Chaiyaphum may be possible because a railroad under construction will pass only a few kilometers south of the deposit, and development of the Baw Hin Khao barite deposit may be possible because planned drilling for oil in Thailand may provide a market.

RECOMMENDATIONS FOR FUTURE WORK

Economic feasibility studies for the development of mineral deposits described in this report should, in general, precede further investigation of the deposits themselves. The following additional investigations are recommended:

1. Detailed geological and geophysical investigations, and closely spaced drilling at the Phu Hin Lek Fai and Phu Thong Daeng base-metal deposits.
2. Exploration of the Phu Hin Lek Fai North and Phu Pa Phai-Phu Poon base-metal prospects by geologic mapping, geophysical surveys, and test drilling.
3. Detailed geologic investigations including closely spaced drilling at the Phu Yang iron deposit, and test stripping and some additional drilling at the Phu Ang iron deposit.
4. A study of possible mining and processing methods for the above deposits.
5. Preliminary examination of prospects in the vicinity of Pak Chom which were not investigated by the authors for security reasons.
6. Closely spaced drilling and sampling of the Pha Baen limestone deposit.
7. Additional trenching and sampling plus drilling at the Baw Hin Khao barite deposit.
8. Additional drilling at the Wang Saphung anhydrite-gypsum deposit to locate the gypsum suboutcrop.
9. A study of possible mining and processing methods for the Chaiyaphum salt deposit.

The following preliminary studies are recommended in exploration for additional deposits:

1. A detailed geochemical stream-sediment survey of the Loei-Chiengkarn area; closely spaced samples should be taken to detect possible additional base-metal prospects.
2. Geochemical and geophysical exploration for base-metal deposits in areas adjoining the Phu Khum 1 and 2 base-metal prospects in the Loei-Chiengkarn area.
3. An investigation of a 3,000-sq km area east of the Loei-Chiengkarn area, extending east to long 102°15′ and from lat 17°20′ north to the Mekong

River. A preliminary geologic reconnaissance is recommended, followed by an airborne geophysical survey, if the results of the geologic reconnaissance are favorable.

4. A detailed helicopter aeromagnetic survey over about 80 sq km within a 5-km radius of the Phu Yang iron deposit (pl. 2, anomaly B) to attempt to detect iron mineralization that may have been missed previously owing to rugged terrain and wide flight-line spacing.
5. A search for additional cement-grade limestone deposits tributary to potential markets.
6. A search for potash and other salts in the Sakhon Nakhon and Khorat Basins (fig. 2) on the Khorat Plateau, beginning with detailed examination and chemical analysis of salt samples obtained from water wells by the Royal Thai Department of Mineral Resources.

DESCRIPTION OF MINERAL PROSPECTS AND DEPOSITS

BASE METALS

PHU HAN-PHU SANG PROSPECT

The Phu Han-Phu Sang area (B 1) is 9 km east of Chiengkarn, 1½ km east of the Phu Yang iron deposit, and 1½ km southeast of the village of Ban Sam Thong (pl. 1). It is reached in the dry season by driving 6 km east from Chiengkarn to the Huai Nam Ping Noi Creek, then turning south along an oxcart track that starts on the east bank of the creek and generally follows the creek valley to the village of Ban Sam Thong. From the village, one follows an oxcart track 1½ km southeast to the base of the Phu Han Mountain. The Phu Han-Phu Sang prospect is principally on the western slope of Phu Han Mountain but extends north to the Phu Sang Mountain.

The Phu Han-Phu Sang area is adjacent to an intrusive contact between granodiorite and Devonian and Carboniferous sedimentary rocks (pl. 1). The contact is in the creek west of Phu Sang (fig. 4) where granodiorite crops out on the west bank and limestone on the east bank. No contact metamorphism was observed.

Geology.—East and south of the intrusive contact, rock exposures are sparse and are confined to a few areas of outcrops or large boulders of shale, sandstone, quartzite, and gossan. The sedimentary rocks are partially altered or weathered and locally contain traces of pyrite.

The principal gossan exposures are outcrops and large boulders (0.5–1.5 m) in the south end of the area (fig. 4), but cobbles and pebbles of gossan are common throughout the southern two-thirds of the area mapped. The gossan consists of vuggy limonite and hematite, much of which is bright yellow or red. A grab sample of the gossan contained the following percentages: Fe, 59.15; Cu, 0.06; Pb, 0.41; Zn, 2.31.

Nine pits 1.5–3.4 m deep were dug at Phu Han (fig. 4). The pits exposed a 1- to 3-m-thick surface blanket of soil, weathered rocks, and gossan boulders underlain (in five pits) by clay and sandy clay, probably representing weathered sandstone and shale or tuff. One pit exposed soil containing fragments of massive barite 1–5 cm long at a depth of 2.1–3.0 m below the surface. This barite exposure probably is part of the Sam Thong barite prospect.

Geochemistry.—Soil samples were taken along east-west traverse lines 100 m apart, and the samples were analyzed for citrate-extractable total heavy metals (copper, lead, zinc). The analytical results indicate the presence of two geochemical anomalies (fig. 4) containing more than 50 ppm citrate-extractable total heavy metals. The southern anomaly may be related to the gossan exposures. Analyses of the soil samples for total copper, lead, and zinc content showed strongly anomalous values only in zinc (as much as 6,000 ppm zinc).

Geophysics.—Magnetic and electromagnetic reconnaissance measurements were made along east-west traverses 200 m apart over the entire area; additional detailed electromagnetic traverses were made along lines 50 m apart south of line 00 (fig. 4). The electromagnetic reconnaissance employed a Slingram electromagnetic instrument with a 50-m coil separation. A similar instrument, with a 100-m coil separation, was used in the detailed traverse. No magnetic or electromagnetic anomalies were detected.

Conclusions and recommendations.—The high zinc concentration in the gossan and the soil indicates the presence of zinc mineralization. The characteristics of the gossan indicate the presence of considerable pyrite, and the distribution of base metals in the soil shows that the mineralization is in at least two deposits. The absence of an electromagnetic anomaly indicates that the pyrite mineralization is not massive. Zinc mineralization may be present, however, as sphalerite is not conductive.

An induced polarization geophysical survey is recommended to attempt to outline the mineralization; a proposed diamond-drill hole would intersect possible sulfides beneath the gossan outcrops. Reconnaissance at the north end of the area at Phu Sang did not reveal significant evidences of mineralization, but extension of the detailed geological and geochemical investigations one-half kilometer to the north is nevertheless recommended.

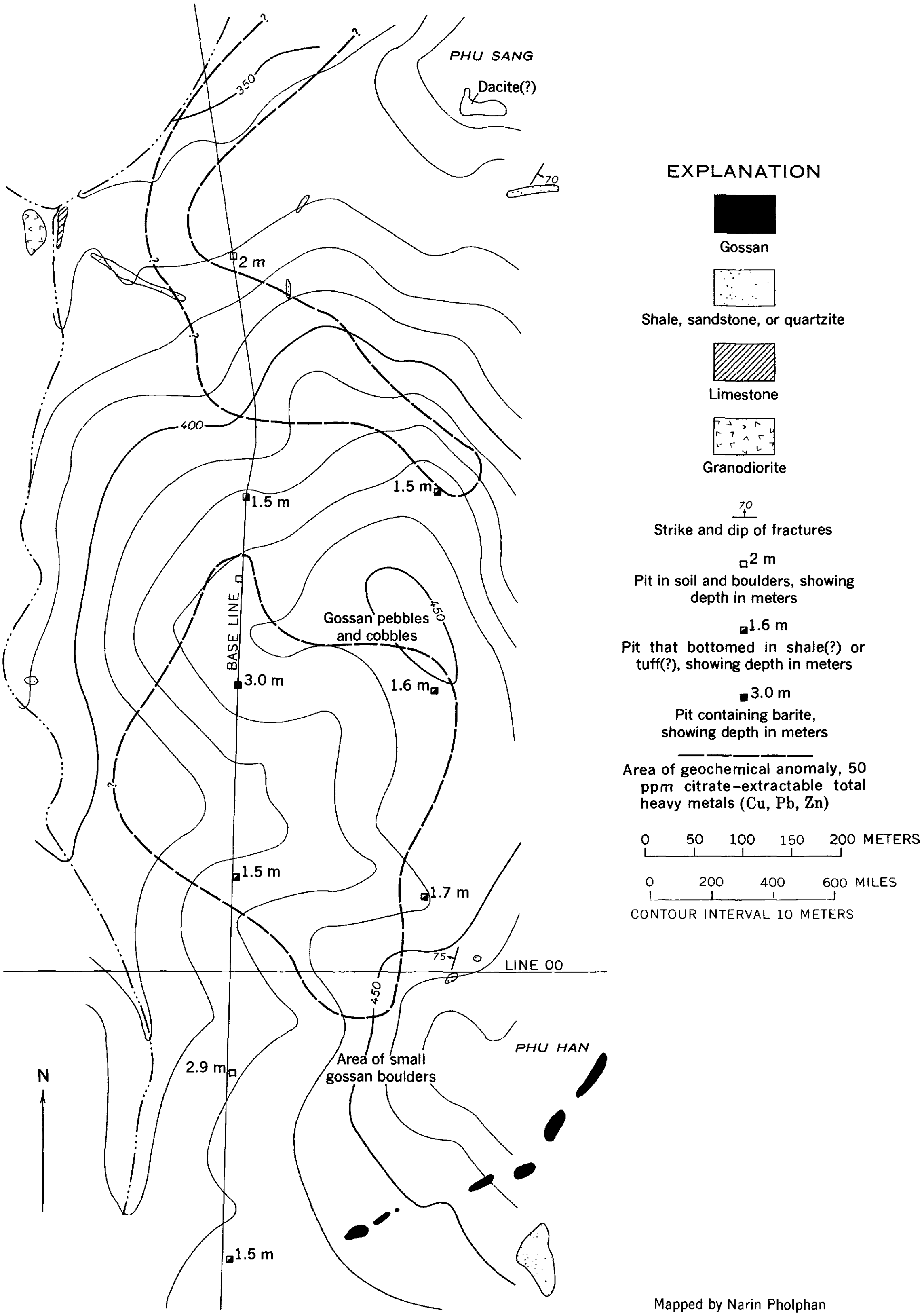


FIGURE 4.—Geological and geochemical map of the Phu Han-Phu Sang base-metal prospect.

PHU LEK (BAN NA MUANG) PROSPECT

The Phu Lek Mountain is 12 km north-northwest of Loei and 2 km southwest of Ban Na Muang village (pl. 1). The village is readily accessible by road from Loei-Chiengkarn highway 1 km to the east (pl. 1). The prospect (B 2) is at the top of the mountain at an elevation of 540 m and may be reached by walking from the village.

The northern slope of the Phu Lek follows an east-trending contact between granodiorite at the base of the mountain and black siltstone at the top (pl. 1). The prospect is within the siltstone and exposed by a shaft 15 m deep. The wall of the shaft exposes a series of quartz veins, as much as 10 cm wide, containing small amounts of iron oxides. The veins strike N. 10° E. and dip vertically. Limonite boxworks and a trace of copper oxide stain indicate the presence of sulfide mineralization. Analysis of a sample of weathered quartz vein material showed the following metal content (in percent): Cu, 0.14; Pb, 1.41; Zn, 1.06.

The mineralized zone is limited in extent and low in grade and is not considered to be of economic interest.

TAGUA AND PHU SUAN PROSPECTS

Two mineral prospects were examined in the Phu Chang area 26 km north-northwest of Loei. The Tagua prospect (B 3A) is 2 km west of the Phu Chang Mountain along the north bank of the Huai Siam Creek 300 m north of the Loei-Tha Li road between kilometer posts 34 and 35. (It is just west of the west edge of pl. 1.) The Phu Suan prospect (B 3B) lies 2 km northeast of the Tagua prospect on the lower northern slope of Phu Chang Mountain (pl. 1). Both prospects are readily accessible by the trail that joins the Loei-Tha Li road from the east at the 35-km post.

The prospects are in the Lower Triassic volcanic rocks near their northern contact with the Kanchanaburi Series (pl. 1).

The Tagua prospect consists of a lenticular quartz vein, 25 to 45 cm wide, exposed for a length of 6 m in a trench. The vein strikes N. 5° W., dips 26° E., and has an andesitic agglomerate wallrock. It contains sparse pyrite, galena, and sphalerite. A channel sample across the vein had the following metal content (in percent): Pb, 3.47; Zn, 1.35.

The Phu Suan prospect consists of a 13-cm-wide shear zone that strikes N. 20° W. and dips 22° N. The shear zone is in andesite wallrock and is mineralized with sphalerite, galena, and pyrite, with quartz gangue. A grab sample was analyzed and found to contain 48.66 percent Zn and 8.88 percent Pb.

Both prospects represent very small but locally high-grade deposits. The small size, weakly developed fractures, and absence of wallrock alteration are not encouraging for future development.

HUAI HOB PROSPECT

The Huai Hob prospect (B 4) is in the Huai Hob Creek 2.5 km southwest of the village of Ban Kok Thong. The village is 18 km west-northwest of Loei and is accessible by road in the dry season. The access road turns north from the Loei-Dan Sai road near the Huai Nam Mon Creek 6 km east of Loei (pl. 1). The prospect is reached by trail from the village.

The Huai Hob Creek exposed the Lower Triassic volcanic rocks which enclose the prospect. The nearest known intrusive rocks are 2 km to the south (pl. 1).

The prospect was examined by D. R. Workman who reported [23] a galena-bearing quartz vein exposed for a length of 100 m and having a maximum width of 1 m. The vein strikes N. 30° E. and is enclosed by epidotized andesite with disseminated pyrite. Pyrite-galena mineralization was observed in the quartz, but geochemical testing did not indicate the presence of significant amounts of base metals. Maxima of 320 ppm lead and 350 ppm zinc were detected in geochemical stream-sediment samples downstream from the vein. The vein was not sampled.

Significant base-metal mineralization is apparently absent, but sampling of the vein is suggested.

BAN KHOK NA DOK KHAM PROSPECT

The village of Ban Khok Na Dok Kham is 26 km east and 5 km north of Loei and is readily accessible in the dry season by the road through the villages of Ban Nong Hat Sai and Ban Nam Suai. The Ban Khok Na Dok Kham prospect (B 5) is 2½ km northwest of the village (pl. 1).

The prospect is in a north-trending limestone ridge belonging to the Kanchanaburi Series. The ridge is between two granodiorite stocks (pl. 1).

The prospect is confined to a single vein, 5–10 cm wide, of massive galena in limestone exposed in a steep-sided gully. The vein is being mined intermittently by local hunters for lead for bullets.

A geochemical stream-sediment reconnaissance located a strong geochemical anomaly in a creek 300 m north of the prospect; reconnaissance soil sampling in the area indicated the presence of a geochemical anomaly at least 450 m long.

The lead mineralization in the area of the prospect may be confined to thin galena veins like the one observed, but wider veins could be present. Detailed geochemical soil survey and geophysical electromagnetic investigations followed by diamond drilling are recommended to determine the extent of the galena vein or veins.

[23] See footnote 2, p. 1.

PHU SAM RUA PROSPECT

Phu Sam Rua (B 6) is 2.5 km southeast of the village of Ban Phia and is accessible by trail from the village. The village, 13 km east-northeast of Loei, is readily accessible by road in the dry season (pl. 1). The prospect is in the Kanchanaburi Series on the lower slope of a mountain formed of massive Ratburi Limestone (pl. 1).

The prospect consists of a small caved pit in a 5-m-diameter area of gossan boulders. Analysis of the gossan showed a metal content of 0.10 percent Cu and 1.89 percent Zn. Local residents report that a small amount of lead was mined from the prospect about 50 years ago, but the analysis showed no lead.

Mineralization appears to be very localized, and the prospect is believed to have negligible economic potential.

PHU THAM SUA PROSPECT

The Phu Tham Sua (B 7) prospect is on a hill 3 km northwest of the town of Loei. The base of the hill is readily accessible by road.

Phu Tham Sua is in a north-trending range of hills of shale, sandstone, quartzite, and limestone of the Kanchanaburi Series.

The prospect consists of veins of massive quartz in quartizite exposed on the crest of the hill. Gossan boulders are scattered on the eastern slope of the hill.[24]

A geochemical soil survey of the area of gossan boulders outlined a base-metal anomaly 200 m long in a north-south direction and 150 m wide. Analysis of the soil samples showed zinc in amounts ranging from 215 to 3,450 ppm, but no anomalous copper or lead values were obtained. One sample showed an anomalous cobalt concentration of 40 ppm.

The geochemical anomaly is small in area and probably represents a much smaller mineralized source, because downslope soil creep probably has expanded the geochemical soil anomaly. The apparent limited size of this mineral prospect, as indicated by the geochemical anomaly, does not encourage further investigation.

PHU HIN LEK FAI AREA

The Phu Hin Lek Fai Mountains are a north-trending range 4 km long and having a maximum relief of nearly 300 m. They are 15 km due east of Loei (pl. 1). The area is readily accessible by road in the dry season from Loei via the villages of Ban Nong Hat Sai and Ban Huai Muang.

Within the Phu Hin Lek Fai Mountains, two mineral prospects have been examined and are herein referred to as Phu Hin Lek Fai (B 8A) and Phu Hin Lek Fai North (B 8B). (See pl. 1.) The access road leads to the Phu Hin Lek Fai deposit; Phu Hin Lek Fai North is 2 km to the north and is accessible only by trail. The road to Phu Hin Lek Fai was repaired and extended to provide access for drilling equipment.

The Phu Hin Lek Fai area has been the subject of intensive study since its discovery in March 1963, following a ground check of an aeromagnetic anomaly. The following work was done:

1. Reconnaissance geological and geochemical traverses in the Phu Hin Lek Fai mountain range. The geochemical reconnaissance discovered the Phu Hin Lek Fai North Prospect.
2. Detailed topographic and geologic mapping of both prospects.
3. Detailed geochemical soil surveys of both prospects.
4. Magnetic, resistivity, electromagnetic, and induced polarization surveys of the Phu Hin Lek Fai deposit and a preliminary electromagnetic survey of the Phu Hin Lek Fai North prospect.
5. Excavation of a trench and adit and diamond drilling of two drill holes at the Phu Hin Lek Fai deposit. Additional drilling is in progress (1966).

The Phu Hin Lek Fai Mountains are in an anticline of the Kanchanaburi Series (Permian and Carboniferous) rocks (pl. 1). The anticlinal axis strikes north-northwest and plunges south. The south end of the mountain range corresponds to the nose of the anticline. The rocks in the area are sandstone, shale, tuff, and limestone; quartz latite is present along the anticlinal axis. The quartz latite may be intrusive, or it may be volcanic and conformable with the tuffaceous beds.

The entire mountain range, except the south end, has been subjected to hydrothermal activity, as indicated by iron-stained rocks, gossan, and rock alteration.

PHU HIN LEK FAI DEPOSIT

GEOLOGY

The Phu Hin Lek Fai deposit is on the west flank of the regional anticline (pl. 1) near the anticlinal axis in a sequence of rocks in the lower part of the Kanchanaburi Series, bounded on the south and west by the rocks in the upper part of the Kanchanaburi Series or in the Ratburi Limestone (pl. 3*A*). The Ratburi Limestone in the area includes beds of black, green, and white dense limestone interbedded with sandstone and shale. The observed exposures generally dip eastward (pl. 3*A*), opposite to the regional anticlinal structure, and may represent drag folding.

The lower part of the Kanchanaburi Series is the host rock for the mineralization and dips steeply west fairly consistently. It is best exposed in the creek bed near the adit (pl. 3*A*). The rocks are principally tuff, sandstone,

[24] See footnote 2, p. 1.

tuffaceous sandstone (see rock descriptions J282B, J363A, J367, J384, p. 93), commonly hydrothermally altered or brecciated, and not readily identifiable (sample J273A, J394, J401, p. 93). Within this sequence also are green limestone (pl. 3*F*) and altered carbonate rocks (sample J126, p. 93).

In addition, igneous rocks are exposed in the eastern end of the trench (pl. 3*A*) and to the east. It is not known whether the volcanic rocks are part of the tuffaceous sequence or are intrusive along the axis of the anticline. They are latite, quartz latite, or rhyodacite, commonly showing alteration effects (samples J131, J377, J389, p. 93).

The principal fault is exposed in the adit (pl. 3*F*), strikes N. 5°–10° W., and dips 46°–60° W. Fault gouge is 2–6 cm thick. Because surface rock exposures are sparse, other faults are inferred:

1. A fault is indicated by breccia 450 m northwest of the adit; a probable east strike is indicated by topography.
2. An east-trending fault is indicated by discontinuity in geophysical anomalies (fig. 5) and by the east-west creek (pl. 3*A*).

Because of rock weathering and alteration, positive identification of some rocks is not possible at Phu Hin Lek Fai. It is also difficult to distinguish between weathered and altered tuff. No detailed studies were made of the alteration, but two samples of "tuff" from the adit were analyzed by X-ray diffractometer by P. D. Blackmon, U.S. Geological Survey. The samples were found to be mainly composed of kaolinite, halloysite, mica, chlorite, montmorillonite, feldspar, and quartz. Minor amounts of pyrite, epidote, garnet, and siderite were also present.

Mineralized rock at the surface consists of magnetite and gossan. The magnetite is principally in two small north-trending zones 400 and 650 m west of the adit (pl. 3*A*). The magnetite forms massive boulders in both zones and crops out at the north end of the westernmost zone. The massive magnetite apparently caused the aeromagnetic anomaly that led to the discovery of the area, but it has very limited extent, as indicated by ground magnetometer surveys.

The surficial evidence of mineralization is mostly in the form of gossan boulders and a few gossan outcrops (pl. 3*A*). The gossan exposures are centered around the adit in an area 1,200 m long and 200 m wide. The term "gossan" as here used includes two rock types:

1. A typical gossan composed largely of vuggy iron oxides (mostly limonite and hematite) having common boxwork texture. Chemical analysis of five gossan samples showed the following average metal content (in percent): Fe, 56.8; Cu, 0.2; Pb, 0.2; Zn, 2.0.
2. An iron oxide-impregnated rock having large amounts of iron oxides and vuggy texture; it contains more gangue and has a much lower porosity than typical gossan. Gossan types intermediate between these two are common. Also common are iron oxide-stained rocks that have been mapped separately from the gossan (pl. 3*A*).

Mineralization near the surface was exposed by the adit and the trench (pl. 3*A*). In the adit (pl. 3*F*), brecciated and mineralized zones are composed of iron oxide-impregnated tuffaceous rocks. The widest zone, which is 6.8 m across, has an average metal content of 24.15 percent Fe, 0.55 percent Cu, and 2.65 percent Zn.

The trench (pl. 3*A*) exposes tuff and latite(?) containing disseminated pyrite and chalcocite(?). Chip-channel sampling of the entire trench showed the following average base-metal content (in percent): Cu, 0.48; Pb, 0.21; Zn, 0.08.

The mineralization exposed by the adit and the trench was tested by diamond-drill holes 1 and 2 (pl. 3*E*). Drill hole 1 intersected a tuffaceous sequence (p. 71) containing disseminated pyrite and local base-metal mineralization. Drill hole 2 penetrated a mineralized zone containing pyrite, chalcopyrite, and chalcocite from a depth of 10.1 to 152.4 m (p. 71). The hole intersected the tuffaceous sequence from the collar to 100.9 m and altered latite(?) from 100.9 m to the bottom at 152.4 m (pl. 3*E*).

Drill hole 3, 100 m northeast of drill hole 2, was drilled by the Royal Thai Department of Mineral Resources after the departure of U.S. Geological Survey personnel. The hole reportedly intersected low-grade copper mineralization in diorite(?) porphyry throughout most of its length (p. 71–72).

The principal mineralized intervals intersected by the drill holes are:

Drill hole	Interval (meters)	Thickness (meters)	Copper (percent)	Lead (percent)	Zinc (percent)
1	23.5–26.2	2.7	2.44		
	43.2–48.8	5.6		None	6.43
2	28.2–59.4	33.2	.49		
	59.4–132.4 [1]	73.0	1.02		
	132.4–152.4	20.0	(not available)		
3 [2]	1.2–4.3	3.1	7,000		<1,000
	29.6–32.6	3.0	6,000		<1,000
	35.4–42.4	7.0	6,800		<1,000
	112.8–118.9	6.1	5,000		<1,000
	132.4–135.7	3.3	5,000		<1,000
	140.0–143.0	3.0	5,000		<1,000
	143.0–218.0	75.0	(not available)		

[1] Includes 1.80 percent copper from 59.4 to 65.7 m and 3.85 percent copper from 69.2 to 71.7 m.

[2] Results for drill hole 3 are given in parts per million and are based on incomplete analytical results.

GEOCHEMICAL SURVEY

Geochemical soil testing was used to outline the areas of base-metal mineralization. At the Phu Hin Lek Fai deposit, samples were taken along north-south lines 200 m apart before the geochemical strike had been determined. The samples were analyzed for citrate-extractable total heavy metals (copper, lead, zinc) and for total copper, lead, and zinc.

The analytical results (pl. *3B*, *3D*) produced anomalous geochemical patterns which outlined the limits of areas of base-metal mineralization. The geochemical anomalies for the individual metals at the Phu Hin Lek Fai deposit cover the same general areas, but detailed correlations are not apparent.

The geochemical anomalies seem to be directly related to the areas of gossan boulders and iron-stained rocks but not to specific mineralized zones, except for the copper anomaly (2,000 ppm copper contour) in the vicinity of the trench. In fact, the trench was excavated to explore the geochemical anomaly.

GEOPHYSICAL SURVEYS

Magnetic measurements were made over most of the area shown on plate *3A*. Two small magnetic anomalies that correspond to the two zones of exposed magnetite indicated on the geologic map (pl. *3A*) were detected. A resistivity survey was conducted along traverse lines spaced 200 m apart (pl. *3C*), using a Wenner electrode configuration and 25-m electrode separation. A large conductive zone (pl. *3C*) that covers approximately the same areas as the geochemical anomalies was outlined; this is interpreted as a pattern produced by conductive acid water in the porous bedrock in the vicinity of, or downslope from, sulfide mineralization.

The electromagnetic surveys were all done along east-west traverse lines after geologic mapping had been completed. First, a Slingram electromagnetic survey was conducted, using a 50-m coil separation and frequencies of 440 and 1,870 cycles per second. The electromagnetic profiles showed the presence of conductive zones at both frequencies. Small changes in conductivity were observed at 440 cycles per second and large changes at 1,760 cycles per second, indicating that the conductivity is related to the zones of comparatively low resistivity that were outlined by the resistivity survey. The Slingram instrument apparently had fairly small depth penetration.

Subsequently, Afmag and Turam electromagnetic equipment was used. The Afmag electromagnetic equipment was used for only two test traverses, which showed that deep-seated conductors were present. These conductors were then outlined by a detailed Turam electromagnetic survey performed in the vicinity of the adit along east-west traverse lines 50 m apart (fig. 5) using a 20-m coil separation. A 550-m long north-trending conductive zone (anomaly) was found to cut through the trench. Strong conductivities were observed near the trench and weaker responses to the north and south (figs. 5, 6). Many other weak conductors were also noted (fig. 5).

An induced polarization survey was conducted over the northern half of the area of the Turam electromagnetic survey (fig. 5) by C. R. Cratchley (written commun., 1966) using a dipole-dipole electrode configuration with 50-m dipoles. Several anomalies were found that were interpreted as near-surface effects or as deep-seated anomalies at a depth of at least 50 m (fig. 5). Shallow local anomalies were found both over the adit and the trench, and two deep-seated anomalies were located east and west of the trench (fig. 5). As line 10 N was the southeasternmost traverse line, the southern limit of the two easternmost anomalies is not known.

PHU HIN LEK FAI NORTH PROSPECT

The prospect (B 8B) is 2 km due north of the Phu Hin Lek Fai deposit, and the baseline shown on figure 7 is the northern extension of the baseline on figure 5. Rock exposures are limited to scattered areas of gossan or hematite boulders and areas of tuff boulders and outcrops. The rest of the area is soil which was sampled and tested geochemically. A broad geochemical anomaly more than 900 m long was outlined by the 500-ppm copper contour, and local areas of soil containing more than 2,000 ppm copper were noted. The limits of the geochemical anomaly to the north, south, and east were not found. A Turam electromagnetic survey in the central part of the area detected two conductive zones (fig. 7). The geological, geochemical, and geophysical results show that this prospect is very similar to the Phu Hin Lek Fai deposit.

TONNAGE AND GRADE

Insufficient drilling has been done to provide detailed tonnage and grade estimates. At the Phu Hin Lek Fai deposit, drilling has shown the presence of low-grade copper-bearing tuff and porphyry over a width of 64.6 m and an average extension in depth (drill holes 2, 3) of at least 170 m. Geophysical electromagnetic and induced polarization surveys indicate a strike length of more than 550 m. Proven and probable reserves are therefore 15 million tons containing about 1 percent copper. Possible reserves at the Phu Hin Lek Fai deposit and the Phu Hin Lek Fai North prospect are tentatively estimated at 50 million tons.

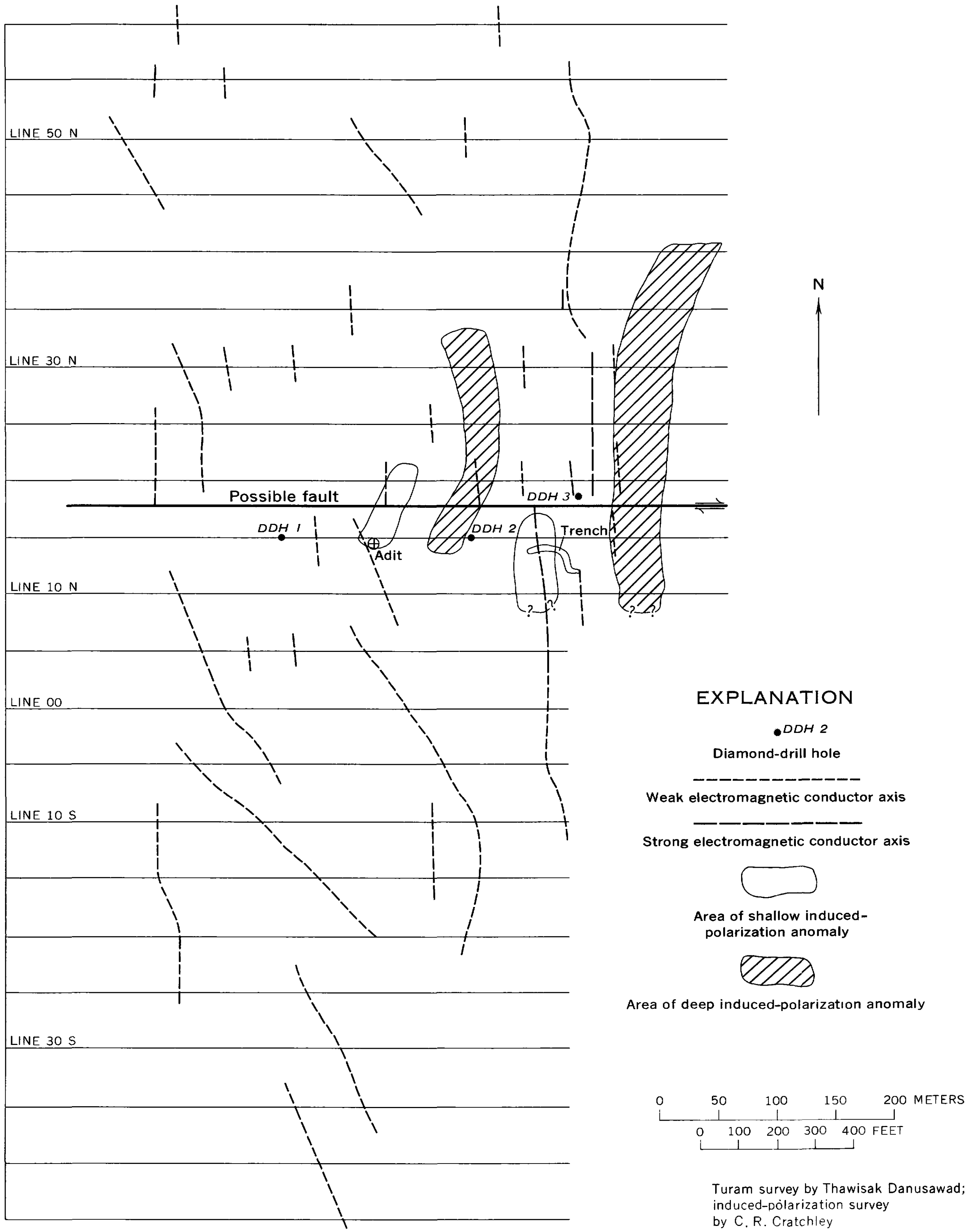


FIGURE 5.—Summary of Turam electromagnetic and induced-polarization surveys at the Phu Hin Lek Fai deposit.

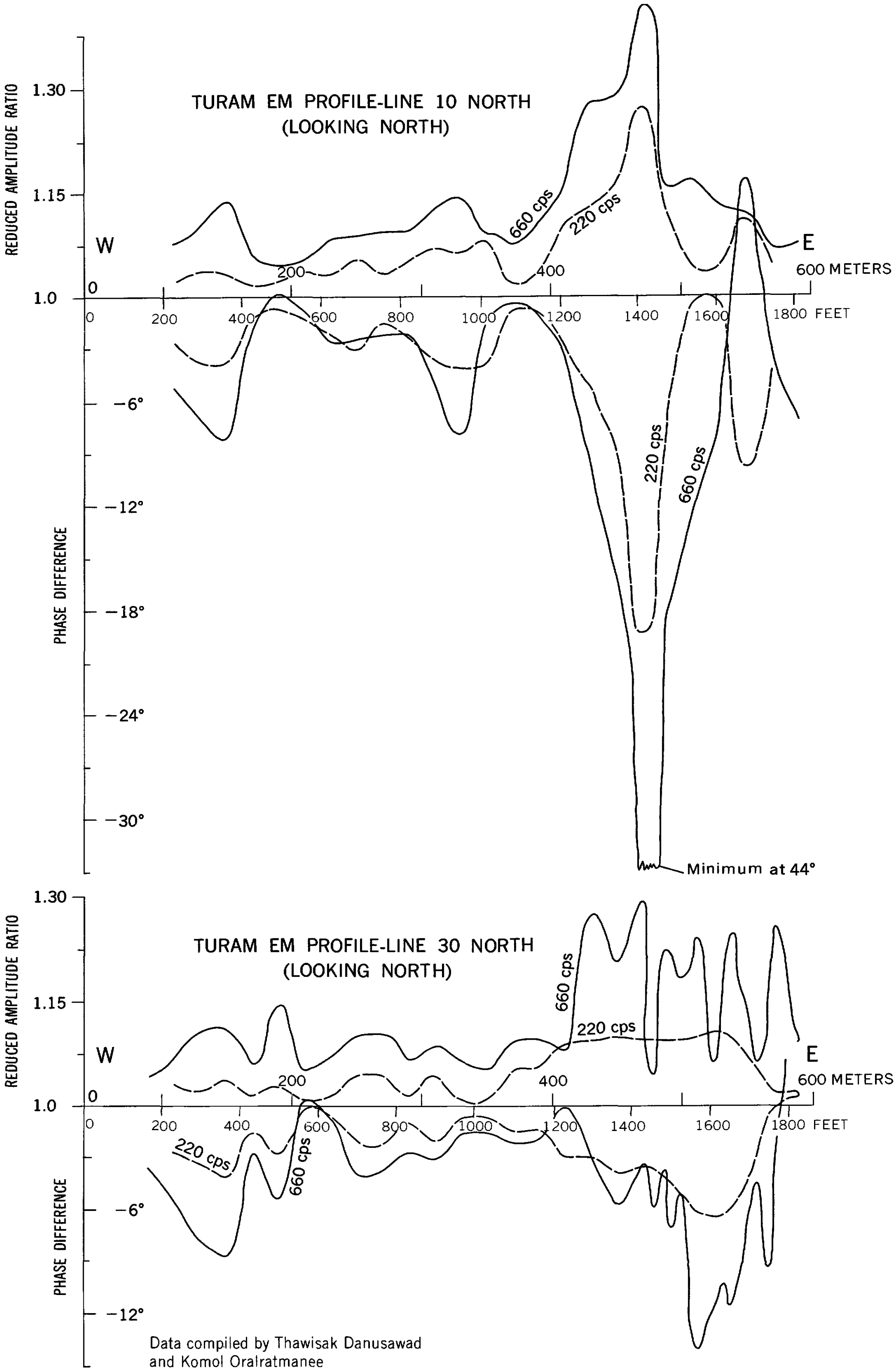


FIGURE 6.—Electromagnetic profiles over the Phu Hin Lek Fai base-metal deposit. (Location of profiles shown in fig. 5.)

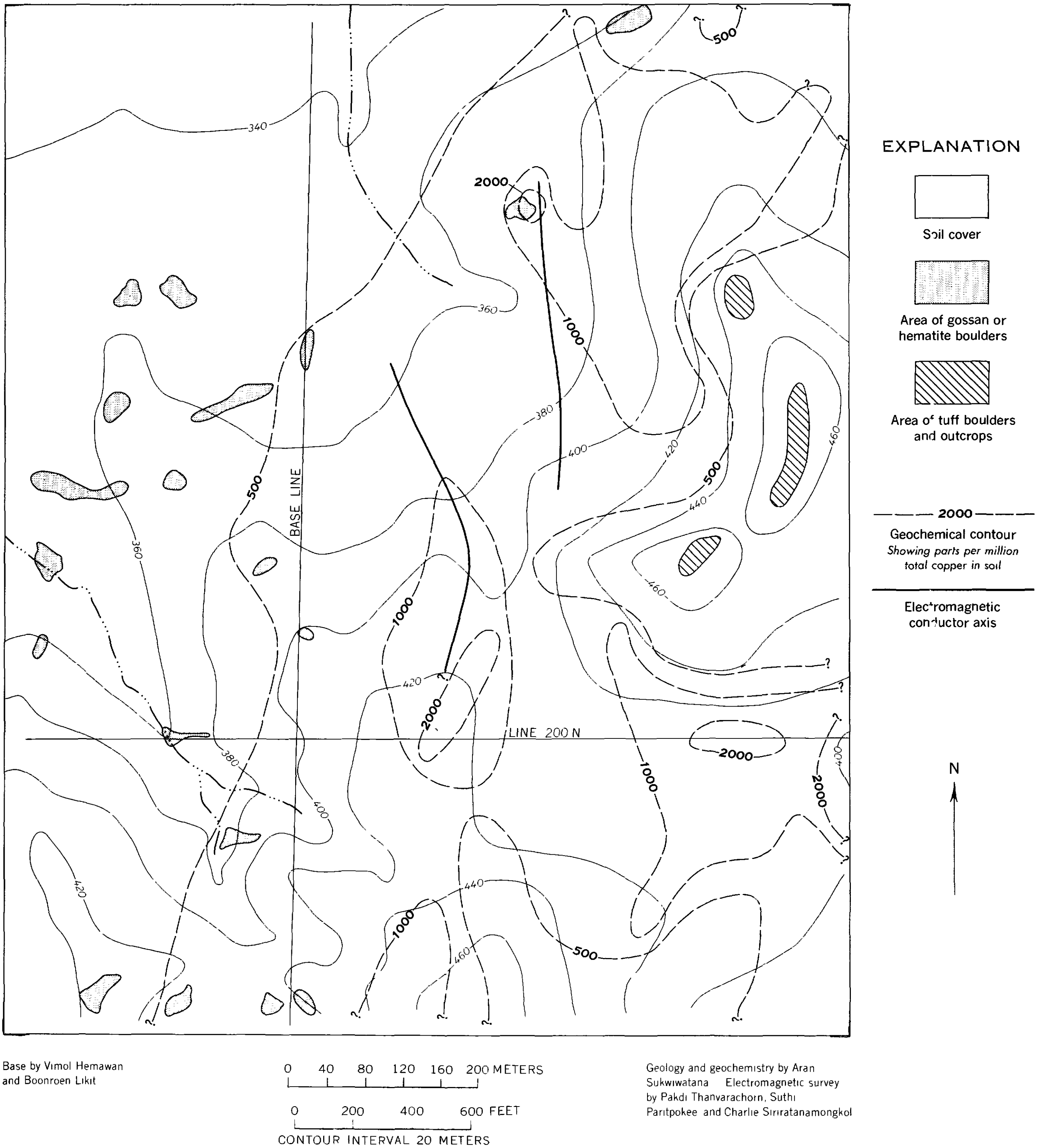


FIGURE 7.—Geologic map of the Phu Hin Lek Fai North prospect showing copper content in soil and electromagnetic conductor axes.

CONCLUSIONS AND RECOMMENDATIONS

The Phu Hin Lek Fai area contains at least two deposits with proven and probable reserves of 15 million tons of copper-bearing material containing about 1 percent copper and additional possible reserves estimated at 50 million tons. The following additional work is therefore highly recommended:

1. Closely-spaced diamond drilling of the Phu Hin Lek Fai deposit.
2. Extension of the geochemical and geophysical surveys at the Phu Hin Lek Fai North prospect.
3. Diamond drilling at the Phu Hin Lek Fai North prospect.
4. Exploration for additional base-metal prospects in the Phu Hin Lek Fai Mountains.

RONG RAE AND KHOK PENG PROSPECTS

The Rong Rae (B 9A) and Khok Peng (B 9B) prospects are 0.5 km apart in the Huai Nam Huai Creek valley 21 km west-southwest to west from Loei and 2 km south of the Loei-Dan Sai road (pl. 1). The prospects may be reached by foot from the road into Huai Nam Huai valley or alternatively by traveling from Wang Saphung along the road up the Huai Nam Huai valley to the village of Ban Ma Khaeng.

Both prospects are in volcanic rocks just east of a possible fault contact between the Khorat Sandstone and the volcanic rocks (pl. 1).

The Rong Rae (B 9A) prospect is the northernmost of the two. It is a mineralized shear zone in tuff; the shear zone strikes N. 14° E., dips 68° N., and is 210 cm wide. It consists of alternating stringers of tuff and of quartz with galena, sphalerite, and pyrite. A channel sample across the shear zone averaged 3.46 percent Pb and 4.44 percent Zn.

The Khok Peng (B 9B) prospect consists of an irregular quartz vein in a fracture zone 10 m long and 1–30 cm wide. Sparse pyrite and galena are visible in the quartz, and a grab sample showed a metal content of 1.16 percent Pb and 1.74 percent Zn.

Both prospects are small and low grade. At Rong Rae, limited future development is possible if the metal content of the vein increases along the strike or down the dip.

PHU THONG DAENG COPPER DEPOSIT

The Phu Thong Daeng deposit (pl. 1, B 10) is on a low ridge along the east bank of the Loei River across the river from the village of Ban Huai Thok. The village is 3 km east of the Loei-Wang Saphung highway and is reached by a road that joins the highway 9 km south of Loei at the village of Ban Khon Kaen. Drill sites at Phu Thong Daeng are accessible by road during the dry season when the Loei River is low enough for vehicles to cross.

Small amounts of copper have been mined in the past from shallow surface pits at Phu Thong Daeng. Details of this activity are unavailable. The first geological examination of the area was made by Saman Buravas,[25] who recommended further investigation.

A detailed examination of the Phu Thong Daeng area was made; it included geological reconnaissance, detailed topographic and geologic mapping, geochemical soil survey, geophysical resistivity and electromagnetic surveys, and pitting, trenching, and diamond drilling.

The Phu Thong Daeng deposit is within an area of rocks, probably belonging to the Kanchanaburi Series (pl. 1), that strike north-northeast and dip steeply east. Phu Yai Mountain east of Phu Thong Daeng is composed of steeply dipping limestone beds tentatively dated as Carboniferous, based on fossil evidence (Kobayashi, written commun., 1965). At Phu Thong Daeng the rocks are mainly tuffaceous beds similar to those at Phu Hin Lek Fai.

GEOLOGY

Surface exposures are almost entirely confined to boulders of gossan, altered and iron oxide-stained volcanic rocks(?), sandstone, and tuff (see samples J162, J163, P46, P51, 94). Bedrock has been exposed, however, by extensive pitting and trenching (pl. 4*A*). Most of the host rocks observed are tuff or tuffaceous sandstone. Locally, porphyritic rhyodacite or quartz latite are present, probably as flows interbedded with the tuff beds. Some of the tuff beds contain rock fragments several millimeters in diameter, which give the weathered and altered rock an apparent porphyritic texture. Therefore, tuff and flow beds cannot be readily distinguished in the field. Both rock types are included under the term "tuff(?)" on plate 4*A*.

The bedding of the tuff at the south end of the Phu Khok hill (pl. 4*A*) strikes N. 137° W. and dips 78°–81° E. No other bedding attitudes were obtainable, owing to rock weathering and alteration and the lack of rock exposures.

No faults were identified, but fracturing was noted in some of the trenches (pl. 4*A*).

Considerable clay alteration is present, but no detailed alteration studies have been made. However, X-ray identification of clay minerals in two samples showed a high kaolinite-halloysite and quartz content, and minor amounts or traces of the following minerals (P. D.

[25] Buravas, Saman, 1955, Report of investigation on geology and mineral resources of Petchabun-Loei: Thailand Geol. Survey Rept. 189 (unpub. rept. in files of Royal Thai Dept. Mineral Resources).

Blackman, U.S. Geol. Survey, written commun., 1966): Chlorite, montmorillonite, illite, pyrite, goethite, malachite, cuprite, delafosite (Cu FeO_2), and calcite.

Mineralization is present at the surface as gossan or iron oxide-stained tuff(?) in float, large boulders, and outcrops. Three mineralized areas were mapped (pl. 4*A*): Phu Baw Lek, Phu Thong Daeng-Phu Khok, and Phu Chieng Muai. At Phu Baw Lek, only a few gossan boulders are present, and iron oxide staining of the tuffaceous rocks is weak at the surface and even weaker in the trenches. At Phu Chieng Muai, massive gossan outcrops occur, but no detailed work was done in this area because of the absence of a geochemical anomaly. The Phu Thong Daeng-Phu Khok mineralized area was explored by trenching and drilling. Trenching exposed massive gossan and gossan boulders consisting of vuggy hematite, limonite, and other iron oxides, and manganese oxides. The gossan has rounded vugs as much as 5 cm in diameter, but commonly 1–2 cm. Limonite boxworks are generally absent. The hand-dug trenches exposed gossan in place which was analyzed as follows (in percent):

Trench	SiO_2	Cu	Fe	Mn	Zn
Phu Khok 1	5.13	0.23	51.83	2.74	2.38
Phu Thong Daeng 1		.46			.32
Phu Thong Daeng 2		.62			.28

In addition, 32 samples from gossan exposed by the bulldozer trenches had the following metal content (in percent):

Copper		*Zinc*	
Range	*Average*	*Range*	*Average*
0.10–2.00	0.48	0.01–0.80	0.34

The gossan also contains traces of Al, Ca, P, Mn, Ba, Be, Co, Cr, Ga, Mo, Nb, Sn, Y, Yb, and Zr, as indicated by semiquantitative spectrographic analysis.

The trenches and the drill holes indicate that the gossan is a surface phenomenon not directly related to subsurface mineralization. Local massive sulfide minerals are present in the drill holes (fig. 8), but most of the minerals are disseminated.

Drill holes 1 and 2 (pl. 4*D*) intersected an upper zone containing approximately 0.3 percent copper to a depth of about 60 m. Below this is the main copper zone which has a thickness of 45–67 m (pl. 4*D*) and an average copper content of 1.08 percent (average of holes 1 and 2). This zone is underlain by weakly mineralized rocks containing about 0.3 percent copper. Incomplete analytical results show a similar mineralized pattern in drill hole 3 (fig. 8).

Semiquantitative spectrographic analyses of core samples showed traces of Al, Mg, Ca, K, Ti, Ag, Ba, Co, Cr, Ga, Mo, Sn, and Zr.

GEOCHEMICAL AND GEOPHYSICAL SURVEYS

Geochemical soil sampling (along east-west traverse lines 200 m apart) and analysis for copper, lead, and zinc showed the presence of geochemical copper anomalies, but no significant lead or zinc anomalies The anomalies (pl. 4*B*) generally correspond to the areas of gossan exposures, except for the gossan of Phu Chieng Muai hill (pl. 4*A*). The 1,000 ppm copper contours apparently outline the principal area of mineralization.

A resistivity survey using a Wenner electrode configuration and a 25 m electrode separation was performed along the geochemical traverse lines. The results show the presence of conductive zones both east and west of the areas of gossan and geochemical anomalies (pl. 4*C*). The conductive zones are probably due to water-saturated alluvial sediments and are unrelated to mineralization.

Electromagnetic surveys consisted of a detailed Slingram survey using a 50-m coil separation and several traverses made with an Afmag instrument, but neither detected a conductive zone. Owing to the great depth of oxidation subsequently found by drilling, a positive response by the Slingram equipment was impossible because of its limited depth penetration, but this is not likely to have affected the Afmag work; massive sulfide mineralization therefore probably is absent.

TONNAGE AND GRADE

Insufficient drilling has been done to outline the potential reserves. One million tons of proven and probable reserves is estimated to be present in a zone 150 m long, 60 m wide, and 45 m thick in the vicinity of drill holes 1 and 2 (pl. 4). Assuming a strike length of 800 m (as indicated by surface gossan exposures), a width of 140 m, and a thickness of 45 m, additional possible reserves are 11.6 million tons.

CONCLUSIONS AND RECOMMENDATIONS

Preliminary drilling results indicate that the Phu Thong Daeng deposit may be a porphyry copper type of deposit in volcanic rocks. To help determine the economic potential of the deposit, the following additional geological investigations are recommended:

1. Detailed studies of rock alteration and mineralization in trenches and drill cores, as well as more detailed geological mapping.
2. An induced polarization geophysical survey over the entire area shown on plate 4*A*.
3. An extensive diamond-drilling program.

PHU POON-PHU PA PHAI PROSPECT

Phu Poon Mountain is just west of the Agricultural Experiment Station adjacent to the Loei-Wang Sa-

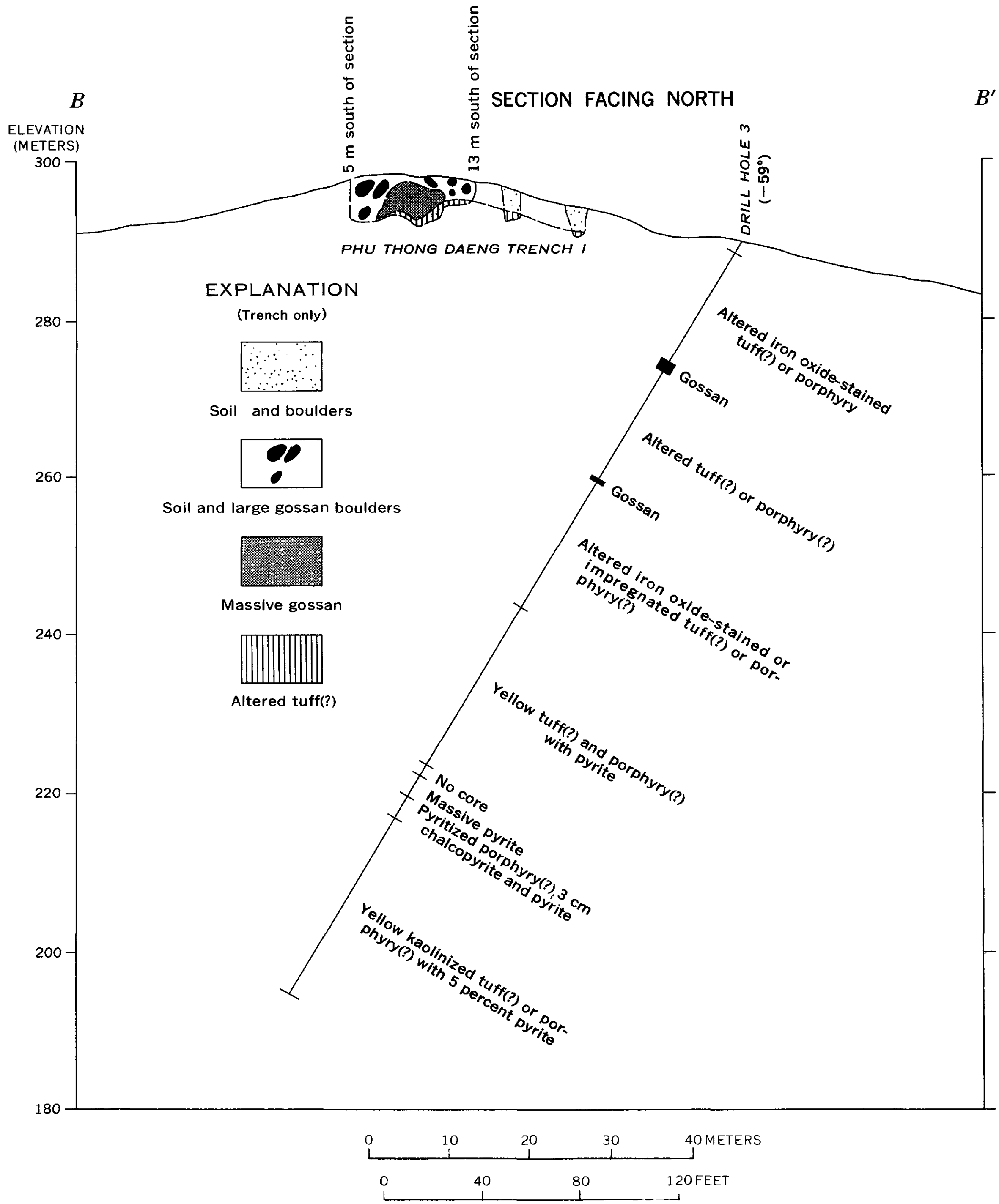


FIGURE 8.—Section *B–B′* through the Phu Thong Daeng copper deposit. (Location of section shown on plate 4*A*.)

phung highway, 10 km south of Loei (pl. 1). Phu Pa Phai is a small hill south of Phu Poon. The prospect (B 11) covers the entire area. The area is readily accessible by car throughout the year.

Ferruginous boulders were previously known in the area.[26] During the present investigation, attention was directed to the area by geochemical reconnaissance and an aeromagnetic anomaly (pl. 2, anomaly M). As a result, detailed topographical, geological, and geochemical work was done over the entire area, and a detailed magnetometer survey was conducted south of Phu Pa Phai.

The area is within a north-northeast-trending belt of rocks of the Kanchanaburi Series. At the south end of the area a granodiorite stock is exposed (pl. 1; fig. 9).

The rocks are interbedded steeply east dipping limestone, shale, sandstone, and tuff (?) (fig. 9) and are offset by an east-west inferred fault 500 m south of the crest of Phu Poon Mountain. Most of a large area of iron oxide-impregnated sedimentary rocks and some gossan is north of the fault (fig. 9). The rocks are probably tuff and sandstone. Locally, iron oxides compose more than half the rock and contain vugs (gossan). The iron oxides are mostly hematite and limonite. South of the fault, dense massive gray limestone is common. The limestone is bleached and recrystallized near its contacts with the iron-stained sediments to the north.

South of Phu Pa Phai is a second smaller area of iron oxide-impregnated strata, and farther south is a granitic intrusive. In this southern area, rock exposures are scarce.

Geochemical soil testing was performed along east-west traverse lines 200 m apart. Analysis of the samples for citrate-extractable heavy metals (copper, lead, and zinc) showed no significant geochemical anomaly (fig. 10) corresponding to the areas of iron oxide-impregnated rocks (fig. 9). A geochemical anomaly was detected at the western base of Phu Poon Mountain, however, where no rocks are exposed except for float. The anomaly is outlined by the 30 ppm citrate-extractable metal contour. Analysis of 14 soil samples for total copper, lead, and zinc showed anomalous maximum copper concentrations of 350 ppm Cu and maximum zinc content of 250 ppm Zn.

A ground magnetometer survey of anomaly M (pl. 2) south of Phu Pa Phai was made by measuring the vertical magnetic field with a Jalander magnetometer along east-west lines 200 m apart. The ground magnetic survey found a weak magnetic anomaly having a maximum magnetic contrast of 500 gammas between two magnetic poles about 1 km apart. Because the airborne magnetic instrument measured the earth's total magnetic field and because the magnetic field is close to horizontal in areas of low latitude, such as Phu Pa Phai, we conclude that the anomaly is due to a magnetic body having a large horizontal magnetic component. The anomaly may be due to a magnetite-bearing intrusive or a "blind" ore body.

Evidence of possible mineralization is present over a large area, but no correlation is possible between geological, geochemical, and geophysical results. Further study of the area is therefore recommended; it should begin with deep-penetration electrical geophysical surveys, such as Turam electromagnetic or induced polarization.

[26] Jalichandra, N., and Bunnag, D., 1954, Report of investigation of the geology and mineral resources of northeastern Thailand: Thailand Geol. Survey Rept. 171 (unpub. rept. in files of Royal Thai Dept. Mineral Resources).

PHU BAW LEK PROSPECT

Phu Baw Lek (B 12) is a low hill 1.5 km northwest of the village of Ban Nong Pham and is accessible by trail from the village (pl. 1, B 12). Ban Nong Pham is 14 km south-southeast of Loei and can be reached by road in the dry season.

Phu Baw Lek is in an area of contact-metamorphic rocks between the Kanchanaburi Series to the north and an instrusive to the south (pl. 1).

Rock exposures at Phu Baw Lek are confined to an area of gossan boulders 20 m wide and 100 m long. The boulders are 20–100 cm in diameter and are composed of banded, vuggy, and brecciated hematite, limonite, and other iron oxides. Brecciation resulted in fractures less than 1 cm apart, and the gossan contains limonite boxworks after sulfides. Analysis of a grab sample of the gossan showed the following base-metal content (in percent): Cu, 0.07; Pb, 0.75; Zn, 1.16.

A geochemical soil survey bracketing the area of gossan boulders detected a weak geochemical anomaly corresponding to the area of gossan boulders having citrate-extractable metal (copper, lead, zinc) concentrations of 16–32 ppm.

Magnetic and electromagnetic surveys found no geophysical anomaly. Electromagnetic measurements were made with Slingram electromagnetic equipment having a 50-m coil separation.

The prospect is very small and no significant mineralization was detected; therefore, no further work is proposed.

NON KHOK KAW PROSPECT

Non Khok Kaw (B 13) is 1.5 km due east of the village of Ban Nong Thum along the new road (under construction in 1966) from Pan Pha Noi to Ban Na Din Dam, which is expected to be an all-weather road. Non Khok Kaw is also 1 km due west of Phu Khum 2 (B 14).

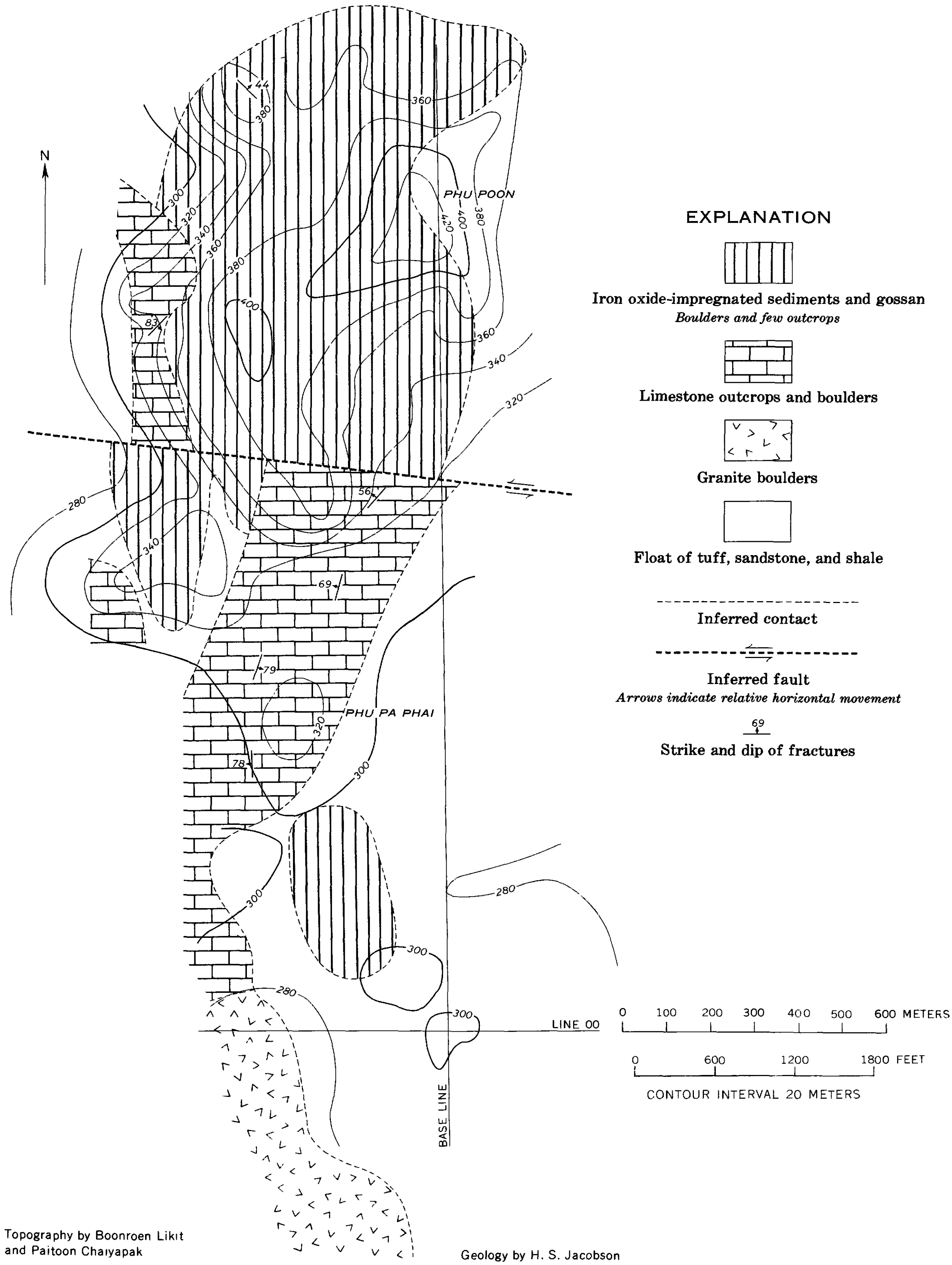


FIGURE 9.—Geologic map of the Phu Poon-Phu Pa Phai base-metal prospect.

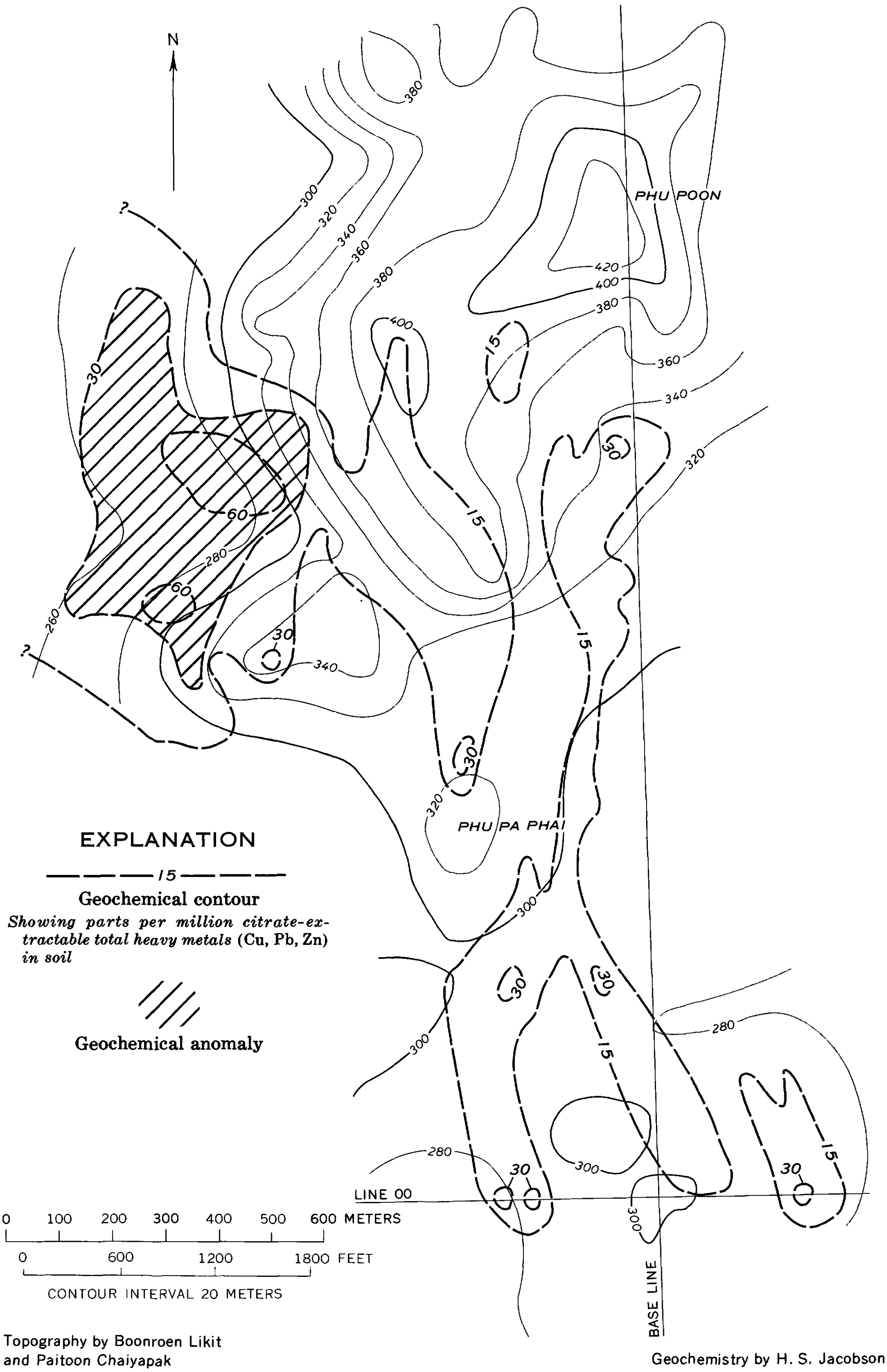


FIGURE 10.—Geochemical map of the Phu Poon-Phu Pa Phai base-metal prospect.

The prospect is at a contact of sedimentary rocks of the Kanchanaburi Series and the same granodiorite intrusive that is associated with the mineralization at Phu Khum 2. The Non Khok Kaw prospect is on a gentle slope of red-brown soil and a few ferruginous boulders and is centered around a very small hill (Non Khok Kaw); an area 5 m in diameter contains large gossan boulders. The boulders are composed of magnetite, specular hematite, limonite, and other iron oxides, and they contain leached cavities with limonite boxworks after sulfide mineralization. A semiquantitative spectrographic analysis indicated traces of Ti, Mn, Ba, Co, Cu, Ga, Mo, Ni, Sn, Sr, and Zr.

A geochemical soil survey indicated a roughly equidimensional anomaly (fig. 11) of citrate-extractable heavy metals (copper, lead, zinc) in the soil. The strongest part of the anomaly, containing more than 50 ppm metal, is about 350 m in diameter. Total metal-content (copper, lead, zinc) analyses of 10 soil samples show that zinc is the predominant metal.

A magnetometer survey detected a magnetic anomaly which corresponds only to the 5-m diameter area of boulders of iron minerals. The prospect probably is too small to have significant economic potential, but some further study with deep-penetration electrical geophysical equipment (Turam electromagnetic or induced polarization) is suggested.

PHU KHUM 1 (BAN KHOK MON) PROSPECT

Geological, geochemical, and geophysical investigations, pitting, and shallow drilling were performed entirely by the United Kingdom Overseas Geological Surveys-Royal Thai Department of Mineral Resources field team.[27] Four diamond-drill holes were drilled under the supervision of the authors.

The Phu Khum 1 prospect (B 14) is 5 km north of the village of Ban Khok Mon, 18 km southeast of Loei, and 4 km east-southeast of the Phu Khum 2 (Ban

[27] See Footnote 2, p. 1.

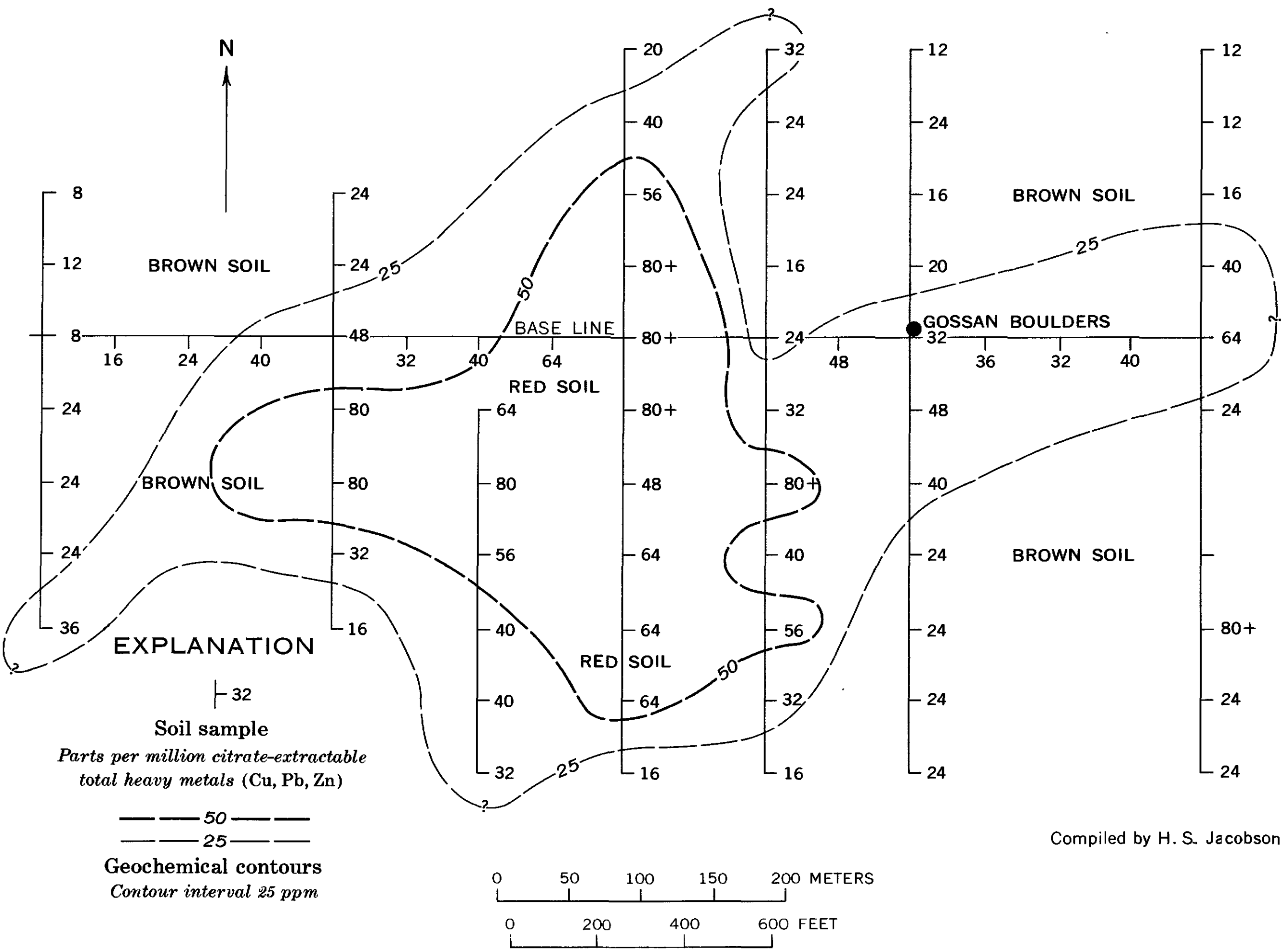


FIGURE 11.—Geochemical map of the Non Khok Kaw base-metal prospect.

Nong Ya Sai) prospect. The prospect is accessible by a dry-weather road joining the Wang Saphung-Udorn road about 3 km east of the village of Ban Na Dok Mai.

Phu Khum 1 is within the area of the Ratburi Limestone (pl. 1), but rocks of other units probably also occur.

The prospect consists of a roughly circular area of rocks, variously described in the past as andesite porphyry, agglomerate, limestone conglomerate, and breccia (pl. 5*A*), surrounded by limestone and siltstone. More recently (Overseas Geol. Surveys and Thai Dept. Mineral Resources, 1966), this map unit has been called "diorite porphyry with marginal intrusion breccia." In the drill cores (p. 73) the "intrusion breccia" has the appearance of a limestone conglomerate consisting of numerous limestone fragments as much as 5 cm in diameter and sparse fragments of other rocks, all in a carbonate matrix.

The other lithologic units mapped (pl. 5*A*) are massive limestone, interbedded limestone and siltstone, and yellow sandstone and siltstone. Low topographic relief in the area has resulted in very poor surface exposure of these rocks, except for the massive limestone.

Diamond drilling of four short "packsack" holes by the United Kingdom Overseas Geological Surveys and four deeper holes drilled under the supervision of the authors disclosed the presence of sulfide mineralization. Drill holes 1 and 2 (pl. 5*D*) located 5–30 percent pyrite in limestone, with pinhead grains of galena. Drill hole 3 (pl. 5*E*) intersected similar material but also found 3 m of massive sulfide mineralization with carbonate gangue containing pyrite, sphalerite, and galena. Chemical analyses by the United Kingdom Overseas Geological Surveys showed as much as 24.8 ounces of silver per ton; the gold content is negligible. Drill hole 4 intersected limestones with local traces of pyrite, galena, and sphalerite.

A detailed geochemical soil-sampling survey with samples at 25-m intervals along east-west traverse lines 50 m apart showed a series of anomalies (pl. 5*B*) commonly containing more than 500 ppm zinc and more than 500 ppm lead. Locally, zinc content exceeds 5,000 ppm; lead, 3,000 ppm. The anomalies have a roughly circular pattern along the perimeter of the area of andesite porphyry and other rocks (pl. 5*A*), indicating that base-metal mineralization occurs along the contact with the massive limestone.

Electrical self-potential, electromagnetic, and induced-polarization surveys were conducted along east-west traverse lines 50 m apart; anomalies were detected in the northwest corner of the area (fig. 12) along the contact zone, which was subsequently tested by diamond drilling. Other self-potential and electromagnetic anomalies (fig. 12) also tend to be associated with the contact. The induced-polarization survey resulted in several areas of high "metal factors" or induced-polarization anomalies (fig. 12). The small anomaly southwest of drill hole 3 probably reflects the mineralization intersected by the drill hole. The long anomaly between the baseline and drill hole 3 was recently tested by a drill hole which intersected 27.5 m of disseminated pyrite (Workman and Cratchley, written commun., 1966).

The geological, geochemical, and geophysical results all show the presence of sulfide mineralization along a contact zone. The zone was partly tested by four drill holes, only one of which penetrated high-grade base-metal mineralization. A few additional diamond-drill holes are recommended to test the induced polarization anomalies.

PHU KHUM 2 (BAN NONG YA SAI) PROSPECT

The geological, geochemical, and geophysical investigations, pitting, and shallow drilling were almost entirely carried out by the United Kingdom Overseas Geological Surveys-Royal Thai Department of Mineral Resources field team.[28] The work done by the authors was confined to geologic and magnetic surveys over the area of iron mineralization and diamond drilling.

The Phu Khum 2 area (B 15) is a range of low hills 2 km long, having maximum relief of about 100 m; it is 2.5 km due east of the village of Ban Nong Thum and 2–3 km southeast of the village of Ban Nong Ya Sai (pl. 1, B 15). The area lies 15 km southeast of Loei and is readily accessible by road in the dry season. All-weather access roads are under construction.

The Phu Khum 2 prospect is along a contact between a granodiorite intrusive on the west and beds of the Ratburi Limestone on the east (pl. 1). The granodiorite in the southwest corner of the area of the prospect (pl. 6*A*) is a medium- to coarse-grained rock containing considerable plagioclase, little orthoclase, and variable amounts of quartz and mafic minerals. Locally, where quartz content is low and mafic minerals increase, the rock approaches the composition of quartz diorite.

Massive Ratburi(?) Limestone adjoins the granodiorite on the east in a north-trending belt (pl. 6*A*). The limestones are white and gray and are bleached and recrystallized at the intrusive contact and along joint planes near the contact. Beds of siltstone and mudstone occur east, west, and below the limestone (pl. 6; fig. 13) but are poorly exposed.

Few bedding attitudes could be measured. South of the fault, near line A (pl. 6*A*), the beds apparently have a shallow east dip, and local drag folding was observed. The principal structures are a series of east-

[28] See Footnote 2, p. 1, Bleackley and others, 1965.

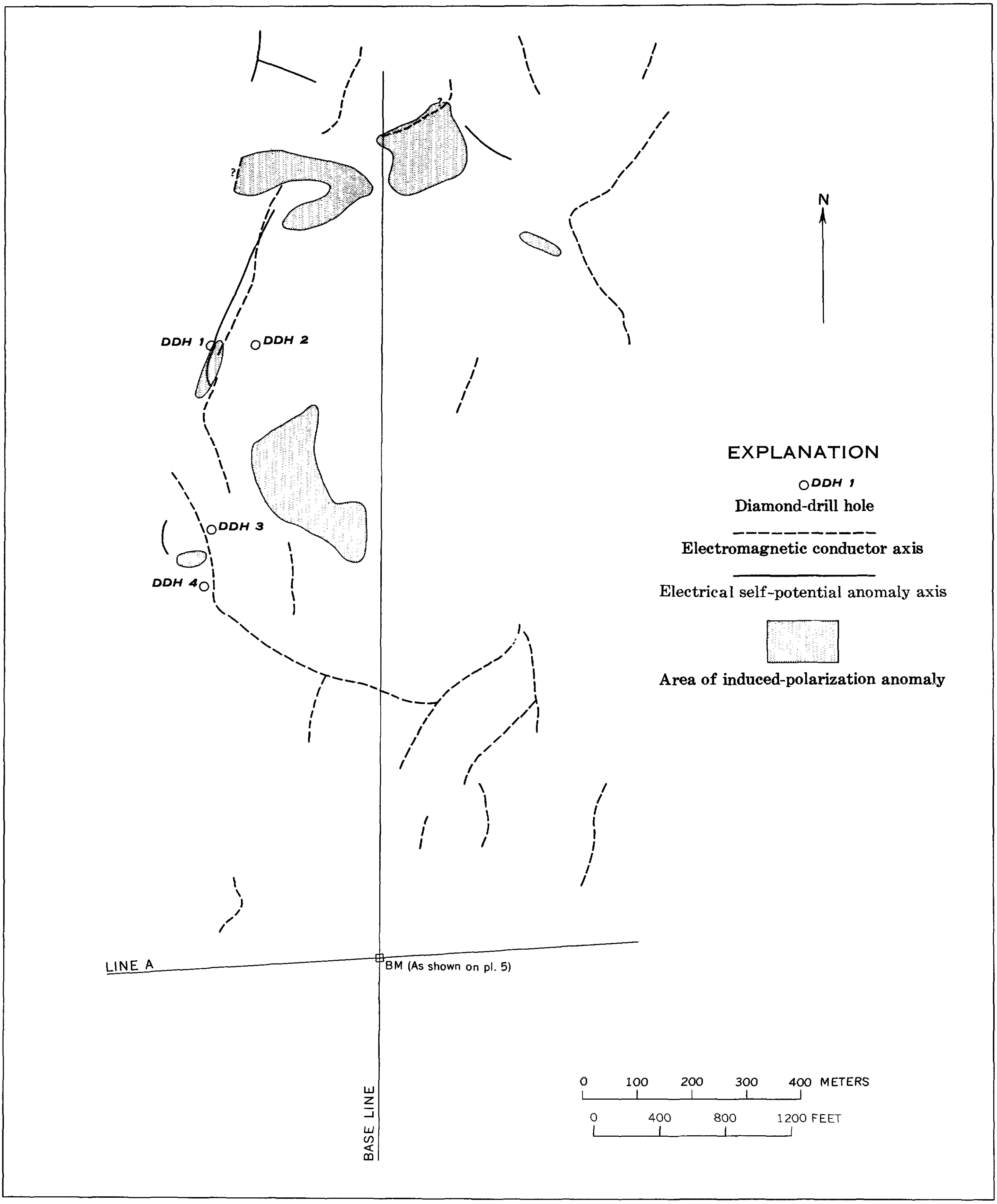


FIGURE 12.—Map showing summary of results from electromagnetic, self-potential, and induced-polarization surveys at the Phu Khum 1 (Ban Khok Mon) base-metal prospect. Data from Bleackley and others, 1965 (see footnote 2, p. 1).

to northeast-trending faults inferred from geological and geophysical observations. The two main joint systems strike west-northwest and north-northwest; dips are nearly vertical.

Rock alteration is limited to contact metamorphism at the granodiorite-limestone contact and to bleaching and recrystallization of the limestone along the walls of some joint planes. Although Phu Khum 2 is primarily a base-metal prospect, small areas of massive hematite-magnetite boulders were observed north of line A and west of the base line (pl. 6*A*). Pitting in this area indicated the presence of two narrow, steeply dipping zones of massive magnetite, one of which is 40 cm wide. The other zone is probably not significantly wider but was not fully exposed.

Numerous old pits near the intrusive contact (pl. 6*A*) show the presence of lead-zinc minerals. Secondary cerussite and smithsonite were observed in the caved pits. Minor amounts of galena, sphalerite, and pyrite occur along some of the joint planes.

Diamond drilling, including two short "packsack" holes drilled by the United Kingdom Overseas Geological Surveys and one hole (DDH 1, fig. 13) drilled under supervision of the authors, found only local traces of base metals. Additional drilling by the Royal Thai Department of Mineral Resources is in progress (1966).

A detailed geochemical soil survey (samples taken every 25 m along east-west traverse lines 50 m apart) showed the presence of very strong geochemical lead and zinc anomalies and weaker copper anomalies. The principal anomalous area (pl. 6*B*) is a northwest-trending zone about 800 m long and averaging about 300 m wide; it is south of line A, where the soil contains more than 2,000 ppm zinc and more than 500 ppm lead. Within the anomaly the zinc in the soil locally exceeds 30,000 ppm and the lead exceeds 30,000 ppm. The central part of the anomaly also contains at least 500 ppm copper. This unusually strong geochemical anomaly is in part caused by contamination from the numerous old pits and dumps (pl. 6*A*). Other smaller geochemical anomalies were noted east and south of this large anomaly; because of the lower mobility of lead in a surface environment, the lead anomalies cover a smaller area than the corresponding zinc anomalies; therefore, the subsurface mineralization is probably more closely related to the lead anomalies.

Magnetic, electromagnetic, electrical self-potential, and induced-polarization surveys were conducted. Magnetic surveys were made south of line A (pl. 6*C*) by C. R. Cratchley [29] and to the north by the authors. Local strong magnetic anomalies of northeast strike, observed north of line A (pl. 6*C*), correspond to the areas of hematite-magnetite boulders (pl. 6*A*). No large magnetic contrasts were observed elsewhere in the area.

An electromagnetic survey was conducted over the entire area (pl. 6*D*) along east-west traverse lines 50 m apart by means of 75-m coil separation with an "electromagnetic gun" instrument. A series of short electromagnetic conductors were detected (pl. 6*D*).

Roughly, the southern one-third of the area of the electromagnetic survey (pl. 6*D*) was also explored with electrical self-potential and induced-polarization equipment. Two local self-potential anomalies and two near-surface induced-polarization anomalies were detected (pl. 6*D*). The induced-polarization anomalies correspond to the principal geochemical anomalies (pl. 6*B*).

The principal geochemical and geophysical anomalies were tested by drill hole 1 (fig. 13), but no ore was found. The very strong geochemical anomalies, however, indicate the presence of lead-zinc minerals; further test drilling is recommended closer to the intrusive contact and along the strike of the geochemical and induced-polarization anomalies.

BAN HUAI PHUK PROSPECT

The prospect is just north of the north edge of the village at Ban Huai Phuk (B 16) and is at a contact of the Kanchanaburi Series and a small intrusive stock. The village is accessible by a road joining the Loei-Wang Saphung highway from the west 1 km north of the point where the highway crosses the Loei River (pl. 1).

The prospect consists of boulders of gossan and vein quartz adjacent to the road north of the village. A small hill a few hundred meters to the east exposes scattered outcrops of hornblende granite. Reconnaissance geochemical soil sampling showed the presence of an anomaly at the prospect.[30]

The prospect is believed to be small, but further study is recommended to determine the extent of the gossan boulder field and geochemical anomaly.

KHUM THONG PROSPECT

The Khum Thong prospect (B 17) is 13 km south of Loei and 3.5 km west of the village of Ban Pak Puan on the Loei-Wang Saphung highway (pl. 1). A dry-weather road west from the village approaches to within 1 km of the prospect.

The prospect is west of a granodiorite stock (pl. 1) in an area of rocks of the Kanchanaburi Series. The igneous host rock at the prospect possibly is a dike.

[29] See footnote 2, p. 1, Bleackley and others, 1965.

[30] See footnote 2, p. 1; Bleackley and Workman, 1964.

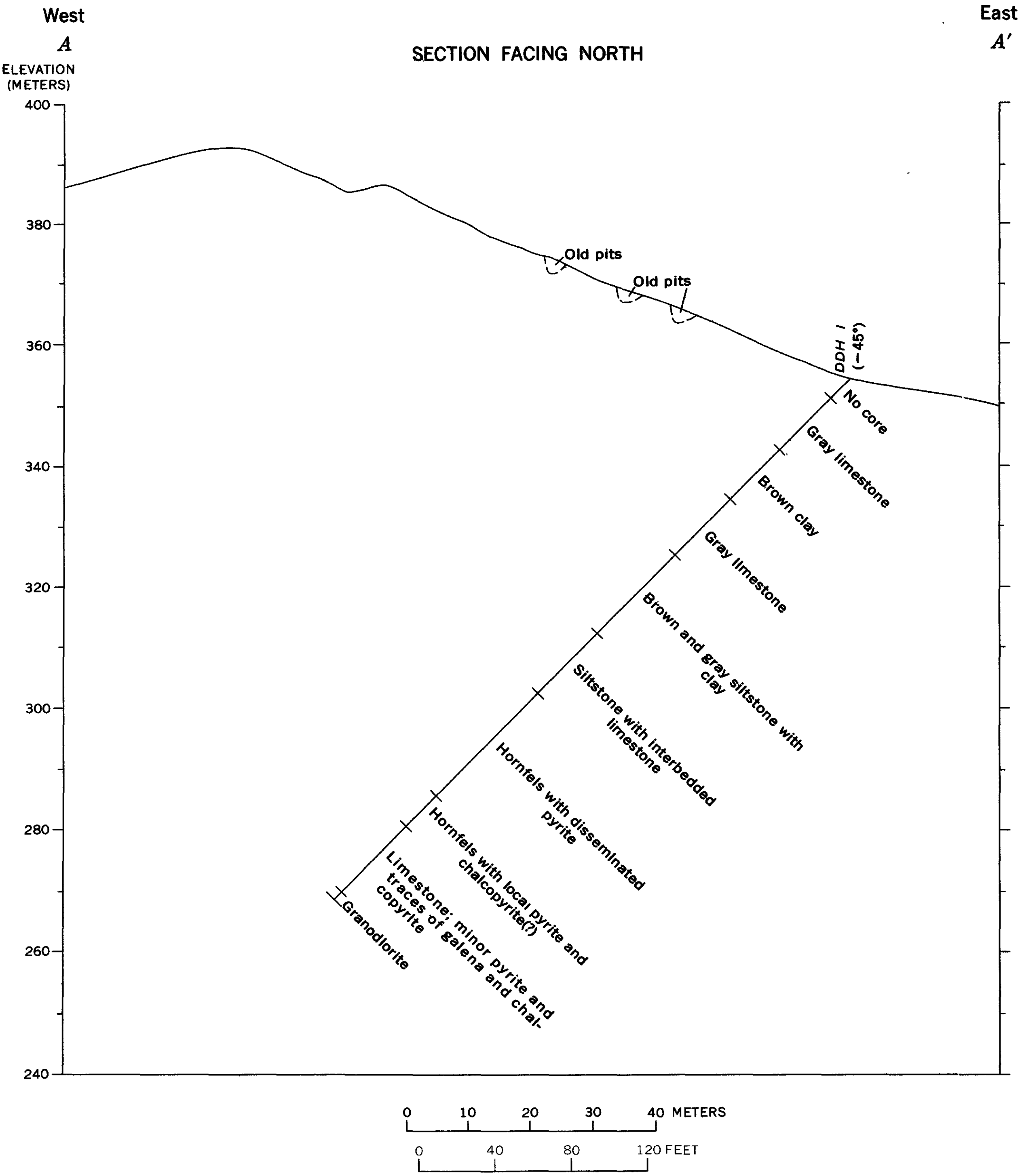


FIGURE 13.—Phu Khum 2 (Ban Nong Ya Sai) base-metal prospect, cross section A–A'. (Position of DDH 1 shown on plate 6.)

The prospect consists of a single partly caved pit 3 m deep and 5 m in diameter. In the pit, a weathered diabase or gabbro outcrop stained by iron and copper oxides is exposed. The area surrounding the pit is covered by soil that was tested geochemically. A geochemical anomaly 140 m in diameter was detected in the soil surrounding the pit. The geochemical anomaly probably resulted from contamination from the dump.

The prospect is very small, but the presence of disseminated copper minerals is of interest.

IRON

PONE BAK THEK PROSPECT

The Pone Bak Thek prospect (Fe 1) is in a roadcut 7 km due east of Chiengkarn (pl. 1) along the new road under construction in 1965–66 parallel to the Mekong River.

The prospect is near an intrusive contact buried beneath alluvium of the Mekong River valley (pl. 1), and is confined to a road section, 70 m long, with red soil and boulders of iron minerals. The boulders include massive hematite and iron oxide-impregnated rocks. Sixty meters north of the road are boulders of granodiorite; one boulder of barite was observed.

A dip-needle magnetometer traverse indicated the presence of a magnetic anomaly 10–20 m long.

The prospect is small, and some of the boulders of iron minerals were used as road fill. It is at a low elevation close to the Mekong River, and will be flooded after the construction of the proposed Pa Mong dam.

PHU LEK (CHIENGKARN) DEPOSIT

Phu Lek is a low hill 1 km south of the east end of the town of Chiengkarn (pl. 1, Fe 2). The hilltop is at an elevation of 300 m, and the base of the hill is at an elevation of 220 m. The lower slopes of the hill will therefore be covered by water after the construction of the proposed Pa Mong dam, and the prospect will be on a small island accessible only by boat. Present access is by road from Chiengkarn.

Phu Lek is at the contact of the granodiorite intrusive south and east of the deposit (pl. 1). Granodiorite is exposed in a short section of the creek at the base of the hill (fig. 14) where it is bounded both north and south by skarn (sample J5, p. 95) outcrops. The contacts between the skarn and the granodiorite strike northwest. Elsewhere in the creek, shale and quartzite are exposed. On the Phu Lek hill, rock exposures are confined to areas of large boulders of iron minerals (0.5–1.0 m in diameter outlined in fig. 14) and float of boulders and fragments. The boulders are mainly massive hematite; associated iron oxides contain 64 percent iron. Additional exposures were obtained by trenching and drilling. Trench 1 exposed weathered quartzite(?) or aplite(?), and trench 2 exposed massive hematite (fig. 15). A diamond-drill hole (DDH 1) was drilled to test the iron exposed in trench 2, and a massive magnetite-hematite body 6.7 m thick was intersected (fig. 15). (The hole was drilled to 54.1 m in May 1966 and subsequently deepened to 104.6 m. The deepened part is not included in fig. 15.)

Below the iron the drill hole cut a contact zone composed mainly of hornfels containing minor local magnetite and pyrite to a depth of 81.7 m. The hole was bottomed in granodiorite.

A preliminary magnetometer survey was performed in 1963, and additional detail was added in 1966. The results of both surveys are shown in figure 16. The magnetic map shows a series of weak magnetic anomalies of 2,000 gammas which roughly correspond to many of the observed areas of boulders of iron minerals. The broader and weaker magnetic anomaly outlined by the 1,000-gamma contour is probably related to a minor magnetite concentration in the intrusive contact zone.

The strike length of the areas of boulders of iron minerals (fig. 14) is 500 m, but the deposit is believed to be irregular and discontinuous. Consequently, a total mineralized length of 250 m is assumed for the reserve calculations. The thickness of the iron interval in the drill hole is 6.7 m, and a downdip extent of at least 60 m is likely (fig. 15). Assuming a specific gravity of 4, the calculated proven and probable reserves are therefore 400,000 tons. Possible reserves are not estimated because the deposit may be cut off downdip by the intrusive.

The Phu Lek deposit is relatively small. We therefore recommend only limited additional drilling to better outline the iron deposit.

PHU YANG DEPOSIT

The Phu Yang iron deposit lies on the crest of Phu Yang Mountain above an elevation of 550 m. It is 8 km southeast of Chiengkarn and 4 km south of the Mekong River (pl. 1, Fe 3).

Access to the deposit is by road from Chiengkarn. The deposit is reached by traveling 6 km east from Chiengkarn along a new all-weather road to the Huai Nam Ping Noi Creek where the Phu Yang access road turns off to the south. The access road is a former elephant trail which was widened and extended to provide access for drilling equipment. It is open only in the dry season to vehicles equipped with four-wheel drive.

The Phu Yang area was investigated for 1 month by the Krupp Rohstoffe Co. team of geologists and geophysicists in 1958 [31] following a preliminary reconnais-

[31] Krupp Rohstoffe Co., 1959, Raw material survey iron and steel industry, Thailand: Expedition 1957–58 Main Rept. (unpub. rept. in files of Royal Thai Dept. Mineral Resources).

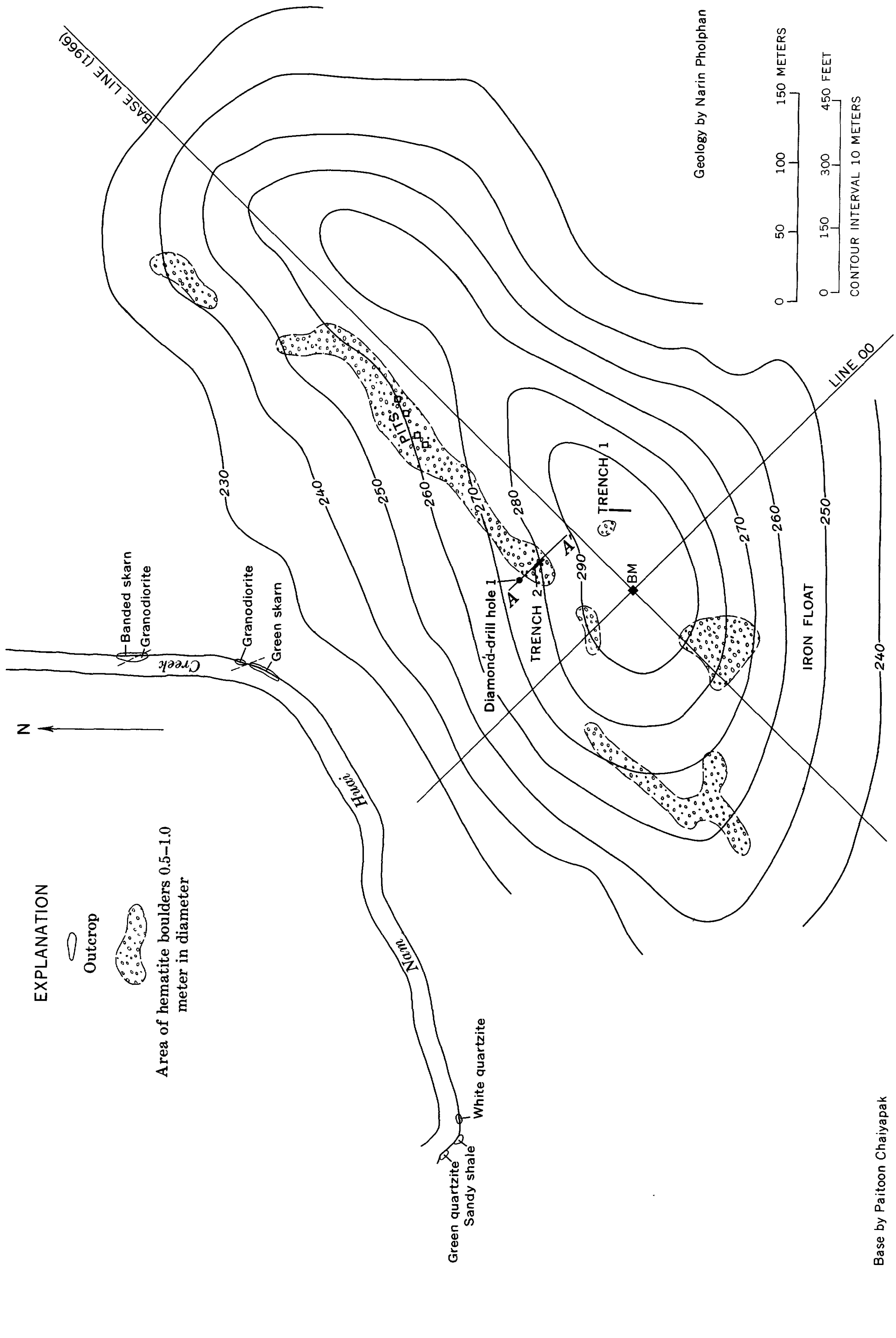


FIGURE 14.—Geologic map of the Phu Lek (Chiengkarn) iron deposit.

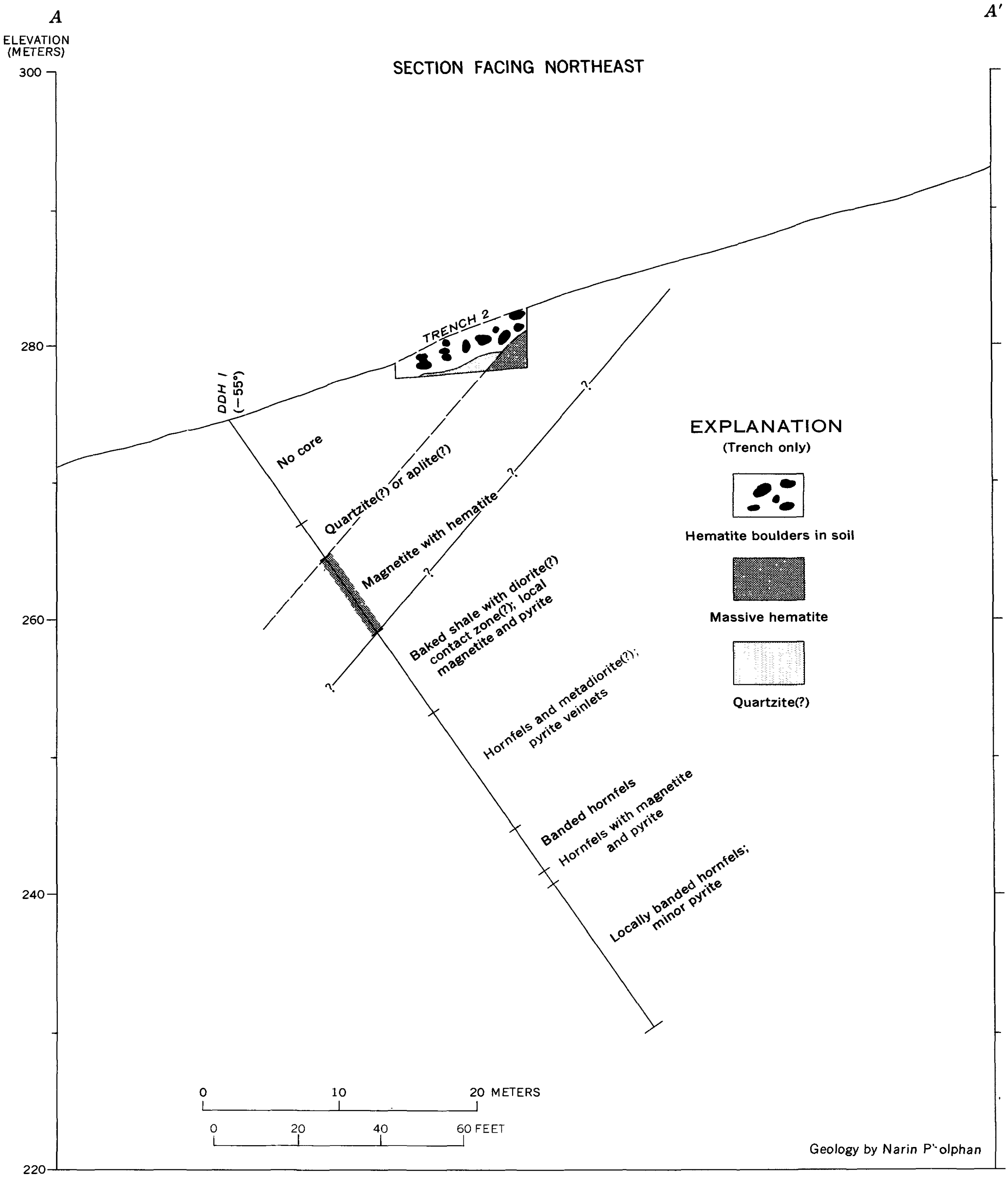


Figure 15.—Section *A–A'* through the Phu Lek (Chiengkarn) iron deposit. (Position of section shown in figure 14.)

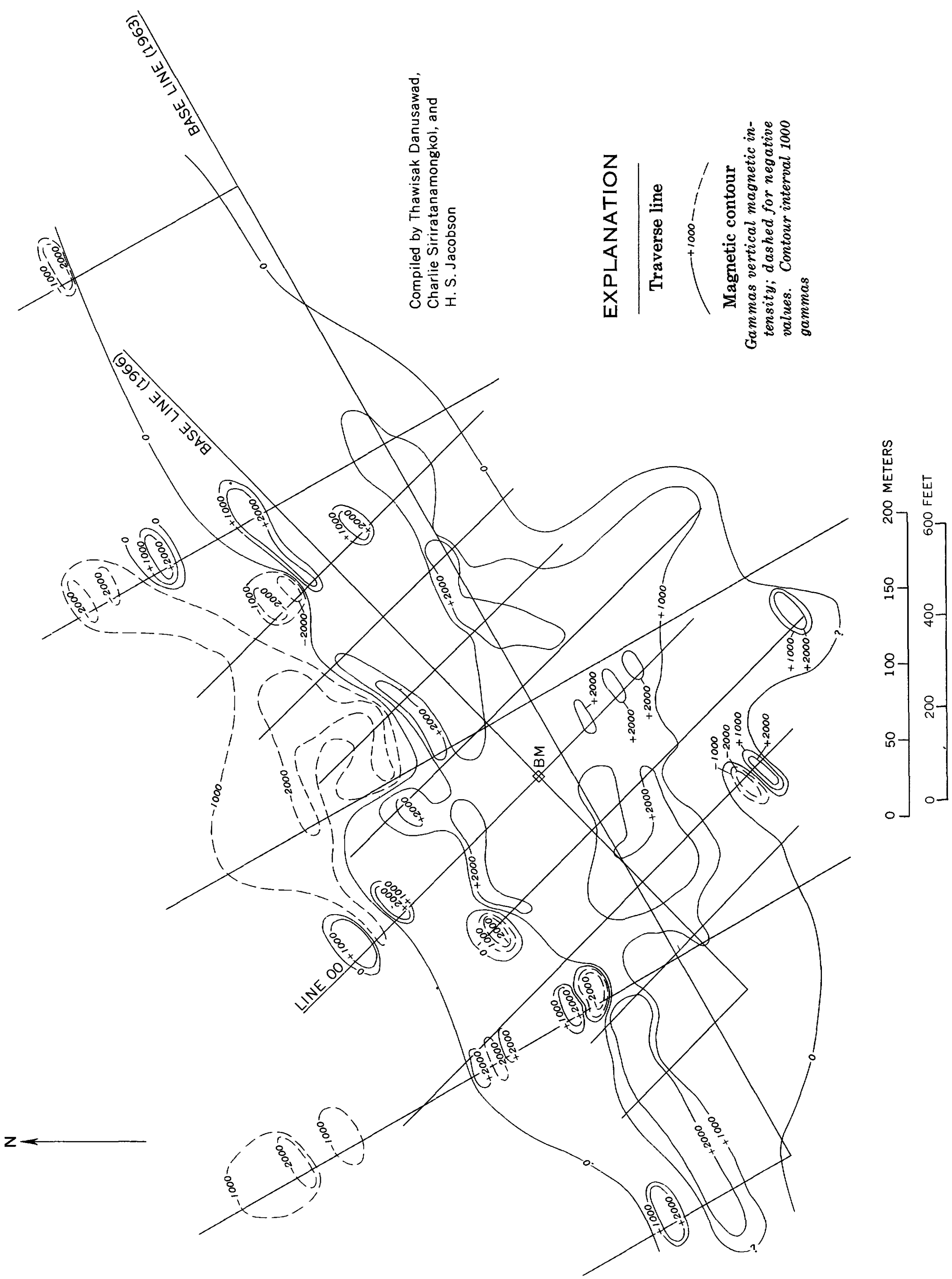


FIGURE 16.—Magnetic map of the Phu Lek (Chiengkarn) iron deposit.

sance by the Royal Thai Department of Mineral Resources. The Krupp Rohstoffe Co. investigations included geological reconnaissance, topographic and geologic mapping, magnetometer survey of part of the area, and excavation of several shallow pits.

The present investigation included (1) geological reconnaissance of the Phu Yang Mountain and adjacent mountains; (2) detailed topographic and geologic mapping of the area of the iron deposit; (3) a detailed magnetic survey; and (4) diamond drilling of 10 holes.

The Phu Yang deposit occurs within a roof pendant of a granodiorite stock (pl. 1) in a series of metamorphosed sedimentary and volcanic rocks (Devonian or older?). The mineralized area is limited by granodiorite on all the lower slopes of the Phu Yang Mountain. (Diamond-drill hole 7 penetrated the top of the granodiorite at a depth of 88.5 m.)

The deposit is a bedded replacement in a section of beds that strike east and have a shallow dip to the south. Many of the beds have been metamorphosed to hornfels.

GEOLOGY

At the surface (pl. 7*A*), boulders of hornfels and granodiorite are exposed north and south of the hematite-magnetite outcrops. The hornblende-biotite granodiorite is virtually unweathered at the surface, probably because of the steep slopes and consequent rapid erosion. In the bottom of drill hole 7, presumably the same intrusive has been described as syenite or monzonite (samples J599A and F; p. 94, 95); the composition was probably changed by contact effects.

The hornfels mapped on the surface (pl. 7*A*) is an undifferentiated composite of hornfels and silicified rocks noted in the drill holes (pl. 7*C*, *D*). These rocks were visually identified in the cores as layered hornfels, silicified andesite porphyry, and silicified rhyolite porphyry. The latter two have been described petrographically as quartz latite, rhyodacite, microdiorite, and diabase (p. 94, 95). Other metamorphic rocks are also present in the drill holes. These are mainly siliceous metamorphosed carbonate rocks. (Sample P58, p. 94.)

The layering in the hornfels probably represents bedding and is parallel to the fractures observed in the surface iron-bearing outcrops. The strike is east; the dip, 20°–30° S. The deposit is tabular, parallel to the layered hornfels, indicating that it is a bedding replacement. The gangue is mainly carbonate.

The only observed evidence of faulting was the clay gouge at the apparent fault contact between the iron mineralization and the underlying metamorphic rocks in drill hole 3 (pl. 7*C*).

A few massive hematite-magnetite outcrops on the Phu Yang ridge (pl. 7*A*) contain sparse cubical leached cavities after pyrite. Massive hematite-magnetite boulders apparently derived from the outcrops are irregularly scattered on the slopes of the mountain but occur principally on the northern slope (pl. 7*A*). Areas containing boulders of iron minerals greater than 30 cm in diameter were mapped, but smaller ones are common on all the slopes. Pitting by the Krupp, Rohstoffe Co. indicated that the surface blanket of boulders of iron minerals and soil on the northern slope of the mountain has an approximate thickness of 3 m and contains 15–25 percent boulders of iron minerals by volume.

In the drill holes (pl. 7*C*, 7*D*), the iron occurs near the surface as hematite-magnetite with occasional vugs from which pyrite has been leached (p. 94–76). This "oxidized zone" has an average thickness of 10.7 m and follows the trace of the surface topography (pl. 7, section *A–A'*). The "oxidized zone" is underlain by its parent material of magnetite with pyrite. The magnetite-pyrite body is a shallow-dipping lens. The lenticular shape is illustrated by the longitudinal section *B–B'* and the dip, by cross section *A–A'*. The average thickness is 34.2 m, including a few short intervals of unmineralized skarn and hornfels. A second thinner lens occurring at greater depth was intersected by drill holes 1 and 2 (see section *A–A'*). The iron mineralization occurs as partly friable medium-grained magnetite containing pyrite as irregular disseminations, pods, and stringers. Local traces of chalcopyrite were also observed. The gangue consists of carbonates, quartz, and unmineralized skarn and hornfels, unreplaced rock fragments, and horses of waste. The quantity of unmineralized rock in the iron deposit increases toward the margins.

MAGNETIC SURVEY

A magnetometer survey was conducted to outline the previously discovered aeromagnetic anomaly at Phu Yang (pl. 2). Measurements of vertical magnetic intensity were made with a Jalander magnetometer along north-south traverse lines 50 m apart. The magnetic map (pl. 7*B*) shows a negative magnetic anomaly corresponding to the magnetic iron outcrops on the top of the mountain, flanked by a positive magnetic anomaly to the south. This magnetic pattern was initially interpreted as representing a shallow-dipping tabular magnetic horizon with east strike and southerly dip.

This interpretation was used as a basis for the diamond-drilling program, and the drilling results subsequently confirmed the interpretation.

Additional local anomalies were detected south and east of the main anomaly (pl. 7*B*). These anomalies are related to localized iron outcrops and areas of boulders of iron minerals.

TONNAGE AND GRADE

Small parts of the iron deposit in outcrops and adjacent to drill holes are in the proven ore category, but most of the deposit must be regarded as probable reserves. More drill holes are needed before the reserves are proven, and the proven and probable reserves are therefore combined.

The probable and proven reserves are calculated from the drilling results and are divided into two zones: the surface hematite-magnetite zone and the underlying magnetite-pyrite zone (see cross section, pl. 7).

The surface hematite-magnetite zone has an estimated surface area of 41,000 sq m and an average thickness of 10.7 m. The specific gravity as determined from drill core is 3.5. The proven and probable reserves are thus about 1.5 million tons.

The magnetite-pyrite zone has an estimated length of 330 m (pl. 7, *B–B′*), a width of 200 m (pl. 7, section *A–A′*), and an average thickness over the whole area of 34.2 m. The average specific gravity determined from some drill cores is 4.1. The proven and probable reserves are calculated to be about 9.25 million tons. This includes more than half a million tons of pyrite. The total proven and probable reserves are thus 10.75 million tons.

The hematite-magnetite boulders scattered on top and on the northern slope of Phu Yang Mountain, plus scattered small iron outcrops, constitute a possible reserve. The surface area of the soil containing boulders of iron minerals is estimated at 200,000 sq m, and the average thickness determined from both drill holes and pits is 3.3 m. Pit maps by the Krupp Rohstoffe Co. show that about 20 percent of the soil-boulder mixture consists of boulders of iron minerals. Using the above data, a possible surface reserve of about half a million tons was calculated.

Possible subsurface reserves of magnetite-pyrite probably occur as follows:

1. Reserves west of drill hole 4 and east of drill hole 6 (pl. 7, section *B–B′*).
2. A possible offset ore body south of drill hole 3, because the iron mineralization was terminated in the drill hole by clay fault gouge.
3. Reserves in the thin magnetite-pyrite zone beneath the main deposit intersected by drill holes 1 and 2 (pl. 7, sections *A–A′*, *B–B′*).
4. Outlying mineralization indicated by the magnetometer survey. These possible reserves together are estimated at 3 million tons; the total possible reserves are thus 3.5 million tons.

The drill cores were split and analyzed at about 2-m intervals (p. 74–76) for iron and sulfur. The iron analyses were subsequently adjusted by subtracting the percentage of iron in pyrite to obtain the percentage of iron in hematite and magnetite, as utilization of the iron in the deposit will first require removal of the pyrite. The adjusted analyses were then averaged and grouped for each drill hole (table 6).

TABLE 6.—*Summary of iron and sulfur analyses of Phu Yang drill-hole samples*

Drill hole	Sample type	Interval (meters)	Thickness (meters)	Iron in hematite or magnetite (percent)	Pyrite (percent)
1	Core	6.2–12.0	5.8	61.59	1.09
	do	12.0–41.5	29.5	57.37	7.10
	do	56.8–60.3	3.5	31.97	15.11
2	do	.9–14.6	13.7	64.89	.43
	do	14.6–60.0	45.4	50.71	5.63
	do	74.3–79.5	5.2	42.07	6.14
3	do	4.6– 9.1	4.5	66.77	.28
4	do	41.7–73.2	31.5	38.94	9.16
5	Sludge	.0–10.7	10.7	50.99	1.11
6	Core, sludge	27.5–38.7	11.2	49.24	8.77
7	Core	1.5–13.7	12.2	62.45	.26
	do	13.7–25.8	12.1	57.74	3.42
	do	28.6–49.8	21.2	47.27	3.70
	do	55.3–82.0	26.7	52.52	6.81
8	do	1.5–11.0	9.5	57.16	1.67
	do	11.0–24.7	13.7	45.94	6.06
	do	24.7–60.3	35.6	36.34	6.08
9	Sludge	.0– 6.1	6.1	11.15	3.14

The averages of the drill holes show (table 6) iron contents in iron oxides ranging from 57.16 to 66.77 percent in the surface hematite-magnetite zone (pl. 7) and 36.34 to 57.74 percent in the magnetite-pyrite zone. The average iron content in the hematite-magnetite zone is 62.4 percent (table 6); in the magnetite-pyrite zone, 45.9 percent. This magnetite-pyrite zone includes local unmineralized skarn and hornfels.

The pyrite content (table 7) ranges from 0.28 to 1.11 percent in the hematite-magnetite zone and from 3.42 to 9.16 percent in the magnetite-pyrite zone. Average pyrite content of the two zones is 0.7 and 6.2 percent, respectively.

Chemical analyses of composite samples from drill holes 2 and 4 show the presence of the following impurities in percent:

Drill hole	SiO_2	Ti	Cu	Zn	P	As
2	7.6–11.2	0.005–0.02	0.04–0.12	1.2–2.3	0.02–0.05	None
4	13.0–15.7	.04–.10	.31–.46	.25–.30	.01–.09	0.01–0.03

The copper in drill hole 4 may be a recoverable byproduct.

Chemical analyses for antimony, gold, and lead showed the absence of detectable amounts of these elements; but traces of Mn, Ba, Co, Cr, Ga, Mo, Ni, Pb, Sn, Sr, and Zr were detected by semiquantitative spectrographic analyses.

The tonnage and grades are summarized in table 7, which shows total reserves of more than 14 million tons, containing an average of 48.5 percent iron in hematite and magnetite.

TABLE 7.—*Summary of tonnage and grade, Phu Yang iron deposit*

Zone	Reserves (millions of metric tons)			Average iron in hematite and magnetite (percent)	Average pyrite (percent)
	Proven and probable	Possible	Total		
Hematite-magnetite	1. 5	0. 5	2. 0	62. 4	0. 7
Magnetite-pyrite	9. 25	3. 0	12. 25	45. 9	6. 2
Total	10. 75	3. 5	14. 25	48. 5	5. 2

CONCLUSIONS AND RECOMMENDATIONS

The feasibility of economic development requires an evaluation of economic factors that are beyond the scope of this report. However, the favorable and unfavorable factors are:

Favorable factors:

1. Low-cost transportation along the Mekong River.
2. Low-cost mining by open-pit methods with minimal stripping.
3. The hematite-magnetite zone is direct shipping-grade iron ore.
4. The magnetite-pyrite zone is amenable to dry magnetic separation, yielding a concentrate having iron content of 66 percent at 90 percent recovery (Apisak To-Krisana and Sunt Rachdawong, written commun., 1966).
5. Possible recovery of valuable byproducts of pyrite, copper, and zinc.

Unfavorable factors:

1. Rather low grade of the magnetite-pyrite zone. (Grade of mill feed could probably be increased by selective mining.)
2. High processing cost because of the need to remove pyrite from the iron ore.
3. Long distance from present markets.

The following additional work is recommended to evaluate the Phu Yang iron deposit:

1. Economic feasibility study.
2. Detailed topographic survey.
3. Additional drill holes on a close-spaced grid.
4. Additional metallurgical testing of the ores.

PHU HIA DEPOSIT

The Phu Hia deposit (pl. 1, Fe 4) is in one of the foothills of Phu Sam Hai Mountain 2.5 km southeast of the village of Ban Umung. The village is 11 km due east of Chiengkarn (pl. 1). Phu Hia is reached by following the all-weather main road east from Chiengkarn about 7 km to the village of Ban Pha Baen. Just east of the bridge at the east end of the Ban Pha Baen village, a dry-weather road joins the highway and leads to Phu Hia via Ban Umung.

The Phu Hia deposit (Fe 4) is in an area of Devonian and lower Carboniferous quartzite, shale, and marble (pl. 1). These rocks are exposed in the creek south of the prospect (pl. 8*A*).

Fractures in rocks exposed in the creek strike north and dip steeply west. This trend may represent bedding. Igneous rocks are not exposed on the surface, but granodiorite was found in the drill holes. Massive magnetite occurs in two outcrops on top of the hill (pl. 8*A*) and as boulders on all the hill slopes. Downdip extensions of the magnetite exposed in outcrop were tested by diamond drilling.

The southern outcrop (pl. 8*A*) was tested below by drill hole 1 (pl. 8*D*). The hole intersected iron mineralization from 18.6–21.3 m and from 25.3–47.8 m below the collar. Analyses of core samples gave the following averages:

Interval	*Thickness*	*Iron*	*Sulfur*
(meters)		*(percent)*	
18. 6–21. 3	2. 7	60. 65	0. 14
25. 3–35. 0	9. 7	65. 86	. 50
35. 0–40. 8	5. 8	55. 11	2. 90
40. 8–47. 8	7. 0	61. 71	2. 89

The average iron content from 25.3–47.8 m is 61.8 percent.[32]

The northern outcrop was explored by drill holes 2–4 (pl. 8*C*), and a probable downdip extension of the outcrop 4.6 m thick was found by hole 4. Drill hole 2 also intersected two narrow zones of magnetite-hematite mineralization (pl. 8*C*). Analyses of core samples for these iron intersections follow:

Drill hole	*Interval*	*Thickness*	*Iron*	*Sulfur*
	(meters)		*(percent)*	
2	6. 1–7. 6	1. 5	69. 57	None
	11. 0–11. 9	. 9	55. 79	None
	11. 9–14. 1	---	---	---
	14. 1–16. 1	2. 0	65. 47	0. 11
3	4. 6–5. 9	1. 3	60. 08	. 11
4	4. 6–9. 1	4. 5	70. 00	. 11

Semiquantitative spectrographic analysis of a composite sample from the main magnetite intersection in drill hole 1 showed the presence of approximately: 7 percent silicon, 1 percent aluminum, 0.7 percent magnesium, 3 percent calcium, and traces of the following elements: K, Ti, Mn, Ba, Co, Cr, Cu, Ga, Mo, Sn, V, Zr.

A magnetometer survey was conducted along lines 40 m apart, and the vertical magnetic field was measured. The magnetic map (pl. 8*B*) shows a strong negative (−16,000-gamma contour) anomaly corresponding to

[32] This probably includes some iron combined with the sulfur as pyrite, but pyrite is not readily apparent in the core.

the northern magnetite outcrop (pl. *8A*) and a strong positive anomaly (+16,000-gamma contour) corresponding to the southern magnetite outcrop.

The magnetic pattern indicates that the two outcrops represent separate magnetic iron deposits with different attitudes. The northern deposit probably is a tabular body with a gentle southeasterly dip, as indicated by the positive magnetic anomaly southeast of the negative anomaly over the outcrop. The magnetic map indicates that the southern deposit has a northeast strike and a steep dip.

The northern deposit exposed by the magnetite outcrop and drill hole 4 (pl. *8A*, *C*) contains proven and probable magnetite reserves of about 25,000 tons. Additional possible reserves indicated by the magnetic anomaly and iron intersections in drill hole 2 are estimated at 50,000 tons.

The southern deposit has an approximate length of 120 m, as indicated by the 8,000-gamma magnetic contour (pl. *8B*), an estimated extension downdip of 90 m, and an average thickness of 20 m (pl. *8D*). The specific gravity determined from drill-core samples is 4.75. The calculated combined proven and probable reserves are therefore approximately 1.03 million tons. If we take into account that the iron deposit may be cut off downdip by the granodiorite, possible additional reserves of only 450,000 tons may be present.

The Phu Hia deposit contains a total of about 1.05 million tons of proven and probable reserves and about 500,000 tons of possible reserves. The average iron content (based on analyses of drill hole 1) is about 62 percent.

The Phu Hia deposit is rather small but high in grade. It is near the Phu Yang iron deposit and can therefore be considered part of the Phu Yang iron district.

Diamond drilling is recommended to test for possible extensions of the deposit southeast of drill hole 4 and downdip from drill hole 1.

PHU KAEO YAI PROSPECT

The Phu Kaeo Yai prospect (Fe 5) lies at an elevation of 580 m on the southeastern ridge of Phu Kaeo Yai Mountain, 14 km southeast of Chiengkarn (pl. 1). The Phu Kaeo Yai Mountain is accessible in the dry season by a road that joins the Loei-Chiengkarn highway 5 km north of Ban That. The mountain is reached by following this road by way of the villages of Ban Na Si, Ban Khok, and Ban Tha Bom.

The prospect is near a contact of Devonian and lower Carboniferous strata and the same granodiorite intrusive that is associated with the Phu Yang deposit (pl. 1).

The core of Phu Kaeo Yai Mountain is a granodiorite intrusion (pl. 1), but aplite (sample J65, p. 96) occurs on the ridge surrounding the iron prospect. The aplite probably represents a border phase of the intrusive rock. The iron prospect is confined to a single massive hematite-magnetite outcrop surrounded by aplite. A grab sample of the iron contained the following percentages: Fe, 64.98; SiO_2, 1.28; S. 0.20.

Two magnetometer traverses at right angles were made over the iron outcrop, and a magnetic anomaly 80 m long and 65 m wide (measured between profile inflection points) was located.

Because the deposit is small and relatively inaccessible it has negligible economic potential.

PHU LEK (BAN THAT) PROSPECT

The Phu Lek Mountain is near the south bank of the Loei River 3 km west-northwest of the village of Ban That on the Loei-Chiengkarn highway (pl. 1). The mountain is accessible throughout the year by trail from Ban That, and in the dry season the base of the mountain can be reached by road. The Phu Lek iron prospect (Fe 6) is at the top of the mountain.

The Phu Lek prospect is on a contact between the granite intrusive to the south and the Kanchanaburi Series of sediments to the north (pl. 1).

At the prospect, a limestone bed is in contact with the granite, and all gradations of rock type from granite to granitic skarn and then to skarn were observed (fig. 17). Iron mineralization occurs within this contact zone, as indicated by boulders of iron minerals. The principal surface exposures of iron minerals are in an area 130 m in diameter at the top of the hill where large boulders of iron minerals (more than 50 cm in diameter) are common. Smaller boulders occur on the slopes of the hill. Additional exposures of iron minerals were obtained in a trench (fig. 17) where an irregular gently, dipping iron-ore body 1.5 to more than 3 m thick was observed. Average dip is 10° E. A clay rock (tuff(?)) underlies the iron ore in the trench. The iron minerals are specular hematite and magnetite. A horizontal channel sample 10 m long in the trench averaged 53.43 percent Fe and 0.14 percent S.

A very detailed magnetometer survey having east-west traverse lines 10 m apart was performed over the top of the hill. A north-northeast-trending pattern of magnetic anomalies was obtained (fig. 18). The strongest anomaly at the intersection of line 00 and the baseline is 10–20 m long and corresponds to the iron-ore deposit exposed by the trench. The remainder of the anomalous magnetic pattern is probably due to the effects of boulders of iron minerals that have rolled downslope.

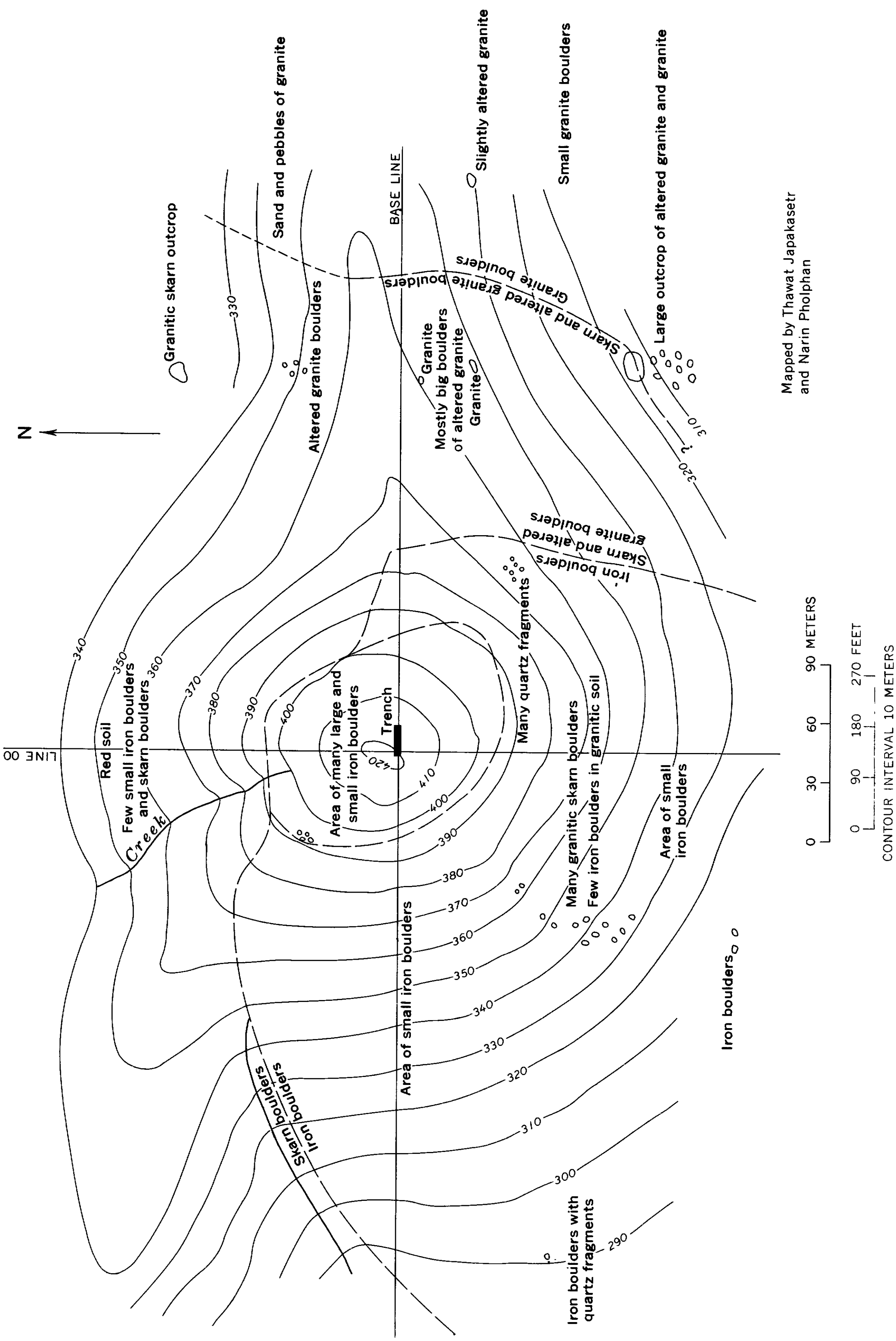
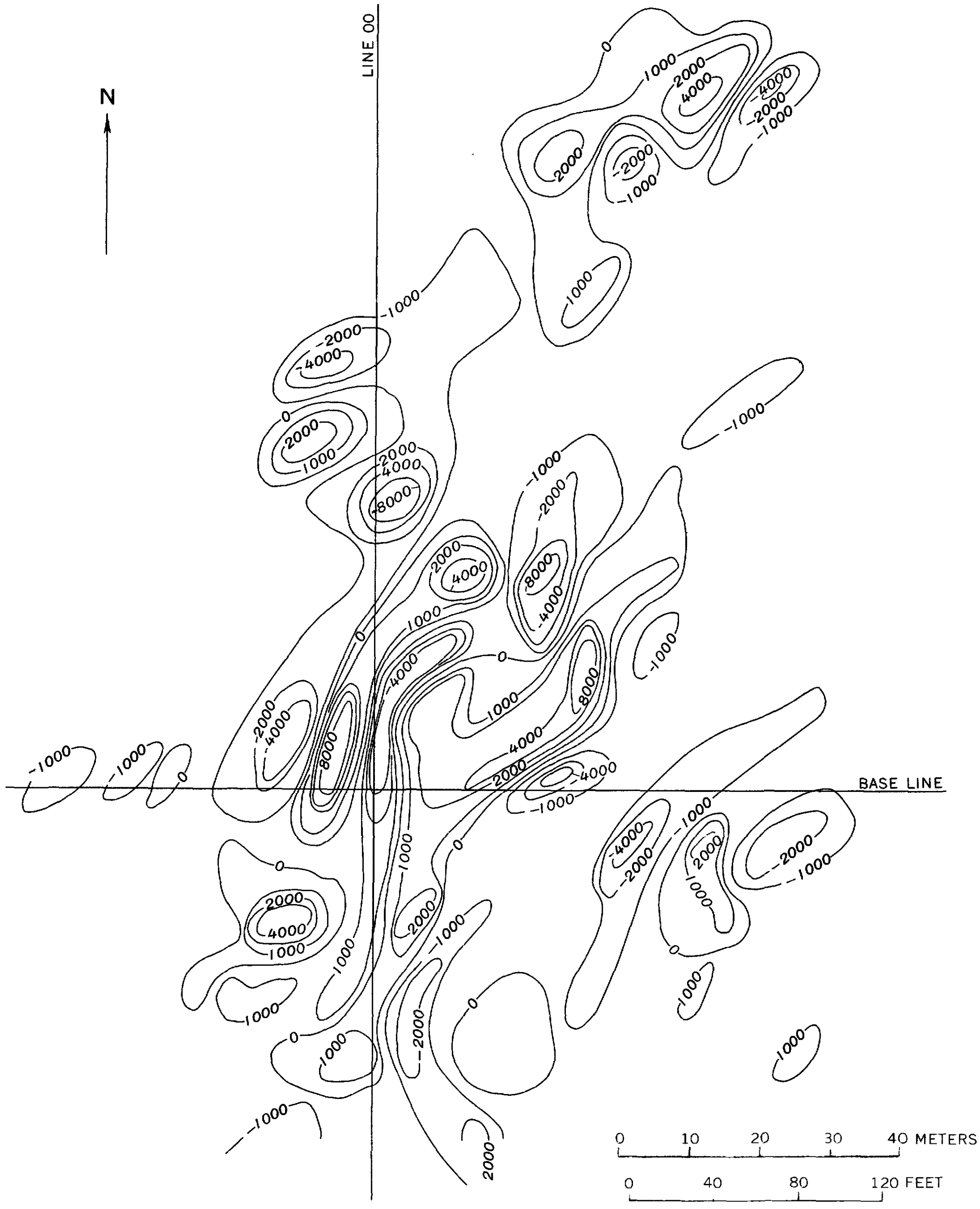


FIGURE 17.—Geologic map of the Phu Lek (Ban That) iron prospect.



Surveyed by Suratin Sahathammikachat
Compiled by Charlie Siriratanamongkol

Figure 18.—Magnetic map of the Phu Lek (Ban That) iron prospect. (Contour interval in gammas, as shown.)

The iron-ore exposure in the trench is thin and has a low angle of dip; its strike length, as indicated by the magnetometer survey, is less than 20 m. Because of its small size, the prospect has little economic potential.

BAN SUP PROSPECT

The Ban Sup prospect (Fe 7) is in a field 1.5 km due south of the village of Ban Sup, 16 km northeast of Loei (pl. 1); it is readily accessible in the dry season by the road from Loei by way of the villages of Ban Rai Tham and Ban Phia. The prospect is in an area of the Kanchanaburi Series, but bedrock exposures are sparse. Intrusive rocks crop out on the northeast and south (pl. 1).

The prospect consists of an area 30 m long and 10 m wide containing ferruginous boulders as much as 2 m in diameter and composed of sand, rock pebbles, and quartz fragments cemented by iron oxides. Fossiliferous shale boulders were observed 50 m east of the boulders of iron minerals.

The iron appears to be lateritic in origin, but the manner of formation of large ferruginous boulders is unexplained. Only a limited quantity of very low grade iron is present, however, and the prospect is therefore not considered of economic interest.

PHU LEK (BAN MAK BIT) PROSPECT

The Phu Lek prospect (Fe 8) is on a knoll surrounded by rice farms, 2.5 km southeast of Loei (pl. 1) and 1.5 km south of Phu Mak Bit Mountain. It is reached by trail from Loei. It is an area of Quaternary alluvium in the Loei River valley (pl. 1).

The rock exposures at Phu Lek are confined to a few scattered boulders indicating an intrusive contact with associated mineralization. The observed boulders were (1) weathered granodiorite or quartzdiorite; (2) dense green quartzite; and (3) garnet-magnetite-hematite skarn containing 25.02 percent Fe, 0.06 percent Cu, 1.75 percent Pb, and 0.68 percent Zn. A magnetometer traverse showed a weak magnetic anomaly 5 m wide, corresponding to the skarn boulders.

The prospect is too small and low grade to be of further interest.

BAN RAI THAM PROSPECT

The Ban Rai Tham prospect (Fe 9) is 1 km S. 60° E. of the village of Ban Rai Tham and 8.5 km east-southeast of Loei (pl. 1). The village is readily accessible by road from Loei in the dry season.

The prospect is in an area of Kanchanaburi Series, about 1 km east of a granodiorite stock (pl. 1); it is confined to sparsely scattered boulders of iron minerals in a small creekbed. A reconnaissance of the surrounding area failed to disclose additional boulders. The boulders are composed mainly of hematite and specular hematite. Shale and metamorphic rocks are exposed nearby.

The prospect is too small to be of further interest.

PHU NOI PROSPECT

Phu Noi (Fe 10) is on the north end of the Phu Khum (Ban Nong Ya Sai) Mountains, 2 km southeast of the village of Ban Nong Ya Sai and 14 km southeast of Loei (pl. 1). The village is readily accessible by car in the dry season, and a trail leads from the village to Phu Noi.

The prospect is in the Kanchanaburi Series of sedimentary rocks, about 1 km east of a granodiorite intrusive (pl. 1). Rock exposures are confined to a few boulders of massive hematite-magnetite on top of a low ridge. No other rocks are visible in the vicinity. The boulders contain sparse leached vugs. A grab sample contained the following metal content (percent): Fe, 62.69; Cu, 0.07; Pb, 0; Zn, 2.32.

A single magnetometer traverse across the prospect showed the presence of a positive anomaly 10 m wide flanked by a negative anomaly 5 m wide having total magnetic relief of 9,300 gammas. The anomaly corresponds to the area of boulders.

Both the geological and geophysical observations indicate a small magnetic iron deposit with high zinc content. The prospect is therefore not of economic interest.

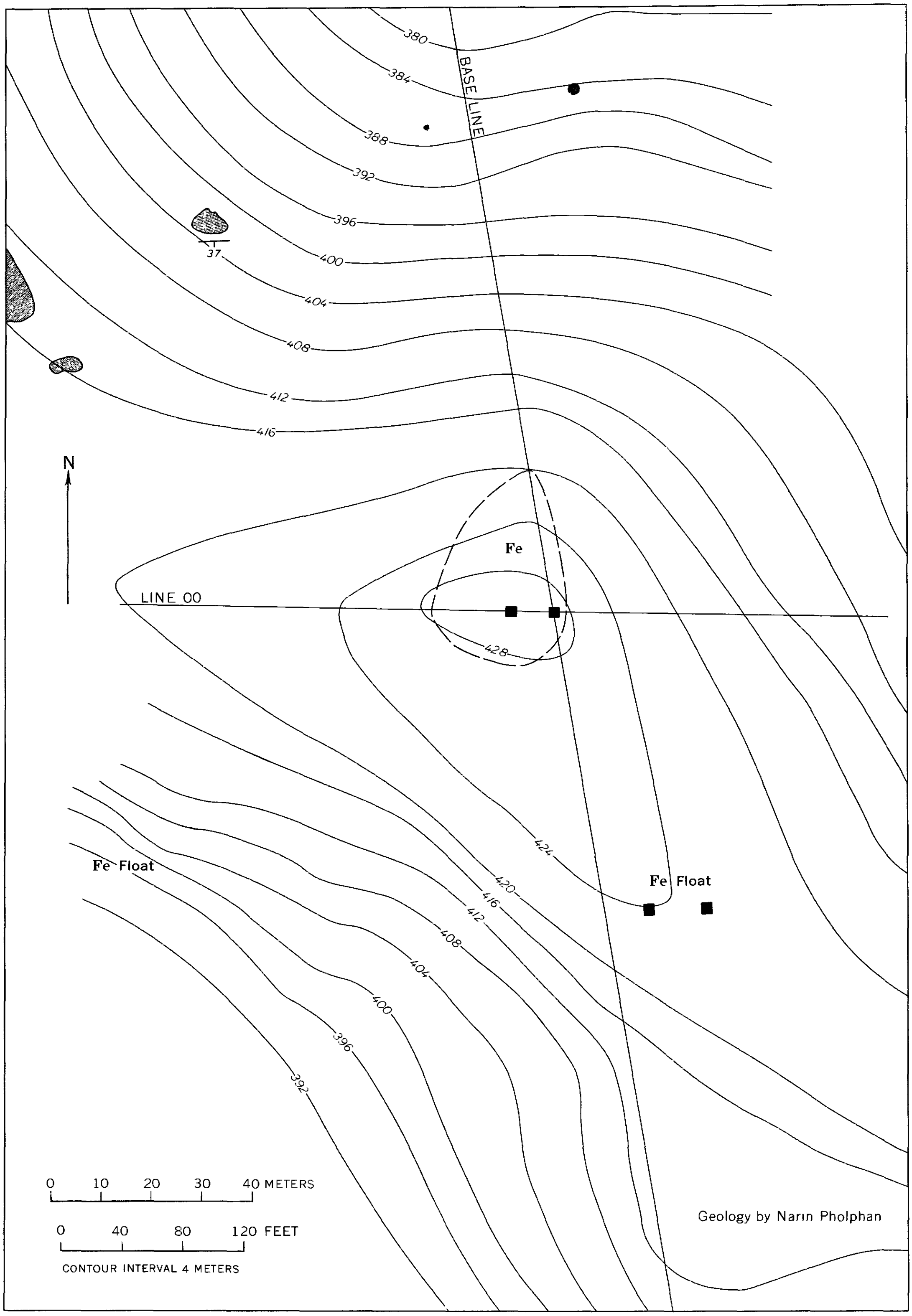
PHU LUAK PROSPECT

The Phu Luak Mountain is 11 km south-southeast of Loei, 2.5 km northwest of the village of Ban Nong Pham (pl. 1). Phu Luak is accessible from the village by trail, and the village may be easily reached by car in the dry season.

Phu Luak is a granodiorite mountain capped by metamorphic rocks, mainly quartzite. The metamorphic rocks are a probable roof pendant of the Kanchanaburi Series.

The Phu Luak prospect (Fe 11) at the peak of the mountain consists of boulders of iron minerals 40–70 cm in diameter in an area 38 m long (fig. 19). Nearby bedrock exposures are confined to quartzite outcrops about 100 m to the northeast. Granodiorite boulders occur about 100 m northeast of the area of quartzite outcrops; two pits dug about 60 m to the south exposed skarn. In the eastern of the two pits dug in the area of boulders (fig. 19), iron-stained weathered bedrock was found; in the other, large boulders of massive hematite and magnetite were exposed. Chemical analysis showed an iron content of 67.9 percent.

A detailed magnetic survey (fig. 20) outlined two



EXPLANATION

Outcrop of gray quartzite

Fe

Area of hematite-magnetite boulders 40-70 cm in diameter

37

Strike and dip of beds

Pit

FIGURE 19.—Geologic map of the Phu Luak iron prospect.

small areas of strong magnetic anomaly, one of which corresponds to the area of boulders (fig. 19). The second anomaly 80 m to south is in an area where iron float was observed. Both anomalies have a length of about 40 m and a maximum magnetic relief of about 12,000 gammas. No magnetic anomalies were detected in a reconnaissance of the area 500 m south of the area shown at the south end of figure 20.

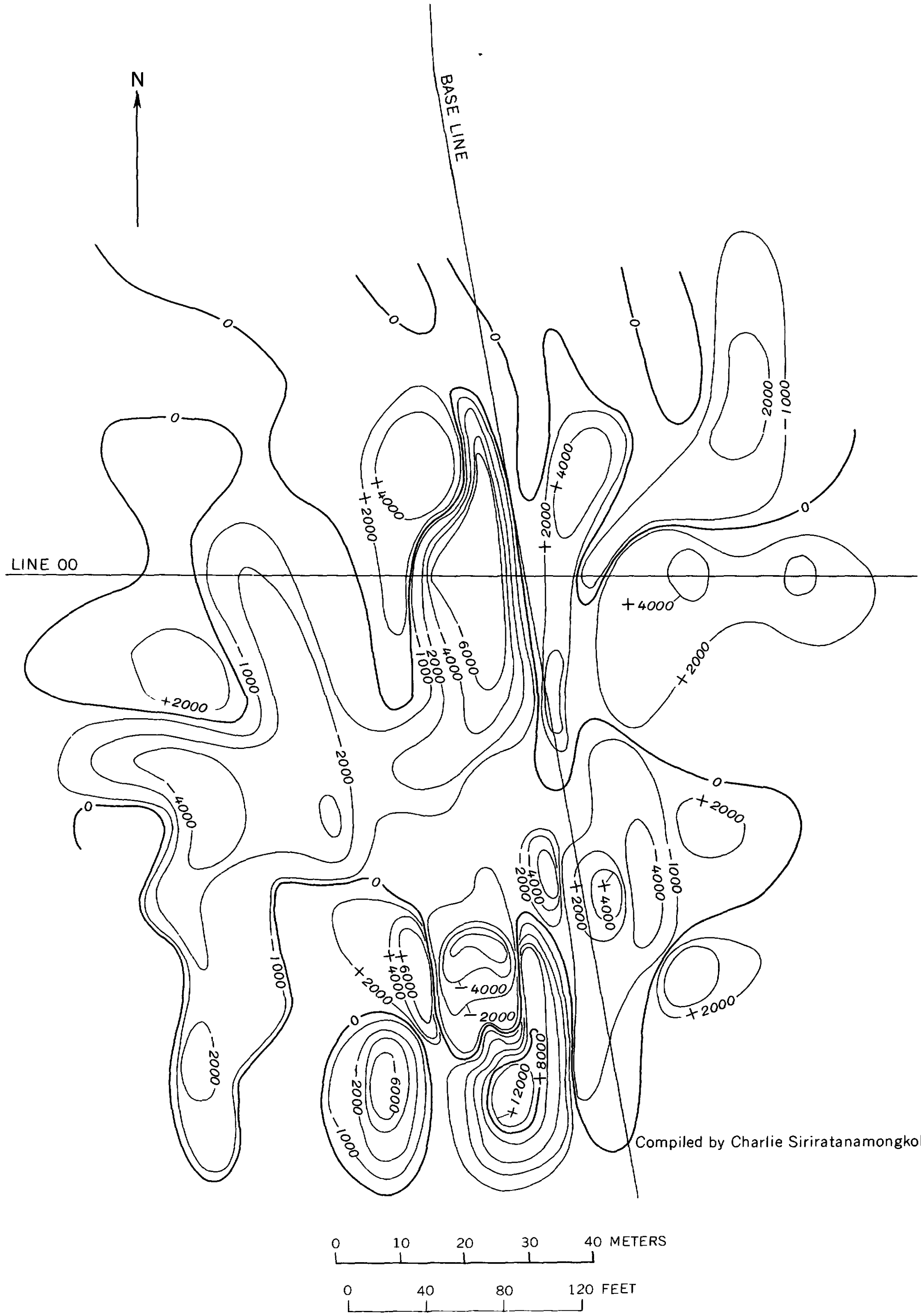


FIGURE 20.—Magnetic map of the Phu Luak iron prospect. (Contour interval in gammas, as shown.)

Both the geological and geophysical results show the presence of a small magnetic iron deposit. This small size plus the relative inaccessibility of the prospect preclude economic development.

PHU ANG DEPOSIT

The Phu Ang iron deposit (pl. 1, Fe 12), about 15 km south-southeast of Loei, underlies Phu Ang hill. The best road access is by traveling about 8 km east from Wang Saphung along the Wang Saphung-Udorn road to the junction with an all-weather road leading north to Ban Pha Noi; from Ban Pha Noi about 3 km northwest on the dry-season road toward Ban Nong Pham to the junction with an all-weather secondary road; and finally west about 3 km to Phu Ang. An alternate route would be east and then south along the dry-season roads connecting Loei with Ban Na Din Dam and Ban Nong Pham, then about 2 km south-southwest along an all-weather secondary road to Phu Ang. Supplies may be hauled by oxcart along either route during most of the wet season.

No road access by car is possible from Loei during the wet season, but access would be possible from Wang Saphung if the stretch of corduroy road extending intermittently for about 2 km north of Ban Pha Noi is kept in repair. The deposit was reached by walking about 8 km west from Ban Pak Puan on the main highway during the wet season of 1964, but because of light rains, this was not necessary during the 1965 rainy season.

The Phu Ang contact-metasomatic iron deposit occurs within fine-grained gently folded clastic rocks and limestone of the Kanchanaburi Series of Carboniferous to Permian age. The sedimentary rocks are intruded by a diorite stock of Permian or Triassic age and by sills(?) of andesite(?) porphyry of probable Early Triassic age. Locally, thin zones of rocks of the Kanchanaburi Series have been contact metamorphosed to form amphibolite(?), skarn, and hornfels. Magnetite-hematite deposits occur as overlapping sill-like bodies along the crest and flanks of a gentle north-plunging anticline.

The following data, except surficial iron-mineral descriptions, are derived from the results of drilling and pitting, inasmuch as the only outcrop in Phu Ang is iron ore. The predominant rock types in the Kanchanaburi Series are tuff, mudstone, limestone, and dolomite. The intrusive stock is dioritic in composition, as determined by mineral-grain studies made on several species of decomposed material by Mrs. Nuansri Suvarnapradip, of the Royal Thai Department of Mineral Resources (written commun., 1964). The iron minerals are "oxidized" or "unoxidized." The minerals in the "oxidized" bodies consist of hematite, magnetite, and goethite, with or without intermixed country rock or gangue. The minerals in the "unoxidized" bodies are magnetite and pyrite, with or without intermixed country rock or gangue.

The iron minerals of the Phu Ang deposit, insofar as known to the depths drilled, appear to occur in a series of overlapping primary lenses throughout a north-south length of possibly as much as 900 m and an east-west width of about 250 m. Transported surficial iron rubble is found as far as about 200 m on either side of the crest of Phu Ang hill. The maximum vertical range of known iron-mineral occurrences is about 200 m.

GEOLOGICAL AND GEOPHYSICAL STUDIES

The Phu Ang deposit was discovered as a result of an airborne magnetic survey conducted on behalf of the Royal Thai Department of Mineral Resources and the U.S. Agency for International Development by Aero Service Corp.[33] No other work was done before the present study, which was initiated in 1963. During this study, work done to evaluate the Phu Ang deposit consisted of topographic mapping; pitting and trenching; surficial, pit, and trench geologic mapping; ground magnetic surveying; and diamond-core drilling. Hunting Surveys, Ltd., on behalf of the United Nations Special Fund, provided additional airborne magnetic information (pl. 2, anomaly R).

Thirty-three pits and three trenches (pl. 9*A*) were dug to a maximum depth of 8 m to provide information on the surface ore body and field of iron-ore boulders. Geologic mapping was done at all pits and trenches, and all 1-cm and (or) 4-cm iron ore taken from 19 pits was screened and weighed. Table 8 shows the depths to the base of the iron ore at all pits and the weight of iron ore (1 cm and (or) 4 cm) at the 19 pits). Geologic data derived from two trenches are summarized on the geologic sections (pl. 9*C–F*).

The topographic data for the map of plate 9*A* were obtained by theodolite survey along east-west lines spaced at 50-m intervals across Phu Ang hill. Geologic data were recorded along these lines as well as at points between lines where outcrops were found. Pit and trench geologic mapping was done by means of tape and hand level.

Measurements of vertical magnetic intensity were made at 5-m intervals along east-west lines spaced 50 m apart. Running averages were made of the readings, and the results were contoured (pl. 9*B*).

Twenty-two diamond drill core holes, ranging from 30 to 206 m in depth, and averaging about 81 m, were drilled at Phu Ang. A total of 1,775 m was drilled.

[33] Agocs, W. B., and Curtis, C. E., 1959, Interpretation airborne magnetometer-scintillation counter survey in Chiang Khan-Loei, Na Khon Sawan, and Chachoengsao areas of Thailand: unpub. rept. in files of Royal Thai Dept. Mineral Resources.

TABLE 8.—*Test-pit data, Phu Ang iron deposit*

Pit	Depth to base of iron ore (meters)	Weight of iron ore (metric tons)	Volume (cubic meters)	Volume-to-weight ratio (tons per cubic meter) [1]
1	1.2	3.4	3.1	1.1
2	3.1	----	----	----
3	4.0?	----	----	----
4	1.7	----	----	----
5	4.0	----	----	----
6	4.4	----	----	----
7	4.4	----	----	----
8	4.4	----	----	----
9	4.8	----	----	----
10	1.3	1.9	2.7	0.7
11	2.8	5.1	4.7	1.1
12	3.4	3.8	5.1	.7
13	6.5	14.9	7.5	2.0
14	(2)	(2)	----	----
15	3.0	5.5	4.2	1.3
16	3.7	5.7	5.0	1.1
17	5.9	5.6	3.3	1.7
18	3.5	4.7	4.8	1.0
19	1.4	1.0	1.5	.7
20	4.7	----	----	----
21	4.0	----	----	----
22	4.5	----	----	----
23	3.9	----	----	----
24	3.4	----	----	----
25	3.0	4.6	4.5	1.0
26	4.0	11.4	8.1	1.4
27	2.3	10.0	5.9	1.7
28	2.5	----	----	----
29	3.1	11.3	6.7	1.7
30	1.2	3.2	3.3	1.0
31	(3)	(3)	----	----
32	2.0	3.5	3.7	.9
33	1.0	3.5	2.8	1.2

[1] The values listed are much less than the specific gravity of solid iron ore because of either or both of two factors: (1) the highly fractured nature of the surface ore body; (2) at some of the pits, not all the iron ore less than 4 cm in diameter was weighed, owing to the excessive time required to screen.
[2] No iron ore.
[3] Negligible iron ore.

Most of the holes were drilled vertically, although some of the first holes were drilled at an angle of 60° W (see pl. 9*C–F*). Core recovery in the ore zones, particularly in the upper unit, was often poor, owing to the highly fractured nature of the uppermost ore zones, as well as to the loss of altered tuff which in places is interbanded with the iron oxide layers. Cuttings, however, were available for most of the zones in which core loss was large.

GEOLOGY

The maximum thickness of rocks of the Kanchanaburi Series penetrated by drilling at Phu Ang was about 200 m. The stratigraphic position in the Kanchanaburi of the beds intersected by drilling is not known. Within the limits cored, however, two units were delineated: an upper tuff and a lower mudstone and (or) limestone-dolomite. The terms "upper" and "lower" are used in a relative sense, because it is not known whether the beds are overturned.

Placement of the contact between the upper and lower units was to some extent subjective and depended upon the following distinctions, none of which alone is necessarily definitive:

Upper unit	*Lower unit*
Mainly tuff; may contain siltstone or mudstone.	Consists of limestone, dolomite, or mudstone.
Generally appears coarser grained (up to silt sizes).	Generally finer grained.
Buff.	Gray.
Contains all or most of the oxidized ore bodies.	Contains most or all of the unoxidized ore bodies.

Many of the boundaries are gradational. It is believed that the mineralized bodies are parallel or subparallel to this contact.

An igneous stock(?) at Phu Ang is indicated by diorite found in drill holes 3, 8, 13, and 14, as well as in pits 15, 16, and 25. The intrusive rock-country rock contact was not located.

Rock determined as andesite(?) porphyry by field examination of hand specimens occurs at several stratigraphic horizons in holes 7, 13, and 15. The porphyry bodies are believed to be sill-like, although possibly they are dikes; none of the bodies are continuous between drill holes.

Thin zones of metamorphic rocks, all probably derived from contact metamorphism of rocks of the Kanchanaburi Series, were intersected in several drill holes. In no case was any zone extensive enough to be found in an adjacent drill hole. The drill holes containing most metamorphosed rock are listed below:

Hole	*Rock*
7	Serpentine or amphibolite.
9	Do.
14	Do.
14	Recrystallized dolomite.
14, 16	Skarn.

The main structure of the country rock at Phu Ang, as judged by the shape of the contact between the upper and lower units, probably is that of a gently north-plunging anticline. Not enough drilling was done, particularly on the west side of the hill, to provide information on the breadth and closure of the anticline, though inspection of the sections suggests that these may be of the order of 300 m and 60 m, respectively. The length might be approximately that of Phu Ang hill, which is about 1,000 m.

Although the only adequate guide to structure is the contact between the upper and lower units, faults other than minor dislocations are probably not present in the area penetrated by drilling, unless the differences of elevation of the contact are explained by faulting rather than by folding. Ore-body shapes shown on the sections (pl. 9*C–F*) are based on the assumptions that the bedding of the country rock is parallel to the upper-lower unit contact, and that the emplacement of the iron-ore bodies was controlled by the bedding.

Some laminations and bedding were noted in the sedimentary rocks of the drill core, and some pyrite- and gangue-filled fractures were noted in the iron-ore bodies. Only a few of the attitudes measured are oriented parallel or subparallel to the attitude of the upper-lower unit contact. It is assumed that, in the case of the sedimentary rocks, the attitudes that did not correspond to the contact were due to local minor folding or faulting. The fractures in the iron-ore bodies could be joints or minor faults, neither of which would be likely to be controlled by sedimentary structures.

Structures within the iron-core lenses are principally joints, although some faults are indicated by the presence of slickensided surfaces at a few localities. The joints are present in all places where the primary surface ore body has been exposed by pitting or trenching. The joints generally have a northerly strike; the dips are variable and may be moderate to steep in an easterly or westerly direction. It is believed that the attitude of jointing does not bear any systematic relationship to the attitude of the iron-ore lenses.

Information about the nature of the contact of the iron-ore body and the country rock is available only for the base of the upper iron-ore layer. Where the contact is between the primary ore body and tuff, the appearance is generally "intrusive," that is, baking(?) and iron oxide impregnation of underlying country rock are exhibited. Small-scale steplike contacts are present in some places. Where the contact is between the rubble of the upper iron-ore layer and tuff or diorite, the surface of the contact is irregular, and no "baking" is present. Iron oxide impregnation of the underlying country rock occurs on a lesser scale than where the overlying iron-ore body is primary, and it is believed to be due to weathering processes.

At Phu Ang, iron oxide minerals occur in (1) surface rubble, (2) surface massive ore, (3) lenses of oxidized ore within the upper unit, (4) zones of iron oxide impregnated tuff within the upper unit, and (5) lenses of unoxidized ore within the lower unit.

The surface rubble, composed of detrital material ranging in size from less than 100 mesh to boulders larger than 0.5 m in diameter, is made up almost exclusively of iron oxide minerals; the rubble lies on the lower flanks and ends of Phu Ang hill. The contact of the rubble with the massive ore from which it was derived cannot be located accurately because of the wide spacing of the pit and drill data. For the reserve calculation, it was estimated that the rubble underlies about 40 percent of the surface area of the iron deposit. The thickness ranges from 1 to 3 m and averages about 2 m.

The surface massive ore is composed of highly weathered and fractured oxidized iron ore lying along the crest and middle flanks of the hill. All the trenches as well as the following pits are believed to be in the primary body: pits 2–9, 12, 13, 16–18, 20–23, and 26–29. The thickness ranges from 2 to 9 m and averages about 4 m.

Several overlapping lenses of oxidized ore, for the most part lying within 50 m of the surface, occur within the tuffaceous rocks of the upper unit. Thicknesses of the drill hole intersections range from 4 to 13 m; the average composite thickness is about 10 m.

Where present, the zone of iron oxide-impregnated tuff occurs directly below the surface massive ore. It ranges in thickness from less than 1 to 13 m and averages about 3 m.

Two to four overlapping lenses of unoxidized ore within the lower unit, all lying more than 50 m below the surface, were intersected by some of the drill holes. The thicknesses of the drill-hole intersections range from 2 to 18 m and average about 9 m.

The oxidized and unoxidized lenses are distinguished on the basis of mineralogy and sulfur content as follows: (1) the oxidized iron minerals consist generally of martite, hematite, goethite, and magnetite, and have a relatively low sulfur content; (2) the unoxidized iron minerals all occur at depths of more than 50 m from the surface and consist mainly of magnetite and pyrite, with rather high sulfur content. Inspection of the drill logs and chemical analyses show that in all except one (drill hole 10), the average surfur content is less than 0.4 percent at depths of less than 50 m, and that except for holes 8 and 11, the sulfur content ranges from 1.3 to 24.7 percent at depths greater than 50 m.

Copper analyses for hole 2 show that the copper content of the oxidized zone is 0.1 percent (hole 2 does not go below 27 m). The following data from hole 14 suggest that the percentages of copper, zinc, and arsenic are greater in the unoxidized zone than in the oxidized zone. The small variations in silica, titanium, and phosphorus contents do not seem to be related to depth.

Composite sample interval (meters)	SiO_2	Ti	Cu	Zn	P	As
0.6–16.2	5. 18	0. 05	0. 13	0. 56	0. 13	0. 01
94.7–99. 8	7. 49	. 07	. 62	. 81	. 12	. 02
102.9–105.9	6. 39	. 05	. 72	1. 04	None	. 02

The iron oxide minerals at Phu Ang occur as (1) massive or fine- to coarse-grained crystalline iron oxide intergrowths, or (2) as iron oxide impregnations of country rock. The crystalline intergrowths may exhibit granular, fibrous, radial, bladed, banded, or platy structures. Both the massive and crystalline intergrowths may be associated with varying amounts of quartz and carbonate gangue minerals, as well as with pyrite, chalcopyrite, and interbanded country rock.

Iron oxide minerals at Phu Ang occur mainly as a massive to fine-grained (less than 1 mm maximum diameter) granular variety, although magnetite crystals as much as 5 mm maximum diameter have been noted. In the unoxidized zone, the minerals consist mainly of magnetite with associated pyrite and traces of chalcopyrite. The pyrite occurs as irregular disseminations, pods, and thin (1–2 mm) veinlets. In the oxidized zone the minerals consist of hematite, goethite, martite, and magnetite. The first two of these minerals occur occasionally in banded, bladed, fibrous, and spherulitic aggregates.

Hematite and goethite may occur as fine-grained disseminations in tuff, usually close to the massive iron oxide concentrations of the lenses, but occasionally in positions not close to known lenses. It is believed that these disseminations of hematite and goethite in tuff were introduced as a later, probably hydrothermal stage of the process of iron introduction that started with complete contact-metasomatic replacement of the country rock now occupied by the lenses.

MAGNETIC SURVEY

The Phu Ang deposit was originally discovered by the Aero Service Corp. aeromagnetic survey, and the aeromagnetic anomaly was subsequently outlined in greater detail by Hunting Surveys, Ltd. (pl. 2, anomaly R).

The aeromagnetic anomaly was investigated in detail by a ground magnetic survey. East-west traverse lines were 50 m apart. The resulting vertical magnetic intensity map (pl. *9B*) shows a complex pattern of magnetic highs and lows with northerly strike. The area of magnetic anomalies corresponds to the area of the magnetite-hematite boulder field on the surface; the magnetic pattern, therefore, is principally a reflection of the boulder field, and the stronger anomalies indicate a greater concentration of magnetic boulders. However, the magnetic anomalies also in part reflect the subsurface magnetic iron lenses, particularly where they reach near the surface. Magnetic profiles showed either positive or negative magnetic highs on some traverse lines where the lenses are near the surface, thus preventing correlation between the magnetic map and the geology. The probable explanation for this difficulty is that the subsurface iron deposit consists of a series of lenses, each of which probably has a negative magnetic pole at its north end and a positive magnetic pole at its south end, because the magnetic field at this low latitude has a small inclination (19°) to the north.

TONNAGE AND GRADE

Calculations show that at Phu Ang there is a total of 11.0 million tons of ore containing an average of 53.9 percent iron as oxide and 2.1 percent as pyrite (table 9). Of this total, 10.9 million tons is proven plus probable ore, and the remaining 100,000 tons is possible ore. The reason for the large ratio of proven plus probable to possible ore is that the relatively large amount of test drilling done at Phu Ang extended nearly to the limits of the ore body as determined by the air and ground magnetic surveys.

TABLE 9.—*Summary of tonnage and grade, Phu Ang iron deposit*

Type of ore	(Reserves (Millions of metric tons)			Average iron (percent)—	
	Proven and probable	Possible	Total	In iron oxides	In pyrite
Oxidized ore:					
A. Surface rubble	0. 5	------	0. 5	[1] 60	[1] 0. 1
B. Surface massive ore	3. 0	------	3. 0	60 6	. 1
C. Lenses in upper unit	3. 7	------	3. 7	58 5	. 1
D. Iron oxide-impregnated tuff	. 4	------	. 4	44. 8	. 1
Unoxidized ore (lenses in lower unit)	3. 3	0. 1	3. 4	43. 0	6. 7
Total	10. 9	. 1	11. 0	53. 9	2. 1

[1] Estimated.

The proven and probable reserves consist of 7.6 million tons of oxidized ore plus 3.3 million tons of unoxidized ore. The oxidized ore, most of which lies within 50 m of the surface, contains an average of 58.6 percent iron as oxides and 0.1 percent as pyrite. The unoxidized ore, all of which lies more than 50 m below the surface, contains an average of 43.0 percent iron as oxides and 6.7 percent as pyrite.

Tonnage calculations were made for five types of iron-ore occurrence: (1) the surface rubble, (2) the surface massive ore, (3) iron-ore lenses within the upper unit, (4) iron oxide-impregnated tuff layers within the upper unit, and (5) iron-ore lenses within the lower unit. The first four categories consist of oxidized ore; the last, unoxidized ore.

Except for the surface rubble, ore correlations within 110 m of an ore intersection in pit or drill hole were classified as proven plus probable ore. The ground magnetic survey data were used to determine the outer limits of the rubble field, which was classified entirely as proven plus probable ore.

The rest of the area within the boundaries of the magnetic anomaly at Phu Ang hill and within the lateral limits of the ore lenses was considered to be underlain by possible ore. The ore in this category constitutes less than 1 percent of the total calculated reserves.

The general method of calculation was to project a given ore lens or group of overlapping lenses onto the map to obtain the area. The average thickness was obtained from the sections. The volume obtained by multiplying an area by the corresponding average thickness of the ore body or bodies underlying the area, multiplied by the specific gravity of the ore, gives the reserves in metric tons. A specific gravity of 4.2 was used for all iron-ore bodies, except the surface massive ore, the iron oxide-impregnated tuff layers, and the surface rubble. Specific gravities of 3.5 and 3.2, respectively, were applied to the first two categories. A content of 2.0 tons of iron mineral per cubic meter, including the −1 cm fines, was estimated for the surface rubble. Table 10 summarizes the data used for the tonnage calculation of the proven and probable ore.

TABLE 10.—*Summary of data used for calculating proven and probable ore, Phu Ang iron deposit*

Type of ore	Area (thousands of square meters)	Average thickness (meters)	Specific gravity	Weight of iron ore (millions of tons)
Surface rubble	123	1.9	[1] 2.0	0.5
Surface massive ore	199	4.2	3.5	3.0
Lenses in upper unit	90	9.9	4.2	3.7
Iron oxide-impregnated tuff of upper unit	38	3.0	3.2	.4
Lenses in lower unit	87	9.0	4.2	3.3
				10.9

[1] Refers to weight of iron mineral per cubic meter.

The average grade for each type of ore occurrence, except for the rubble, was obtained by weighting the assay values according to the sample length, as well as according to distances between drill holes. The average grade of the iron rubble was estimated to be 60 percent iron and 0.1 percent sulfur. The chemical values upon which the calculations were based are given on p. 87–88.

CONCLUSIONS AND RECOMMENDATIONS

The feasibility of economic development at Phu Ang requires an evaluation of economic factors that is beyond the scope of this project. The most important of these factors is the proposed Pa Mong dam, which would provide cheap electric power as well as raise the water level of the Loei River so that the Phu Ang ore could be transported by barge from the Loei area. Other favorable and some unfavorable factors are:

Favorable factors:

1. Favorable conditions for low-cost mining of about 7.6 million tons of oxidized ore having an average of 58.6 percent iron and a relatively low sulfur content. The oxidized ore is probably also relatively low in Cu, Zn, and As.
2. Probable amenability of the unoxidized ore to dry magnetic separation.
3. Possibility of recovering chalcopyrite and pyrite as byproducts from the unoxidized ore.
4. Probable ease of separating soft clayey lenses of country rock from iron ore in oxidized zone.

Some unfavorable factors:

1. Possible high cost of mining about 3.4 million tons of unoxidized ore at depths of more than 50 m.
2. The unoxidized ore is relatively high in sulfur, and probably also in Cu, Zn, and As.
3. High-cost processing to remove chalcopyrite and pyrite from the unoxidized ore.
4. Great distance from present treatment plants and markets.
5. Lack of coal for treatment in Loei area.

The following work is recommended:

1. Economic feasibility study of mining, transportation, ore treatment, and marketing factors.
2. Detailed topographic survey.
3. Test stripping by bulldozer as well as some additional drilling.
4. Metallurgical testing of the ore.

PA PAO PROSPECT

The Pa Pao prospect (Fe 13) is on a ridge 30 m high, 2.5 km due east of the village of Ban Pak Puan on the Loei-Wang Saphung highway (pl. 1). The prospect is reached by trail from the village. It is in an area of Kanchanaburi Series strata where outcrops are sparse.

Iron laterite boulders 20–40 cm in diameter were observed at two small hilltops 700 m apart. No other laterite exposures were observed, but some may be hidden by the heavy mantle of tropical vegetation. The laterite boulders are composed of rock fragments (mostly shale), as much as 15 mm long, cemented by iron oxides. Analyses of one laterite sample showed an iron content of 42.81 percent.

Inasmuch as the prospect is small and low grade, it is not of economic interest.

PHU FAI MAI PROSPECT

Phu Fai Mai is a small hill 1 km due south of Phu Ang and 5 km due east of the village of Ban Pak Puan on the Loei-Wang Saphung highway (pl. 1). The prospect (Fe 14) is reached by trail from Phu Ang, which, in turn, is readily accessible by road in the dry season.

The prospect adjoins the area of the Phu Ang iron deposit to the south, and the same rock types are probably present.

The iron prospect is confined to a few massive magnetite-hematite boulders as much as 20 cm in diameter in an area of dense vegetation. Analysis of one boulder showed an iron content of 67 percent. A reconnaissance magnetometer traverse across the hill failed to detect a magnetic anomaly.

The prospect is considered too small to be of further interest.

PHU KHOK-PHU KHUM THONG PROSPECT

Phu Khok and Phu Khum Thong are two adjacent hills 2.5 km west of the village of Ban Pak Puan on the Loei-Wang Saphung highway (pl. 1). A dry-weather road west from Ban Pak Puan approaches to within 1 km of the prospect. The prospect (Fe 15) is readily accessible by trail.

North of the prospect is a granodiorite intrusive (pl. 1), which probably caused the thermal metamorphism observed at the prospect.

At Phu Khok, boulders of skarn are present which are probably genetically related to the intrusive. These rocks include garnet-quartz-magnetite skarn, quartz-calcite-epidote skarn, and quartz-hematite-magnetite (skarn?) with 60–70 percent quartz.

The only other rocks noted in the area were boulders of iron minerals at the tops of the two hills. At Phu Khok, the boulders are massive dense magnetite having an average iron content of 65.60 percent Fe (two samples); whereas at Phu Khum Thong to the south, the boulders have a vuggy texture characteristic of gossan and are composed primarily of hematite and limonite. A grab sample contained the following percentages: Fe, 55.04; Cu, nil; Pb, nil; Zn, 2.18.

A reconnaissance magnetometer survey located a very strong magnetic anomaly at the top of Phu Khok hill. This anomaly, which is 20 m wide, corresponded to the area of magnetic iron boulders. No other anomalies were detected.

Because the boulders at Phu Khum Thong have the appearance of gossan, geochemical soil samples were taken to test for a possible base-metal deposit, but no anomaly was found.

The geological and geophysical data indicate a very small iron deposit with little economic potential.

PHU DIN BAW EELERT PROSPECT

Phu Din Baw Eelert is 17 km south of Loei and 5 km due west of the Loei-Wang Saphung highway at a point 2.5 km south of the village of Ban Pak Puan (pl. 1). Access to the prospect (Fe 16) is by a trail that starts at the Loei-Wang Saphung highway 2.5 km south of Ban Pak Puan.

The prospect is in an area of the Kanchanaburi Series (pl. 1), but bedrock exposures are sparse.

At Phu Din Baw Eelert, massive magnetite-hematite boulders scattered in an area about 100 m long and 10 m wide have an iron content of 60.35 percent Fe. Iron-laterite pebbles and boulders are scattered for at least 1 km east of the massive magnetite-hematite boulders. The laterite is composed of rock fragments cemented by iron oxides. A pit showed the laterite to be a surface veneer extending to less than 30 cm below the surface.

Reconnaissance magnetometer traverses showed the presence of a magnetic anomaly corresponding to the area of boulders, but no other anomalies were detected.

The area of massive hematite-magnetite boulders is small, and no extensions are indicated by the magnetic survey. This part of the prospect probably is too small to be of economic interest. On the other hand, the widely dispersed iron laterite may be of value as a low-grade iron deposit or as road-surfacing material. Further study of the laterite at Phu Din Baw Eelert is therefore recommended.

PHU PHUN PROSPECT

Phu Phum is a small hill 8 km west-northwest of the town of Wang Saphung (pl. 1) and 3 km northwest of the Huai Eelert water reservoir. A dry-weather road from Wang Saphung to the village of Ban Khok Sathon passes within 700 m southwest of the prospect, which is in an area of sedimentary rocks of the Kanchanaburi Series (pl. 1).

The prospect (Fe 17) is confined to an area of ferruginous boulders 10 m long and 3 m wide. The boulders are 40–80 cm in diameter and are composed of hematite and other iron oxides. Some of the boulders are massive, but others contain leached cavities.

The prospect is too small to warrant further investigation.

OTHER IRON PROSPECTS

In two areas, iron deposits of limited size are closely associated with base-metal deposits. They are described on pages 23 and 36.

MANGANESE

The mineral-location map (scale 1:200,000) prepared by Methikul and Pengkum [34] shows the general locations of four manganese deposits in the area northeast of Chiengkarn, as well as the general locations of one iron-manganese and five manganese occurrences in the Pak Chom area. Twelve manganese localities were studied during the present work (pl. 1). Seven of these localities are in the area northeast of Chiengkarn (pl. 10*A*) and include the four recorded by the Royal Thai Department of Mineral Resources. None of the Pak Chom localities were visited because of poor security conditions and (or) lack of time, but two localities southeast of Chiengkarn and three localities in the Ban Chiang Klom area south of Pak Chom were inspected.

[34] Methikul, Amorn, and Pengkum, S., 1959, Geology and mineral survey report for Amphoe Chiengkarn, Amphoe Sri Chiengmai, Amphoe Wang Saphung, and Amphoe Nong Bua Lamphu: Thailand Geol. Survey Rept. 230 (unpub.).

One locality in the Pak Chom area includes two manganese occurrences (pl. 1, Mn 10A, 10B).

The semidetailed work in the area northeast of Chiengkarn included trenching, pitting, channel sampling, topographic and geologic mapping, and electromagnetic geophysical work. Reconnaissance inspections in the other areas were restricted to brief examinations of already-existing prospect pits. Only one channel sample was taken during this reconnaissance work.

All the 12 manganese localities shown on plate 1, except the three in the Ban Chiang Klom area, are in north-striking steeply dipping Devonian and lower Carboniferous rocks. The Ban Chiang Klom localities are in rocks of the Kanchanaburi Series.

Manganese is found in the form of oxides at all the localities; rhodochrosite is present at a few localities. The most common type of deposit consists of manganese oxides in pods and fracture coatings in weathered brecciated rock or porous beds. The maximum depth at which this type of ore was encountered in about 40 pits and trenches was 4.0 m; the average depth was about 2.5 m.

Less common than the pod-type deposit is rhodochrosite and (or) manganese oxides in veins. Vein deposits were apparently controlled mainly by foliation, although fractures may have controlled some.

None of the occurrences visited seem to be of sufficient size or grade to support large-scale mining. To date, the only mines in the area have been small-scale producers of chemical-grade ore. All have now been either worked out or abandoned. Well-guided physical exploration and drilling at some of the known localities might result in blocking out enough ore to support small-scale mining, however, if cheap labor continues to be available to hand sort the ore. The present (1966) value of chemical-grade ore is about $100 per ton. This price would support mining of most modest-sized deposits, even where long haulage is necessary.

The presence of a large deposit in the general area investigated is not probable, but it cannot be ruled out on the basis of available data. Search for such a deposit would be costly in time and manpower. If such a search were to be undertaken, systematic prospecting of the stream beds in the Chiengkarn, Ban Chiang Klom, and Pak Chom manganese areas should be an early phase of the work. Relatively unskilled prospectors can readily recognize manganese float, and it was in this manner that many of the presently known prospects and mines were discovered.

HUAI MUANG MINE

The Huai Muang mine (pl. 1, Mn 1; pl. 10*B*) is at an elevation of about 400 m in a valley near the headwaters of Huai Suak Thai Creek and is reached by going about 2 km north-northeast along a poor road up the Huai Suak Thai valley. Ban Huai Suak may be reached from Chiengkarn by river during the rainy season or by road along the river during the dry season.

The Huai Muang mine is in a north-trending steeply dipping quartzite unit of an interbedded sequence of quartzite, phyllite, slate, chert, conglomerate, sandstone, siltstone, and shale. Strikes of bedding and foliation within the sedimentary and metasedimentary rocks are northerly for the most part, and, on the average, the dips are steeper than 50°. More than half the measured dips are to the east. Some dark fine-grained igneous(?) rock was noted during reconnaissance in the hills west of the mine.

Not enough data were obtained to allow mapping of the rock units, either within the mine or along the road, but the presence of folding and faulting is indicated.

The manganese occurs mainly as manganese oxide pods in the clayey matrix of weathered, brecciated quartzite, and as fracture coatings in quartzite. Rhodochrosite, probably from small veins, has been reported.

Previous investigations include reconnaissance visits by Vija Sethaput,[35] Saman Buravas,[36] and Amorn Methikul and S. Penghum,[37] all from the Royal Thai Department of Mineral Resources. Mr. L. S. Gardner, of the U.S. Geological Survey, visited the mine in 1959 and prepared a memorandum report (written commun., Sept. 2, 1959). Mr. R. M. Smith, also of the U.S. Geological Survey, visited the mine in 1960, and prepared a report (unpub. data). General geologic observations have been made by the Royal Thai Department of Mineral Resources. Data on geology, mining methods, beneficiation practices, and reserve estimates were supplied by Gardner and Smith.

Most mining to date had been completed by the time the present investigation started in mid-1963. Production from 1956–60 was 12,000 metric tons, from seven or more small pits and one main pit (R. M. Smith, unpub. data). The main pit was 27 m wide, 46 m long, and 5 m deep at the face. All the pits were abandoned and had caved by 1963, at which time the only clearly distinguishable working was about 50 m of underground workings at the site of the adit shown on plate 10*B*.

Work done at Huai Muang consisted of general geologic reconnaissance of the nearby hills surrounding the mine area; a reconnaissance geologic traverse along

[35] Sethaput, Vija, 1954, Report of investigation of the Huai Suak manganese deposit: Thailand Geol. Survey Rept. 177 (unpub. rept.).

[36] Buravas, Saman, 1955, Report of investigation on geology and mineral resources of Petchabun-Loei: Thailand Geol. Survey Rept. 189 (unpub. rept. in files of Royal Thai Dept. Mineral Resources, Bangkok).

[37] See footnote 31, p. 40.

the road for about 3 km east of the mine, topographic and geologic mapping of the mine area, channel sampling of a mine cut, pitting, geologic mapping of most of the pits, and a sampling of three pits.

The principal rock unit in the mine area is probably a north-trending steeply dipping quartzite member of the Devonian and lower Carboniferous sequence. The east trend of the quartzite recorded on plate 10*B* could be that of a slump block, as it is at right angles to the regional strike. Smith noted a bedding strike of about N. 15° E., and dip of 55°–85° SE. near the mine.

Only manganese oxides were found in the underground workings, although rhodochrosite has been reported from the Huai Muang area. The manganese oxides occur as pods in the clayey matrix of weathered brecciated quartzite, as well as fracture coatings in quartzite. Analysis of a selected chip sample of material from one of the pods showed a content of 39.2 percent Mn. However, a horizontal, 12-m chip-channel sample across the face of a previously mined opencut near the portal of the adit showed a content of only 3.9 percent Mn. Other constituents in the channel sample are 4.7 percent Fe and 54.9 percent SiO_2.

Seventeen pits located on a 50-m grid (pl. 10*B*) were dug to depths of as much as 6.5 m. All the pits passed below the surficial zone of manganese impregnation of weathered quartzite. Pit 16 was not on the grid but was dug 10 m away from pit 15 to check the possible continuity of a manganese-bearing zone in pit 15.

All the pits except pit 16, which contained only quartzite boulders, were mapped geologically. Of these, only pits 2, 12, and 15 contained any appreciable concentration of manganese. Bulk samples from the walls of the manganese-bearing parts of these pits contained only 1.8, 2.6, and 2.3 percent Mn, respectively.

The following description of the occurrence of the manganese minerals is taken from Smith's unpublished data, supplemented by the present study of underground workings and pits.

Psilomelane, pyrolusite, and probably several other oxides of manganese of probable illuvial origin occur in irregular rounded tabular masses or lenses in the basal 0.15–3 m of alluvium. They were found in a hillside zone about 120 m wide, which extends more than 200 m up the slope. The lenses ranged in thickness from a few cm to 1.8 m; in width, from 0.3 to 10 m; and in length, from 0.3 to 12 m. The run of the mine ore averaged about 50 percent MnO_2. Most or all of this zone had apparently been mined out by the time the present work had started.

The present study confirmed Smith's interpretation that the manganese deposit was of illuvial origin. The manganese was probably mainly originally derived from primary manganese carbonate and oxide veins known to be present in the region. Weathering of a dark fine-grained igneous rock containing as much as 0.77 percent Mn also could have contributed. In the Huai Muang area, leaching of silica from quartzite, leaving a porous clayey matrix capable of accepting Mn, seems to be the most important ore control. This is demonstrated in the adit where quartzite is barren, whereas weathered quartzite contains manganese oxide impregnations.

No ore body was found in any of the pits; therefore, no calculation of ore reserves can be made. However, as the maximum length of ore lens reported by Smith (written commun., 1960), on the basis of data collected while the open-pit mining was still in progress, was only 12 m, it is apparent that the data from the pits spaced 50 m apart do not preclude the presence of more surficial ore bodies of this size.

More test pitting on a closer spaced grid is recommended on a low-priority basis for the area in the vicinity of pits 2, 12, and 15. Geologic reconnaissance is recommended in the region on a low-priority basis.

PHU LON MINE

The Phu Lon mine (pl. 1, Mn 2; pl. 10*A*) is at an elevation of about 500 m on a steep hillslope near the headwaters of Huai Suak creek about 5 km (airline) from Ban Huai Suak. The mine is reached by traveling about 6.5 km along a poor road eastward from Ban Huai Suak along Huai Suak creek, thence about one-half kilometer northeast along a small tributary stream to the end of the road at the Huai Khok Kha mine, and then following the same tributary along a foot trail about 1 km upstream. The Phu Lon mine lies about 100 m higher than the streambed on the northwest bank.

The Phu Lon mine is in north-striking steeply dipping quartzite and phyllite. The quartzite is probably conformably interbedded with the phyllite. The ore occurred as pods of manganese oxide in weathered quartzite and phyllite, similar to the Huai Muang occurrence.

No previous geologic investigations have been made. The mine was found by prospectors who discovered float cobbles of manganese oxide in the streambed below the mine. Mining has now ceased, and all known ore has been removed.

The present work was restricted to sketch geologic mapping within an area of which all points were within 200 m of an old opencut from which the main production reportedly came. The cut was cleaned out and was somewhat extended and deepened, but only two small pods of manganese oxide in weathered quartzite were found. Neither pod was larger than 1 m in length or width.

The reserves cannot be estimated for the Phu Lon mine area as no production data are available, and no ore is visible in the old pits, which are now entirely, or partly, caved. No further work is recommended.

HUAI KHOK KHA MINE

The Huai Khok Kha mine (pl. 1, Mn 3; pl. 10*C*) lies at an altitude of 340 m about 1 km south of the Phu Lon mine. The access was previously described. The only previous geologic investigation was made by Methikul and Pengkum,[38] who noted that the manganese occurred as a vein about 2 m wide and concordant with phyllite and quartzite.

Rock types noted in the mine area include quartzite, phyllite, and shale, all probably conformably interbedded. The bedding and foliation for the most part have a northerly strike. The dips are mainly greater than 50° E.

Work done at Huai Khok Kha consisted of topographic and geologic mapping (pl. 10*C*), clearing out of the old mine trench, some additional trenching, and an electromagnetic survey across the ore zone exposed by the old trench.

At the Huai Khok Kha mine, manganese oxides and rhodochrosite are in a vein about 1 m wide. The total length of the vein, which strikes north and dips 57° E., is 12 m. The vein is roughly parallel to the bedding of the enclosing quartzite. The only ore now to be seen occurs in several pillars and in the bottom and south faces of the trench.

Additional shallow trenching roughly parallel to the strike was done for about 25 m to the north and 10 m to the south. No ore was revealed; but this is not regarded as conclusive evidence that ore is not present, because the strike could have changed. The steep slope and deep overburden east of the vein precluded effective trenching at right angles to the strike. Drilling will be required for further evaluation.

Two 1-m horizontal channel samples taken across the strike from one of the pillars and from the bottom of the trench showed 34.5 percent and 38.6 percent Mn, respectively. Silica and iron values averaged less than 4 percent and 7 percent, respectively.

Four east-west electromagnetic traverses spaced at 25 m were run across the strike to distances of about 70 m on either side of the vein. Readings along the traverse lines were made at 10-m intervals. The next to the northernmost of the traverse lines passed across the mineralized zone exposed by the trench. No significant anomalies were found on any of the traverses.

Assuming that the geophysical results indicate that the mineralized zone exposed in the trench does not continue downward or along strike, no appreciable reserves are indicated to the depth or strike length (75m) covered by the traverses. No other outcrop of manganese minerals were found in the area covered by plate 10*C*.

A 50-m-deep vertical drill hole positioned about 15 m east of the center of the trench is recommended on a low-priority basis to test the character of the ground below the east-dipping vein seen in the trench.

[38] See footnote 31, p. 40.

HUAI KAN PROSPECT

The Huai Kan prospect (pl. 1, Mn 4; pl. 10*D*) is at an elevation of about 420 m on a ridge about 1 km east of the Huai Khok Kha mine. In 1963 it was reached by about 2 km of steep road from the Huai Khok Kha Camp. The road is now in disrepair. No previous geologic investigations have been made.

At the Huai Kan prospect, manganese oxide is a lens in north-striking steeply dipping quartzite. A small amount of surficial manganese oxide rubble was mined from the flanks of the occurrence.

Work in the Huai Kan area consisted of a limited amount of pitting at the small manganese locality at the southwest end of the ridge shown by plate 10*D*, as well as on both flanks of the ridge; topographic and geologic mapping; and an electromagnetic survey at the site of the manganese minerals.

The main rock type noted was quartzite. Well-defined bedding exposed by pit 9 strikes north and dips 75° E.

The only manganese minerals other than small amounts of surficial manganese rubble found in some of the pits on the flanks of the ridge were uncovered at the site of an old prospect pit. At this locality, pits 6 and 7 and trench 1 expose a flat to moderately east-dipping lens of manganese oxides having a probable north strike. The total length is about 15 m; the thickness averages about 0.5 m. Only about 3 m of dip length is exposed in trench 1. The lens thins and steepens toward the east.

Three vertical channel samples taken at 2-m intervals in pit 7 have a weighted average grade of 27.3 percent Mn.

Five northwest-southeast electromagnetic traverses spaced at 25 m were run across the ridge to a distance of about 65 m on either side of the crest. Readings along the traverse lines were taken at 10-m intervals. The middle traverse line passed across the southwest edge of pit 6. No significant anomaly was found in any of the traverses.

The measured ore has a length of 15 m, a thickness of 0.5 m, and a width of 3 m in the direction of dip. The same dimensions of length and thickness probably continue for another 3 m of width. Therefore, the tonnage of measured plus probable ore, assuming a specific gravity of 3.5, equals about 150 tons of rock containing a probable average grade of about 27 percent Mn. Drill data are needed before a realistic estimate of possible reserves can be made.

One or two short holes inclined to the northwest from places along the southeastern part of the ridge are recommended on a low-priority basis to test the down-dip extent of the surficial manganese lens. If results are favorable, exploration for possible deeper lenses might be undertaken by drilling.

PRAKIT PROSPECT

The Prakit prospect (pl. 1, Mn 6; pl. 10*A*) is at an elevation of about 320 m on a hillslope north of Huai Suai creek about 4 km (airline) east of Ban Bu Hom. It is reached by following a trail north for about 0.5 km from Ban Dong Mak Fai village. The village is in the valley of Huai Suai Creek about 5 km by poor road from Ban Bu Hom. No previous geologic investigation has been made.

Manganese oxides occur as impregnations of porous beds and as fracture coatings in north-northwest-striking east-dipping quartzite.

Work in the Prakit area consisted of cleaning out and slightly enlarging the trench from which all the ore in the Ban Dong Mak Fai area was derived. A sketch geologic map was made of the trench wall, and a channel sample was taken.

No outcrop was found in the trench area. Quartzite is the main rock type exposed by the trench; its attitude is N. 20° W, 55° E.

Manganese oxides occur as impregnations of porous beds and as fracture coatings. Analysis of a 2-m horizontal chip-channel sample across the strike of the manganese-bearing zone, which seems to be parallel to bedding, showed 8.2 percent Mn and 72.2 percent SiO_2. No large pods of manganese oxide were noted.

Before the trench was slightly lengthened and deepened, it measured 7 m long, 2 m wide, and 5 m deep. About 20 tons of battery-grade ore, now stockpiled at Ban Dong Mak Fai, are said to have come from this trench. Using the above dimensions, a grade of about 10 percent Mn is calculated to be the average for the material removed from the trench. The upgrading was no doubt done by hand sorting.

Reconnaissance to the north and to the south along the strike of the deposit did not disclose any manganese minerals. In the trench, however, no manganese is seen in the first few meters below the surface, where the rock is highly weathered; so surface prospecting is not likely to be conclusive. No further work is recommended.

BAN DONG MAK FAI PROSPECT

The Ban Dong Mak Fai (pl. 1, Mn 7; and pl. 10*E*) prospect is at an altitude of about 250 m on the south edge of the valley of Huai Suai Creek, about 400 m from Ban Dong Mak Fai and about 400 m south-southeast of the Prakit prospect. No previous geologic investigation has been made.

At Ban Dong Mak Fai, manganese oxide minerals occur as impregnations and fracture coatings in northwest-striking steeply dipping quartzite.

Work in the Ban Dong Mak Fai area consisted of sketch topographic and geologic mapping (pl. 10*E*) and digging an opencut 23 m long and 4–6 m deep near a prospect adit 3 m long.

The main rock type is quartzite with some interbedded phyllite. The bedding attitude averages about N. 20° W., 85° SW. There may be a geologic relation between the mineralization at the Prakit area and that at the Ban Dong Mak Fai area, because they are roughly on strike.

Manganese oxides occur as impregnations and fracture coatings in quartzite. Analysis of a 0.8-m horizontal chip-channel sample taken across bedding exposed in the face of the adit showed 12.5 percent Mn and 68.8 percent SiO_2. The average Mn content of two chip-channel samples totaling 7.0 m taken across the two most strongly mineralized zones exposed by the opencut was only 3.4 percent.

No indication of appreciable reserves was found in the Ban Dong Mak Fai prospect area, and no additional work is recommended.

HUAI TAD MINE

The Huai Tad mine (pl. 1, Mn 5; pl. 10*A*) is at an altitude of about 460 m on the east bank of Huai Tad Creek near its headwaters on the steep south slope of Phu Yot Huai Bun. The locality is reached by a 4.5-km trail from Ban Bom Yai up Huai Suai Creek to Huai Tad Creek, and thence about 2 km along the creek to the mine. Ban Bom Yai is reached by proceeding eastward about 3 km on a poor road along Huai Suai Creek from Ban Dong Mak Fai village. No previous geologic investigation had been made.

No bedrock is exposed in the area of the Huai Tad mine, but north-striking steeply dipping quartzite and phyllite were noted on a ridge about 0.5 km west of the mine. Some vein quartz and gossan(?) float were seen on the same ridge.

The mine workings are caved, and no manganese minerals were found in place. However, a 50-ton stockpile on a ridge west of the caved mine workings contains rhodochrosite and manganese oxides. Trenching failed to reveal the source of the minerals; probably the mine has been completely worked out.

Analysis of a selected grab sample from the stockpile showed 33.8 percent Mn and 20.2 percent SiO_2.

No basis is available to make a reserve estimate. No further work is recommended.

DEPOSITS SOUTHEAST OF CHIENGKARN

Two deposits, the Phu Hin Lek Fai prospects and the Phu Tham Mup mine, about 15 and 20 km, respectively, southeast of Chiengkarn (pl. 1, Mn 8, and Mn 9) were investigated briefly. No further work is recommended at either occurrence.

PHU HIN LEK FAI PROSPECT

The Phu Hin Lek Fai deposit (pl. 1, Mn 8) is reached during the dry season by turning east from the Loei-Chiengkarn highway at a point about 4 km north of Ban That and then driving northeast on a secondary road through the villages of Ban Na Si, Ban Khok, and Ban Na So. After reaching Ban Na So, the Nam Huai valley is followed for about 3.5 km to the end of an oxcart road. The prospect is then reached by walking about 1 km east.

The prospect consists of an area, 5 m wide, of manganiferous boulders paralleling the slope of the hill. Boulders of silicified quartzite(?) as much as 2 m in diameter, containing irregular pods and stringers of manganese oxides, were observed. Chemical analysis of a grab sample indicated a manganese content of 8.1 percent. Because of the small size and grade of the prospect, no further work is recommended.

PHU THAM MUP MINE

The Phu Tham Mup mine (pl. 1, Mn 9) is 4.5 km east-southeast of the village of Ban Tha Bom and may be reached in dry weather by turning east from the main highway at a point 4 km north of Ban That, then driving on a secondary road to the mine through the villages of Ban Na Si, Ban Hin Tang, and Ban Tha Bom.

The mine is essentially a prospect pit exposing an irregular zone, 1-5 m wide, of manganiferous quartzite which strikes N. 10° W. and dips 68°–75° SW. The manganese oxide is in irregular pods within the quartzite. Chemical analysis of a grab sample indicates a manganese content of 4.6 percent. Visual estimates indicate as much as 30 percent manganese oxides in other samples.

Three truckloads of manganese ore have reportedly been shipped from the mine. No further work is recommended at this property because apparently most of the reserves have been removed.

DEPOSITS IN THE BAN CHIANG KLOM AREA

Four manganese occurrences, the Huai Nam Kam (north), Huai Nam Kam (south), Huai Pla Kang, and Huai Tab Chang prospects are within an area 10 km south and southeast of Ban Chiang Klom (pl. 1, Mn 10A, 10B, 11, 12). Further work is recommended only at the Huai Pla Kang prospect.

HUAI NAM KAM AND HUAI TAB CHANG PROSPECTS

The Huai Nam Kam (north), Huai Nam Kam (south), and the Huai Tab Chang prospects contain only small reserves of manganese in thin veins in sandstone and siltstone. No further work is recommended.

HUAI PLA KANG PROSPECT

The Huai Pla Kang prospect is about 7 km south of Ban Chiang Klom. It is reached by traveling 1 km north on the highway from Ban That, then turning east and proceeding on a newly constructed road which passes through Ban Tin Pha and leads to Pak Chom via Ban Chiang Klom. The prospect may be reached by walking about 4 km south-southeast from a point about 18 km along the road northeast from Ban Tin Pha.

Huai Pla Kang is the only manganese prospect in the Loei-Chiengkarn area known to occur in rocks of the Kanchanaburi Series. At the prospect, a hillside cut 6 m deep exposes a flat-lying shale bed 2 m thick containing some irregularly shaped masses of manganese oxide as much as 0.5 m in maximum exposed dimension. A 5 m horizontal channel sample taken along the face of the opencut contains 15.2 percent Mn.

The exposed rocks have little economic potential because of their low manganese content. Additional pitting is recommended on a low-priority basis.

GOLD

BAN PHIA PROSPECT

The Ban Phia prospect is 1 km northwest of the village of Ban Phia (pl. 1) in the Huai Nam Lai creekbed 13 km northeast of Loei. The area is readily accessible by road in the dry season.

The prospect is a gold placer in the stream gravels of the creek. It is largely derived from the granodiorite intrusive about 3 km to the north.

Panning of the stream gravels shows a very low gold content in the alluvium, but no assays were obtained.[39] Residents have panned gold in the past, but no production statistics are available.

The grade is apparently too low to sustain production, and no further study is suggested.

[39] See footnote 2, p. 1.

BAN KHAM DUANG PROSPECT

The Ban Kham Duang prospect (fig. 1) is near the west edge of the Khorat Plateau about 65 km (airline) distance northwest of Udorn. It is reached by driving about 40 km north on the highway from Udorn to Ban Na Hi, thence about 40 km westward and northwestward to Ban Sri Chieng Mai, which is on the south bank of the Mekong River several kilometers west of Vientiane, the capital of Laos. During the dry season, Ban Kham Duang may be reached from Ban Sri Chieng Mai by driving about 25 km southwest through the villages of Ban Sieo, Ban Phon Thong, and Ban Pho Tak.

The presence of gold at Ban Kham Duang had probably been known to the villagers for some time before 1963. Geologists of the Royal Thai Department of Mineral Resources had discovered platinum before the present project was activated in 1963 (Amorn Methikul, unpub. data).

The present work consisted of drilling and sampling 26 core holes (fig. 21) on three north-trending lines across the east-flowing Huai Kham Duang Creek. The lines were spaced about 1 km apart, and the drill holes, for the most part, were spaced at about 100 m apart. Thirty-seven core samples were collected and panned. The concentrates were examined under binocular microscope. Only three of the samples contained visible gold; none contained visible platinum. Additional drilling with a Banka rig was done in 1964 by the Royal Thai Department of Mineral Resources, but the results of analyses are not yet available.

The bedrock, according to the geologic map by Haworth and others (1964, pl. 2), consists of the sedimentary rocks of the Khok Kruat Formation, which is stratigraphically near the top of the Khorat Series.

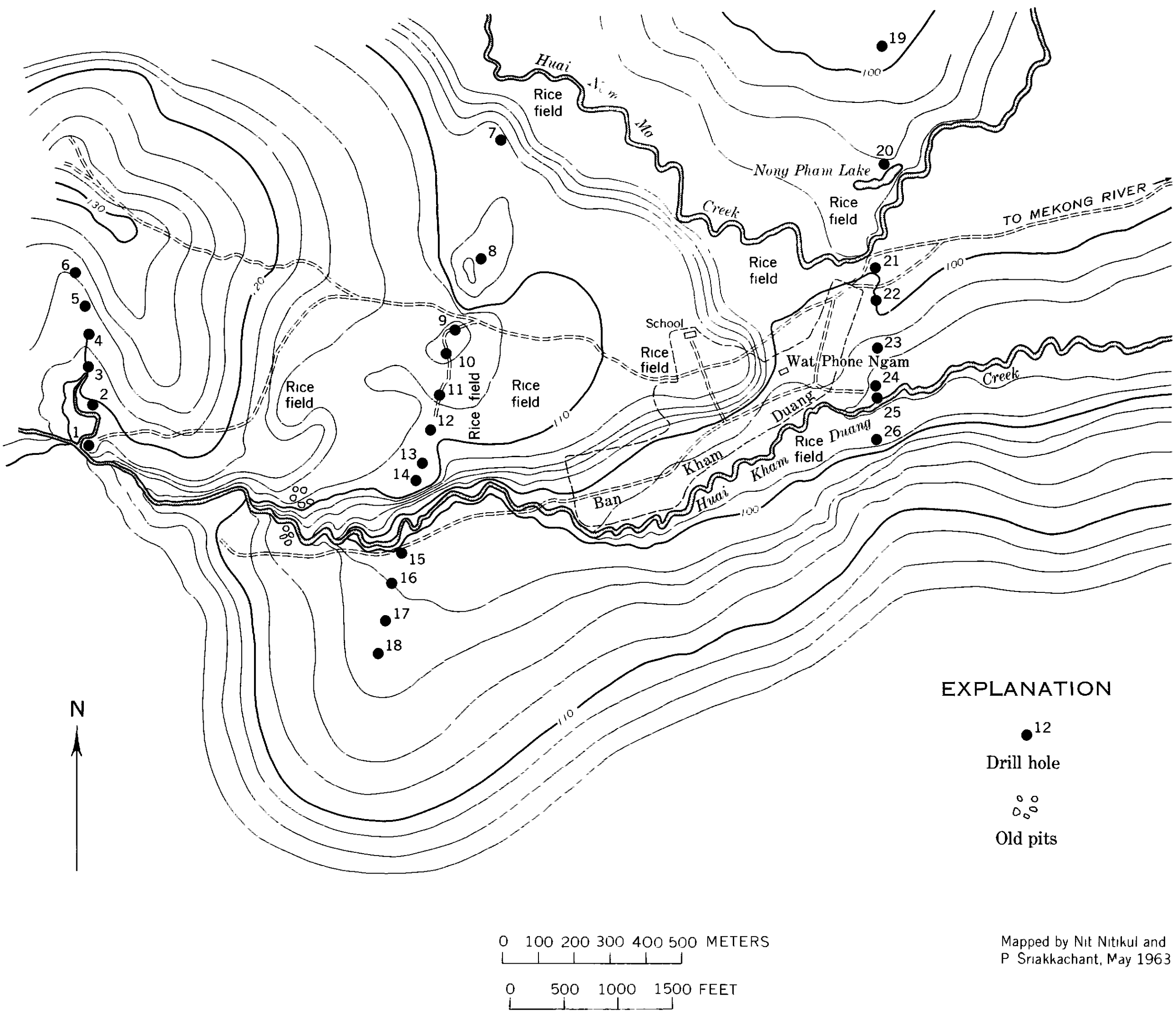


FIGURE 21.—Location of drill holes in the Ban Kham Duang area.

The predominant bedrock encountered during drilling was red siltstone.

Overlying the bedrock is an alluvial cover of gravel, laterite, silt, and loam. The total thickness ranges from less than 1 m to more than 9 m and averages about 3.7 m. When present, the flat-lying gravel bed rests directly on the siltstone and ranges in thickness from 0.30 to 3.35 m. The average thickness is 0.8 m.

The gold occurs only in the gravel bed found at the base of the alluvium. The gravel was found in 21 of the 26 holes and was absent in four of the others. One sample was lost. Table 11 summarizes the drill data.

TABLE 11.—*Summary of drilling data, Ban Kham Duang gold prospect*

Drill hole	Depth to bedrock (meters)	Thickness of gravel bed (meters)	Drill hole	Depth to bedrock (meters)	Thickness of gravel bed (meters)
1	4.09	(1)	14	2.44	0.30
2	1.22	(1)	15	3.36	.61
3	.92	0.31	16	.92	.31
4	2.44	(1)	17	3.66	.61
5	1.53	(1)	18	9.76	.30
6	(2)	--------	19	7.32	2.74
7	3.96	3.35	20	7.02	.92
8	1.53	.31	21	1.83	.30
9	4.09	.43	22	3.36	1.53
10	1.22	.30	23	2.75	1.22
11	3.36	.92	24	3.66	.30
12	4.27	.61	25	3.96	.60
13	4.88	.91	26	3.05	.61

[1] Not present.
[2] Sample lost.

Visible gold occurs in samples from holes 9, 13, and 23. No visible platinum was noted in any of the samples, although it is present in the gravel pit along Huai Kham Duang Creek about 800 m west of the village. Amorn Methikul (unpub. data), probably referring to the same pit, states that gold and platinum occur in equal amounts (approximately 1.4 g of gold and 1.3 g of platinum per cu m).

The results of the present work indicate that the gold is sporadically distributed in the Ban Kham Duang area. Because of this, as well as because of the considerable alluvial cover, the prospect is not considered to have economic possibilities. No further work is recommended at Ban Kham Duang.

LIMESTONE

PHA BAEN LIMESTONE (CEMENT-GRADE) DEPOSIT

The Pha Baen deposit (N 1) was investigated because analysis of a limestone sample showed it to be cement grade and because it is close to the Mekong River where low-cost barge transportation may make utilization possible. Numerous other massive limestone deposits present in the Loei-Chiengkarn area (pl. 1) were not investigated.

The Pha Baen deposit is a hill 3.5 km due east of the village of Ban Pha Baen on the south bank of the Mekong River (pl. 1) and 9 km east of Chiengkarn. The village is readily accessible by an all-weather road. The deposit is reached from the village by a dry-weather road that joins the main road from the south, east of the bridge at the east end of the village.

At present the Mekong River is 2.5 km away from the deposit, but raising of the water level to 230 m above sea level by the proposed Pa Mong dam would bring the shoreline to within about 100 m of the deposit.

The limestone is in a sequence of Devonian and lower Carboniferous rocks (pl. 1), which locally includes beds of massive limestone. Pha Baen is a hill 1 km long and 0.5 km wide consisting of shale capped with limestone. The base of the hill is at an elevation of 260 m, and the peak is at 521 m. The upper slopes of the hill are limestone cliffs.

The limestone is of probable Devonian age (pl. 1). It is nearly flat lying and overlies poorly exposed shale. The limestone is massive, dense, gray, and fine grained.

No detailed tonnage measurements were made, but proven and probable reserves were estimated at 12 million tons. Additional possible reserves could be present in the surrounding area.

A single grab sample of the limestone was analyzed as follows:

	Percent		*Percen*
SiO_2	0.19	K_2O	0.02
Al_2O_3	.27	H_2O-	.03
Fe_2O_3	.11	H_2O+	.16
FeO	.12	TiO_2	.02
MgO	.5	P_2O_5	.02
Na_2O	.05	MnO	.05
CaO	55.0	CO_2	43.30

The favorable and unfavorable factors for economic development are:

Favorable factors:

1. Location close to low-cost river transport.
2. Good-grade cement limestone.
3. Shale present adjacent to the limestone.
4. Low-cost open-pit mining with minimal stripping.

Unfavorable factors:

1. Rather low tonnage.
2. Long distance from present markets, but construction of the proposed Pa Mong dam and the industrial development of the adjacent areas may provide a market.

In order to fully evaluate this deposit, the following work is suggested:

1. Geologic reconnaissance of the surrounding area to attempt to locate additional cement-grade limestone.
2. Detailed topographic and geologic mapping, including surface sampling.
3. Diamond drilling and sampling.
4. Economic feasibility studies.

BARITE

BAN HUAI PHOT PROSPECT

The Ban Huai Phot prospect (N 2) is 0.5 km east of the village of Ban Huai Phot, 2 km northeast of the village of Ban That on the Loei-Chiengkarn highway (pl. 1).

The prospect is in an area of shallow Quaternary alluvium underlain by shale. One old partly caved pit at the prospect exposes the shale, but no barite. A stockpile containing about 2 tons of barite is at the edge of the pit.

No other evidence of barite was noted in the area, and no further investigations are proposed.

BAN TIN PHA PROSPECT

The Ban Tin Pha prospect (N 3) is about 1 km west of the village of Ban Tin Pha and 4 km east of the village of Ban That on the Loei-Chiengkarn highway (pl. 1). The Ban Tin Pha prospect is readily accessible in the dry season by a road that joins the highway about 2 km north of the highway bridge over the Loei River.

The prospect is in an area of poorly exposed sandstone and shale of probable Devonian and early Carboniferous age (pl. 1).

Barite exposures are scattered over an area about half a kilometer square. All the exposures except one are scattered barite fragments and boulders on the gently sloping topography. The single barite bedrock exposure is an outcrop of massive barite 5 m wide and 30 m long. Analysis of a grab sample of barite showed a $BaSO_4$ content of 99.4 percent.

The observed barite mineralization is limited in extent but high in grade. The strike length and the width are unknown, and geologic mapping and pitting are recommended to determine the extent of the barite.

The prospect may be similar to the Baw Hin Khao deposit to the south (see below).

BAW HIN KHAO DEPOSIT

The Baw Hin Khao deposit (N 4) is on a north-northwest-trending ridge 7 km southeast of the village of Ban That on the Loei-Chiengkarn highway and 5 km south of the Ban Tin Pha village (pl. 1). The base of the ridge is readily accessible by a dry-weather road from Ban That, which joins the highway at the school just north of the bridge over the Loei River.

No previous geologic work had been done, but local prospectors and miners had explored part of the area and made some small barite shipments from prospect pits.

During the present investigation a detailed surface topographic and geologic map was made, and eight trenches were excavated, mapped, and sampled.

The deposit is within a sequence of limestone, shale, tuff, and dolomite beds within the Devonian and lower Carboniferous sequence (pl. 1). The beds strike north-northwest and dip steeply east (fig. 22). The barite is present as bedded replacement deposits in dolomite. The main deposit has a strike length of 1,200 m; two smaller deposits have been noted to the west. Barite replacement of the dolomite is irregular and includes all gradations from scattered barite nodules in dolomite to massive barite. Three lithologic units were mapped (fig. 22): (1) barite: massive barite with little dolomite; (2) dolomite: dolomite with variable amounts of barite; and (3) shale or mudstone.

Areas of barite outcrop and boulders have a maximum width of more than 20 m. The trenches (fig. 22) exposed massive barite in widths from less than 1 m to as much as 9 m, with an average width of 5.2 m. The massive barite exposures in the trenches, however, were generally flanked by soil with barite boulders; the true width was therefore not determined. Vertically, barite was observed from an elevation of 350 m at the south end of the ridge to 550 m at the hilltop.

The proven and probable reserves of massive barite in the main deposit were calculated, assuming a strike length of 1,200 m, a thickness of 5 m, and an average depth of 100 m. The resulting reserves are 2.5 million tons of barite.

Possible reserves include (1) downdip extensions of the main deposit; (2) areas of barite boulders and soil; (3) reserves in other nearby deposits, such as the deposit exposed by trench 1 (fig. 22); and (4) low-grade reserves of dolomite with barite. The possible reserves are conservatively estimated as exceeding 3 million tons.

Partial analytical results for trench 6 indicate that the massive barite contains about 93 percent $BaSO_4$ and that the zone of barite and soil contains about 81 percent $BaSO_4$.

If a market and low-cost transportation for the barite can be found, economic development of this deposit should be feasible because reserves are large and grade is high, and the deposit is amenable to low-cost mining. Part of the deposit is probably minable by simple wash-

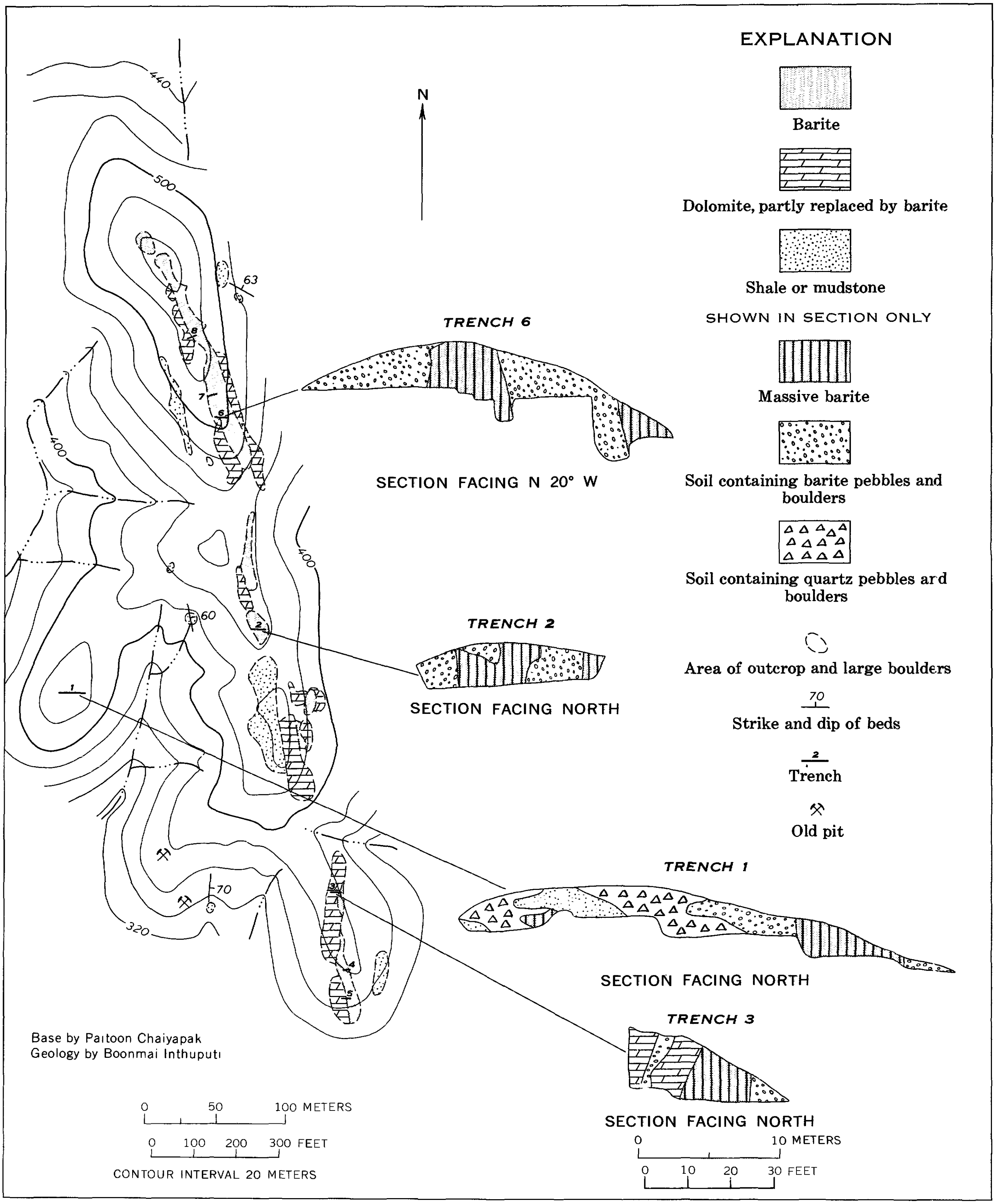


FIGURE 22.—Geologic map and sections of the Baw Hin Khao barite deposit.

ing to separate barite boulders from soil, and opencut mining with little stripping is probably feasible for parts of the deposit.

Lengthening and deepening of all the trenches (fig. 22) followed by sampling and diamond drilling is recommended to determine the total thickness, overall grade, and dip of the barite deposit.

ANHYDRITE-GYPSUM

LOEI DEPOSIT

One water well drilled in the town of Loei (N 5) by the Groundwater Division of the Royal Thai Department of Mineral Resources found a section of interbedded anhydrite-gypsum, mudstone, and marl from a depth of 76.2 m below the surface to the bottom of the well at 106.0 m. A second well, 2.5 km to the south, cut this section from a depth of 61 m to the bottom at 320 m. At Loei the anhydrite-gypsum section is overlain by 47 m of Quaternary alluvium in the Loei River valley. This thick alluvial cover, which includes gravel beds, discouraged further investigation; but a similar deposit (Wang Saphung) with thin cover was more fully examined.

WANG SAPHUNG DEPOSIT

The Wang Saphung deposit (N 6) is located 1 km east of the town of Wang Saphung at the junction of the highway to Loei and the road to Udorn (pl. 1). It is therefore readily accessible throughout the year.

The anhydrite-gypsum-bearing section is overlain by a maximum of a few meters of Quaternary alluvium (pl. 1), and its stratigraphic position is uncertain. The nearest bedrock exposures belong to the Kanchanaburi Series, and the sequence of interbedded limestone and shale observed in the drill cores is similar to some sections in this series. The anhydrite-gypsum-bearing section is therefore tentatively placed within the Kanchanaburi Series, though anhydrite and gypsum have not been reported in the series elsewhere in Thailand (Brown and others, 1951). On the other hand, anhydrite and gypsum are present in the Triassic to Cretaceous Khorat Series in northeast Thailand, and gypsum occurs in the Tertiary Mae Sot Series in north Thailand.

The deposit was discovered when a deep water well (C45L3) was drilled by the Groundwater Division of the Royal Thai Department of Mineral Resources; two diamond-drill holes were drilled under the authors' supervision east of the water well (fig. 23). The drill holes intersected a stratigraphic sequence having an apparent west dip of 27° [40] (east-west cross section, fig. 23). It contains three principal units: (1) surface clay-mudstone unit; (2) dolomitic limestone interbedded with mudstone (thickness to 51.3 m in drill hole 1); and (3) anhydrite and gypsum interbedded with limestone, tuff (?), shale, and mudstone (thickness more than 215.1 m, bottom not reached in drill hole 2).

Detailed core logging (p. 82) and core sampling and analysis (p. 89) showed that the 215-m anhydrite-gypsum-bearing section intersected by drill hole 2 (fig. 23) contained 17.2 m of gypsum in four intervals (table 12) 1.6–8.2 m thick, plus many gypsum beds whose maximum individual thickness is 1.5 m. The logs and analyses also showed that almost two-thirds of the section (132.6 m) is mostly anhydrite with local interbedded shale and that the remainder is mostly mudstone or shale with local anhydrite or gypsum.

Gypsum occurs mainly near the top of the section (table 12), and the thickest gypsum intersection of 8.2 m is at the top of the section in drill hole 2. The gypsum and anhydrite were frequently indistinguishable in the core, and chemical analyses (p. 89) were used for mineral identification.

TABLE 12.—*Summary of analyses of Wang Saphung gypsum intersections more than 1.5m thick*

Drill hole	Interval (meters)— From	Interval (meters)— To	Thickness (meters)	Percent— CaO	Percent— SO_3	Percent— H_2O
1	94.2	97.2	3.0	35.43	47.84	14.52
2	45.8	54.0	8.2	32.40	44.62	20.02
	59.7	61.3	1.6	32.82	44.84	20.20
	71.0	76.5	5.5	34.70	48.26	16.36
	257.2	259.1	1.9	35.69	38.91	16.44

Very large reserves of anhydrite are present, but no attempt has been made to calculate them because no market for anhydrite exists at present.

Proven and probable reserves of gypsum in the bed at the top of the section (fig. 23) are estimated at about one-half million tons, assuming an average thickness of 5.6 m and a length equal to the indicated width of 200 m (fig. 23). Large additional possible reserves are present, but they have not been estimated because no data on the strike length are available.

The gypsum intersections at the top of the section in drill hole 2 (45.8–54.0 m and 59.7–61.3 m, table 12) are nearly pure gypsum. In other intervals (table 12) the gypsum is mixed with anhydrite.

Projection of the anhydrite-gypsum section up the dip indicates that the topmost gypsum bed may occur just below the surface due east of the collar of drill hole 2 (fig. 23). A high-grade gypsum deposit of limited tonnage may therefore be present just below the surface. Diamond drilling is recommended to find the

[40] Dip based on drill-hole intersection of top of anhydrite—gypsum bearing section. Other near-horizontal dips indicated by bedding in core.

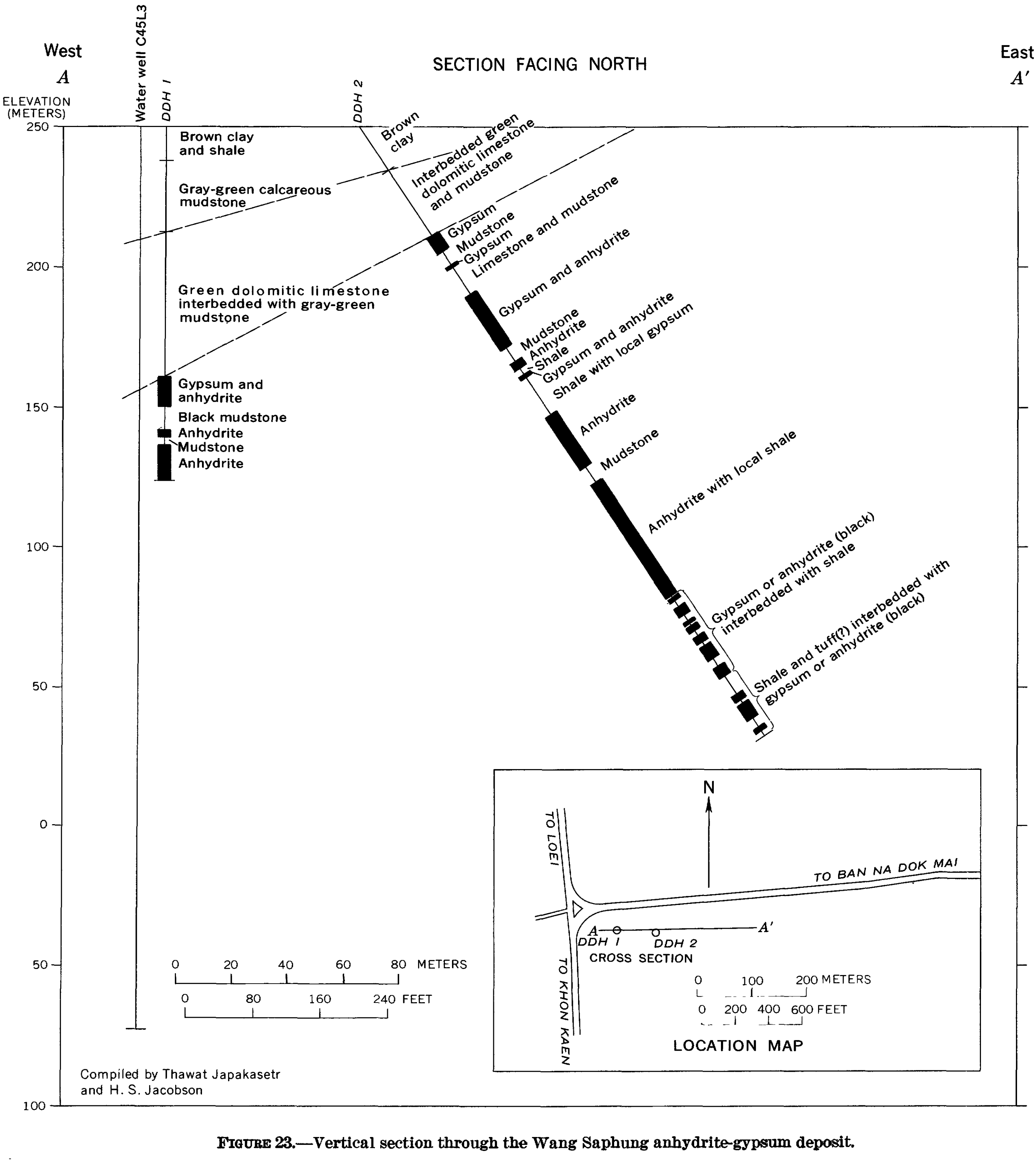


Figure 23.—Vertical section through the Wang Saphung anhydrite-gypsum deposit.

gypsum suboutcrop and to determine its length and width.

SALT

CHAIYAPHUM DEPOSIT

In contrast to most of the other mineral localities investigated, the Chaiyaphum deposit is on the Khorat Plateau about 300 km northeast of Bangkok (fig. 1) and 95 km north of Khorat (fig. 2). The deposit is at the town of Chaiyaphum which is accessible by means of an all-weather road from Khorat.

Rock salt (halite) was discovered in 30 drill holes in the Khorat Plateau (fig. 2) during the past decade by the ground-water resources development program conducted by the Royal Thai Department of Mineral Resources (Haworth and other, 1964). The salt discoveries totaling 1,253,538 million tons were described in detail by L. S. Gardner.[41]

The UN Special Fund specified that the salt should be investigated in "an area west of the general line Udorn-Chaiyaphum, where drilling shall be carried out for shallow rock salt." The salt discovered when a water well was drilled in the town of Chaiyaphum best met these specifications; therefore the authors' work was confined to this area.

The Maha Sarakam Formation occurs in two basins (Khorat and Sakhon Nakhon) within the Khorat Plateau (fig. 2) over a total area of about 50,000 sq km. The formation is composed of more than 700 m of interfingering beds of sandstone, shale, salt, and gypsum. In the 30 drill holes, salt was encountered in thicknesses as great as 247 m, at depths below the surface of 67–410 m. Commonly, the salt occurs in beds 2–100 m thick.

In the vicinity of Chaiyaphum the Maha Sarakam Formation was studied in detail, using data from water-well logs. The logs show a section of predominant shale and siltstone, with one massive salt intersection in well H2–10 (pl. 11*B*). The absence of salt in most of the other wells indicates that Chaiyaphum was a restricted local basin. Therefore, subsequent holes were drilled close to the discovery well.

Because the Chaiyaphum area is mostly flat farmland without rock exposures, the geologic data are entirely from the five drill holes (pl. 11*C*). The drill holes have an aggregate length of 847 m; core recovery generally exceeds 95 percent.

All the drill holes intersect the same sequence of sedimentary horizons at similar depths, indicating a uniform nearly flat-lying section (pl. 11*D*). The section includes a massive salt bed averaging 103.2 m thick overlain by an average of 61.2 m of sand, clay, gypsum, and anhydrite. Sandstone occurs beneath the salt. This sandstone may be part of the Maha Sarakam Formation or may be part of the saltless underlying Khok Kruat Formation.

The salt bed is composed of halite with minor gypsum(?) or anhydrite. The halite occurs as glassy crystals, as milky white halite, or smoky halite. The smoky halite is colored by organic carbon, and the core has a petroliferous odor when broken. Carbon content of a selected specimen was 0.16 percent, mostly in aliphatic and aromatic hydrocarbons (infrared spectrographic analysis, U.S. Geol. Survey), indicating that the organic material is similar to that found in normal marine sediments (V. E. Swanson, written commun., 1965).

The gypsum and anhydrite occur in the salt as stringers ranging from 1 to 10 mm in thickness, commonly 2–5 mm thick.

The five drill holes (pl. 11*C*) established the presence of the salt within the polygonal area bounded by the holes. We assume that the salt bed continues beyond this area for a distance equal to one-third the average distance between the drill holes, or 310 m. The surface area of the proven and probable reserves is thus 3 million sq m. The specific gravity of the salt determined from drill cores is 2.15. Using these data, the proven and probable reserves were calculated to be 660 million tons.

The Chaiyaphum salt bed probably terminates a short distance to the north and west (fig. 2), but it may extend at least a few kilometers to the south and east. The possible reserves can therefore be conservatively estimated at 1,500 million tons.

All the salt cores were sampled in 4.4–7.3 m intervals. Chemical analyses were made of individual samples for drill holes 2 and 3 (p. 90), and composite samples for drill holes 2–5. The results of the analyses (in percent) of the composite samples are given below:

Drill hole	NaCl	$CaSO_4$
1		
2	97.09	2.87
3	96.04	3.44
4	96.85	3.39
5	97.36	2.30
Average	96.83	3.00

The analyses of the composite samples show that the salt bed is almost pure halite. The presence of less than 0.01 percent combined water indicates that the $CaSO_4$ occurs in anhydrite. Analyses of the individual core samples (p. 90) show little deviation from the average grade of the composite samples.

Chemical analysis showed the presence of trace amounts of SiO_2, MgO, K_2O, Br, and CO_2, and semiquantitative spectrographic analysis detected traces of Al, Ti, Ba, Cr, Cu, Sn, Sr, and Pb (p. 91). Most of

[41] Gardner, L. S., Haworth, H. F., and Na Chiengmai, P., Salt resources of Thailand: Unpub. rept. in files of Royal Thai Dept. Mineral Resources.

the trace-element content is rather uniform, but a distinct increase in potassium toward the east from an average of 0.0085 percent in drill holes 4 and 5 to an average of 0.030 percent in drill holes 2 and 3 was noted.

The potential development of the salt deposit depends on economic factors beyond the scope of this report. However, the favorable and unfavorable factors are:

Favorable:

1. Very large reserves of high-grade salt.
2. Railroad transport will be available because a railroad now under construction will pass a few kilometers from Chaiyaphum.
3. Electric power will be available from hydroelectric plants now under construction or planned.
4. The salt is at a relatively shallow depth under a cover of clay rocks.

Unfavorable:

1. Long distance from markets.
2. An industrial water supply is at present not available at Chaiyaphum.

An economic feasibility study for the development of the Chaiyaphum salt deposit is needed, and a geologic investigation to explore for potash east of Chaiyaphum and throughout the salt-bearing areas of the Khorat Plateau is recommended.

GEOLOGIC LOGS OF DIAMOND-DRILL HOLES

BASE-METAL PROSPECTS AND DEPOSITS

PHU HIN LEK FAI DIAMOND-DRILL HOLE 1

By THAWAT JAPAKASETR

Interval (meters)	Description
0 – 4. 1	Overburden. No core.
4. 1– 4. 2	Light-tan altered tuff(?).
4. 2– 5. 4	Gossan; local hematite.
5. 4– 10. 7	Tan and green, slightly to strongly altered tuff(?) or porphyry [1] (?).
10. 7– 16. 5	Green to gray porphyry(?), about 1 percent pyrite.
16. 5– 18. 3	6-cm core; mostly pyrite with green porphyry(?) gangue and 6-cm core of heavy vuggy gray to brown rock (cerussite?).
18. 3– 20. 2	No core.
20. 2– 21. 4	White recrystallized limestone.
21. 4– 23. 1	Gray to green limestone with some pyrite and unidentified dark-green mineral.
23. 1– 26. 2	Green to gray calcareous volcanic sedimentary rock, porphyritic texture. Probably is water-laid coarse tuff with calcite veinlets; disseminated pyrite and chalcopyrite(?).
26. 2– 33. 9	Light-gray to green partly silicified mudstone(?) or tuff(?); green mineral (chlorite?) along fractures. At 33.04 m, a 4-cm core fragment of pyrite and magnetite.
33. 9– 43. 2	Gray, green, brown, and black mudstone or tuff(?), partly silicified and fractured; some pyrite.
43. 2– 48. 8	White, brown, and black partly altered and mineralized tuff or mudstone; clay alteration and silicification; mineral in heavy vuggy rock (smithsonite?) concentrated locally in interval.
48. 8– 54. 3	White to gray crystalline limestone; local tuff(?).
54. 3– 55. 9	Banded silicified mudstone or tuff, banding perpendicular to core; minor pyrite.
55. 9– 70. 7	Brecciated tuff; pyrite veinlets; calcite gangue in fractures; minor chalcopyrite locally.
70. 7– 83. 0	Similar to 55.9–70.7-m interval, but less brecciation.

See footnote at end of table.

[1] The term "porphyry" as herein used refers to a rock which has porphyritic texture and which may be an altered fragmental tuff or an altered volcanic porphyry.

PHU HIN LEK FAI DIAMOND-DRILL HOLE 2

By THAWAT JAPAKASETR

Interval (meters)	Description
0 – 3. 3	Overburden.
3. 3– 10. 1	Yellow altered and iron-oxide impregnated tuff(?) or porphyry(?). Probably a weathered pyritic zone.
10. 1– 11. 2	Pyritic tuff or porphyry; strongly sheared; an unidentified blue-black mineral.
11. 2– 26. 8	Altered gray to brown brecciated tuff; small amount of pyrite and chalcopyrite(?).
26. 8– 28. 8	Cryptocrystalline gray quartz (chert).
28. 8– 38. 7	Altered gray to brown tuff(?) or porphyry(?); disseminated magnetite, pyrite, and chalcopyrite(?); local skarn and green garnet(?).
38. 7– 59. 4	Gray, yellow, and green altered tuff(?) or porphyry(?), locally rich in magnetite and pyrite; about 1 percent chalcopyrite; some green garnet(?); chlorite(?) along fractures.
59. 4– 65. 7	Mostly magnetite with pyrite in green sandy loose rocks; about 1 percent chalcopyrite; local green garnet(?). Porphyry(?) or tuff(?) from 63.3–64.5 m.
65. 7– 67. 0	No core.
67. 0– 89. 9	Altered gray to green tuff(?) or porphyry(?) containing magnetite, pyrite, chalcopyrite, and bornite(?). Chalcopyrite, 1–2 percent; locally as much as 10 percent. Magnetite and pyrite as much as 20 percent.
89. 9–100. 9	Gray to brown altered clay rock; minor magnetite; hornfels(?) in part.
100. 9–152. 4	Altered latite(?) with some pyrite and magnetite; local malachite and chalcopyrite; iron oxide staining conspicuous at many places; greenish, probably because of disseminated malachite grains.

PHU HIN LEK FAI DIAMOND-DRILL HOLE 3

By NARIN PHOLPHAN

Interval (meters)	Description
0 – 1. 2	No core.
1. 2– 8. 0	Weathered, altered clay rock and shale with iron oxides.
8. 0– 19. 5	Weathered, altered porphyry(?); iron oxides along fractures; a few malachite(?) grains.
19. 5– 57. 9	Altered diorite(?) porphyry, disseminated malachite(?) and green mineral (chlorite?) on fracture surfaces.
57. 9–127. 3	Quartz diorite(?) porphyry; local yellow-green disseminated malachite(?) or chlorite(?); minor disseminated magnetite and pyrite; less than 1 percent chalcopyrite disseminated and in veinlets.

Interval (meters)	Description
127. 3–151. 9	Gray and green porphyritic rock containing green phenocrysts; most of it contains more than 1 percent chalcopyrite as disseminations, fracture fillings, and in quartz veinlets; calcite gangue; some pyrite.
151. 9–186. 0	Gray and green porphyry as in interval 127. 3–151.9 but containing less than 1 percent chalcopyrite.
186. 0–210. 0	Quartz diorite(?) porphyry; contains about 1 percent chalcopyrite.
210. 0–218. 0	Quartz diorite(?) porphyry; contains about 1–2 percent chalcopyrite.

PHU THONG DAENG DIAMOND-DRILL HOLES 1-3

By THAWAT JAPAKASETR

Interval (meters)	Description
Hole 1 [1]	
0 – 1. 5	No core.
1. 5– 3. 0	Gossan. Vuggy iron oxides (hematite, limonite, etc.) and about 5 percent gangue. Gangue is iron-impregnated clay.
3. 0– 14. 6	Altered iron oxide-stained yellow-brown clay and tuff. Local short intervals of gossan.
14. 6– 16. 4	Gossan. Vuggy iron oxides; clay gangue, and iron oxide-stained clay or tuff.
16. 4– 25. 9	Altered iron oxide-stained tuff. Iron oxide content variable. Most is weakly stained. Few core fragments of gossan (mostly limonite) from 23.4–25.9 m.
25. 9– 47. 9	Altered coarse fragmental light-brown to red-brown tuff(?) or porphyry(?). Weak iron oxide staining and alteration. Few core fragments of vuggy gossan at 31.4–36.6, and 39.6 m. Gossan (hematite, goethite?); iron oxide staining decreased at bottom of interval.
47. 9– 83. 6	Gray and green to brown altered coarse fragmental tuff(?) or porphyry(?); weak iron oxide stain.
83. 6– 86. 0	Green andesite prophyry. Plagioclase phenocrysts in fine-grained dense green matrix.
86. 0– 96. 4	Green, gray, and tan altered coarse fragmental tuff(?) or porphyry(?). Variable weak iron oxide staining. Few malachite grains at 90.9 m.
96. 4–103. 4	Most is iron oxide with clay gangue and minor disseminated pyrite; unidentified black mineral may be chalcocite.
103. 4–108. 3	Gray to brown altered coarse fragmental tuff(?) or porphyry(?). Few black mineral grains may be chalcocite. At 108.27 m, core contains 2 cm of chalcocite(?), pyrite, and quartz.
108. 3–112. 5	No core.
112. 5–115. 6	Green dense very fine grained and coarse-grained tuff(?) or porphyry(?) with sparse disseminated unaltered pyrite.
Hole 2 [2]	
0 – 3. 3	No core.
3. 3– 23. 8	Light-gray to tan altered tuff with weak iron oxide stain.
23. 8– 31. 7	Strongly iron oxide-impregnated tuff, friable; minor quartz.
31. 7– 32. 6	No core.
32. 6– 34. 5	Red-brown altered coarse fragmental tuff(?) or porphyry(?); moderate iron oxide staining.
34. 5– 41. 5	Light-gray to green altered coarse fragmental tuff(?) or porphyry(?); weak iron oxide staining.
41. 5– 68. 3	Light-gray altered coarse fragmental tuff(?) or porphyry(?); moderate iron oxide staining and about 1 percent of a disseminated black mineral (chalcocite?). At 55.5 m, core contains 2 cm of massive chalcocite altering to malachite.

See footnotes at end of table.

Interval (meters)	Description
Hole 2 [2]	
68. 3– 68.6	White clay (kaolin?).
68. 6– 71. 4	Friable to dense massive maroon and brown iron oxides (hematite and goethite); trace of pyrite and unidentified black mineral.
71. 4– 84. 5	Light-gray, green, and tan altered coarse-grained fragmental tuff(?) or porphyry(?) with trace of unidentified black mineral.
84. 5– 88. 4	Light-gray to tan sandy coarse fragmental tuff(?) or porphyry(?); little iron oxide stain; trace of pyrite.
88. 4–112. 3	Green coarse fragmental tuff(?) or porphyry(?) and dense fine-grained green tuff with disseminated pyrite (1–5 percent pyrite).
Hole 3	
0 – 1. 5	Overburden.
1. 5– 10. 7	Altered weathered clayey rock; iron oxides common (ironoxide-stained tuff?).
10. 7– 17. 7	Altered tuff(?) or porphyry(?); iron oxide stained.
17. 7– 19. 2	Mainly vuggy hematite; probable gossan with visible boxworks and quartz.
19. 2– 34. 8	Altered tuff(?) or porphyry(?); local silicification, kaolinization, and manganese oxide staining.
34. 8– 35. 4	Vuggy hematite (gosson) with quartz.
35. 4– 46. 9	Iron oxide-stained altered tuff(?) or porphyry(?); much clay (kaolin?).
46. 9– 53. 4	Strongly iron oxide-impregnated tuff(?) and vuggy gossan composed of iron oxides, quartz, and chalcopyrite(?).
53. 4– 76. 8	Yellow tuff(?) and porphyry(?); locally silicified or kaolinized; pyrite disseminations and fracture coatings; quartz-pyrite veinlets.
76. 8– 78. 3	No core.
78. 3– 81. 4	Massive pyrite with hematite and about 10 percent green porphyry(?) gangue.
81. 4– 83. 9	Green pyritized porphyry (?).
83. 9– 84. 8	No core.
84. 8–110. 4	Yellow kaolinized tuff(?) or porphyry(?) with about 5 percent pyrite and unidentified disseminated black mineral. At 84.8, 3 cm of core is chalcopyrite intergrowth with pyrite.

[1] Average core recovery 22.5 percent.
[2] Average core recovery 22.3 percent.

PHU KHUM 1 (BAN KHOK MON) DIAMOND-DRILL HOLE 1

By H. S. JACOBSON

Interval [1] (meters)	Description
0 – 2. 1	Overburden.
2. 1– 8. 8	Recrystallized bleached gray limestone; iron oxide staining.
8. 8– 23. 3	Dense black and gray locally bedded limestone; bedding 30°–45° to core axis; calcite stringers and veinlets and trace of pyrite.
23. 3– 30. 0	Light-green limestone with occasional calcite stringers and trace of pyrite; 7-cm clay (fault gouge?) at 24.3 m.
30. 0– 32. 9	Black partly recrystallized limestone with stringers and pods of pyrite; pyrite 5–30 percent.
32. 9– 64. 7	Dense black limestone with occasional thin calcite veinlets; minor pyrite as thin stringers and disseminations; locally bedded, bedding 30°–35° to core axis.
64. 7– 75. 0	Interbedded dense black and light-green limestone; bedding 30°–40° to core axis; few calcite stringers and minor pyrite.
75. 0– 76. 4	Partly recrystallized light-green limestone with calcite and pyrite in pods and stringers; few pinhead galena grains.

See footnote at end of table.

Interval [1] (meters)	Description
76.4– 97.8	Strongly bleached recrystallized limestone, trace to 30 percent pyrite as disseminations, irregular pods, and stringers; average 5 percent pyrite estimated.
97.8–105.0	Bleached pale-greenish-gray limestone with calcite stringers and minor pyrite.
105.0–106.7	Bleached green limestone; about 5 percent pyrite as disseminations and irregular pods.

[1] Average core recovery more than 90 percent.

PHU KHUM 1 (BAN KHOK MON) DIAMOND-DRILL HOLE 2

By H. S. JACOBSON

Interval [1] (meters)	Description
0 – 2.3	Overburden.
2.3– 17.1	Limestone conglomerate: 2- to 5-mm diameter subangular to subrounded fragments of limestone, shale, and siltstone in green limestone matrix; trace pyrite.
17.1– 67.9	Green conglomeratic limestone and green limestone; commonly 2- to 5-mm diameter limestone fragments in limestone matrix; locally larger fragments or no fragments; occasional calcite stringers and veinlets toward bottom of interval; trace disseminated pyrite.
67.9– 70.1	Partly altered and bleached conglomeratic limestone; 1- to 3-mm spots of unidentified yellow-green mineral common; trace disseminated pyrite.

[1] Average core recovery more than 90 percent.

PHU KHUM 1 (BAN KHOK MON) DIAMOND-DRILL HOLE 3

By D. R. WORKMAN and THAWAT JAPAKASETR

Interval (meters)	Description
0 – 1.7	No core.
1.7– 11.9	Green conglomeratic limestone and limestone: 2- to 5-mm rock fragments of black and yellow siltstone, and limestone in green limestone matrix.
11.9– 13.1	Pink and green limestone, mottled, bleached; few calcite stringers and veinlets.
13.1– 36.1	Green conglomeratic limestone and limestone as above (1.7–11.9), but containing large fragments locally as much as 20 mm long.
36.1– 57.4	Gray conglomeratic limestone and limestone with 2–5-mm rock fragments similar to above but different in color. Calcite stringers and veinlets scattered throughout interval. Calcite pods (1–2 cm) from 50.7–57.4 m.
57.4– 59.9	Gray conglomeratic limestone and limestone with calcite pods, stringers, and veinlets. Disseminated pyrite grains and crystals.
59.9– 69.9	Gray brecciated mineralized limestone and gray or white mineralized limestone. Limestone, locally thin bedded, bedding at 40° to core axis. Sulfide minerals as follows: 59.91–60.04, trace of galena and sphalerite and about 10 percent pyrite. 60.04–62.66, disseminated pyrite with traces of galena at 60.55, 61.84, and 62.66 m. 62.66–69.94, sparse scattered pyrite, galena, and sphalerite grains.
69.9– 82.1	White and gray limestone with pyrite pods and stringers. In part thin-bedded laminated limestone. Locally, brecciated limestone. Few grains of galena at 75.24–75.89 m; few grains of metallic mineral (galena?) between 74.34 and 74.95 m. Locally, trace of galena from 80.01–82.14 m; gouge (fault?) at 69.94 m.
82.1– 86.9	Bleached, white, partly sugary textured limestone with calcite pods and stringers. Occasional pyrite pods and trace of galena and sphalerite.
86.9– 90.0	Sulfide mineralization as follows: 86.89–88.44, mostly fine-grained galena and pyrite; some sphalerite. Pods of brown-yellow glassy mineral. 88.44–88.72, trace of galena and sphalerite. 88.72–89.12, same as 86.89–88.44. 89.12–89.68, mostly galena, sphalerite, and pyrite (about 60 percent galena and sphalerite). 89.68–89.86, same as 86.89–88.44. 89.86–89.96, same as 89.12–89.68.
90.0–109.7	White to light-gray crystalline limestone. A few paper-thin stringers of dark-gray mineral at 90 m and limestone breccia from 100.38–100.94 m.

PHU KHUM 1 (BAN KHOK MON) DIAMOND-DRILL HOLE 4

By THAWAT JAPAKASETR

Interval (meters)	Description
0 – 36.1	White to gray fossiliferous limestone; crinoid stems; 5 cm of limestone breccia with some galena and sphalerite at 12.0 m.
36.1– 36.5	Limestone breccia with some pyrite and traces of galena and sphalerite.
36.5– 37.4	Gray breccia.
37.4– 40.2	White to gray limestone.
40.2– 40.8	Gray breccia.
40.8– 95.3	Limestone breccia with trace galena and sphalerite. White to gray limestone.
95.3–106.7	White recrystallized limestone.

PHU KHUM 2 (BAN NONG YA SAI) DIAMOND-DRILL HOLE 1

By D. R. WORKMAN and THAWAT JAPAKASETR

Interval (meters)	Description
0 – 3.8	No core.
3.8– 15.7	Massive light-gray limestone; some black disseminations (manganese?) and pink patches (dolomite?).
15.7– 27.4	Light-brown clay; poor core recovery.
27.4– 40.2	Massive light-gray crystalline limestone.
40.2– 58.5	Brown and gray siltstone with some clay; poor core recovery.
58.5– 72.2	Siltstone with local interbedded limestone; poor core recovery.
72.2– 96.3	Light-colored hard metamorphosed siltstone (hornfels) with disseminated pyrite and some calcite veins.
96.3–103.0	Hard metamorphosed siltstone (hornfels) as above. Locally mineralized with minor pyrite and traces of chalcopyrite(?) especially from 98–101 m; calcite fracture fillings.
103.0–115.0	Light-gray crystalline limestone. Minor pyrite; trace of chalcopyrite and galena in stringers and veinlets, except 1 m with moderate pyrite and minor galena and chalcopyrite at 106 m.

Interval (meters)	Description
115. 0–118. 4	Light-gray crystalline limestone with minor pyrite and local traces of chalcopyrite and galena. Metamorphosed to skarn at bottom of interval (116.2–118.9 m).
118. 4–120. 1	Granodiorite with trace of pyrite.

IRON DEPOSITS

PHU LEK (CHIENGKARN) DIAMOND-DRILLHOLE 1

By Narin Pholphan and C. T. Pierson

Interval (meters)	Description
0 – 1. 8	Overburden.
1. 8– 9. 1	No core.
9. 1– 12. 2	Quartzite(?) or aplite(?) with magnetite from 11.0–12.2 m.
12. 2– 18. 9	Magnetite with hematite.
18. 9– 25. 4	Baked shale with some stringers of diorite(?) (contact zone); minor pyrite.
25. 4– 26. 2	Diorite(?) with as much as 30 percent magnetite and pyrite.
26. 2– 30. 8	Banded hornfels with local banding 48° to core axis.
30. 8– 36. 3	Metadiorite(?); some interbedded hornfels with banding 49° to core axis; some 2-mm pyrite veinlets.
36. 3– 39. 6	Gray banded hornfels with pyrite along fractures.
39. 6– 42. 5	Gray banded hornfels with many magnetite-pyrite veinlets as much as 1.5 cm wide at 30°–49° to core axis; magnetite as much as 30 percent.
42. 5– 67. 1	Gray, locally banded hornfels; calcite veinlets and pyrite along fractures. Banding 30°–49° to core axis.
67. 1– 81. 7	Gray and green hornfels; local magnetite; some epidote(?) and disseminated pyrite.
81. 7–104. 6	Granodiorite; local magnetite and patches of epidote(?); contact zone.

PHU YANG DRILL HOLES 1–10

By Boonmai Inthuputi and H. S. Jacobson

Interval (meters)	Description
Hole 1	
0 – 6. 2	Overburden: soil and hematite-magnetite boulders.
6. 2– 12. 0	Hematite, some magnetite; dense but with leached vugs after pyrite; minor noncalcareous gangue.
12. 0– 15. 4	Magnetite and hematite with 5–30 percent pyrite. Dense, fine-grained, and partly friable magnetite; pyrite in disseminations, pods, and stringers; minor oxidation and few leached cavities.
15. 4– 41. 5	Magnetite and hematite with 5–20 percent pyrite and quartz gangue. Magnetite locally has breccia texture with quartz between magnetite. Disseminated pyrite and pyrite in pods and stringers. Magnetite dense and locally friable. Calcite gangue as much as 5 percent.
41. 5– 56. 8	Green hard banded siliceous hornfels; banding 54°–65° to core.
56. 8– 60. 3	Irregularly mineralized limestone; 10–70 percent calcite, 30–80 percent magnetite, and 10–20 percent pyrite. Occasional breccia texture.
60. 3– 84. 0	Green hard siliceous banded hornfels. Banding 60°–70° to core. Trace of pyrite.

Interval (meters)	Description
Hole 2	
0 – 0. 9	Overburden: soil and hematite-magnetite boulders.
0. 9– 10. 4	Hematite with minor magnetite. Leached cavities after pyrite, locally porous. Calcareous gangue.
10. 4– 14. 6	Hematite and minor magnetite; porous, cavities leached after pyrite, 1–5 percent pyrite. Minor noncalcareous gangue.
14. 6– 22. 6	Dense and friable magnetite; minor hematite; 1–15 percent pyrite as irregular pods; quartz and carbonate gangue; brecciated texture.
22. 6– 27. 6	Breccia(?), irregular angular fragments of magnetite in skarn(?); 5–10 percent pyrite in irregular pods.
27. 6– 31. 7	Magnetite; brecciated texture and 1- 10-mm pods of pyrite; carbonate gangue.
31. 7– 33. 2	Green skarn(?) and mineralized skarn(?) breccia with 30–50 percent magnetite and 2–5 percent pyrite as disseminations and irregular pods; calcite gangue.
33. 2– 38. 6	Magnetite and fragments of unreplaced skarn(?); local brecciated texture; about 5 percent pyrite as disseminations and pods; calcite gangue.
38. 6– 39. 9	Green skarn(?).
39. 9– 41. 7	Massive magnetite and 5–10 percent pyrite and local included unreplaced fragments of skarn(?).
41. 7– 42. 4	Green skarn(?); about 20 percent magnetite in pods.
42. 4– 50. 6	Dense massive magnetite with 5–10 percent pyrite and occasional skarn(?) fragments.
50. 6– 55. 2	Dense massive magnetite, alternating with 10–20-cm sections of unmineralized skarn(?). About 5 percent pyrite in pods and stringers.
55. 2– 60. 0	Dense massive magnetite with 5–20 percent pyrite in irregular elongated pods. Carbonate gangue.
60. 0– 74. 3	Banded green and white hornfels. Banding 60°–80° to core. Local traces of magnetite and pyrite.
74. 3– 79. 4	Banded magnetite; 10–20 percent pyrite and as much as 30 percent hornfels gangue.
79. 4– 79. 5	Green skarn(?); as much as 5 percent magnetite and pyrite.
79. 5– 87. 2	Vaguely banded green and white hornfels with minor magnetite and pyrite.
Hole 3	
0– 4. 6	No core.
4. 6– 9. 1	Dense hematite; some leached cavities after pyrite. Minor magnetite.
9. 1– 10. 3	Brown plastic clay: fault gouge?
10. 3– 12. 2	No core: cuttings show about 50 percent magnetite
12. 2– 18. 2	Green hornfels with rectangular white porphyroblasts (silicified andesite?). Trace of pyrite.
18. 2– 20. 3	Very hard green siliceous hornfels; as much as 5 percent pyrite.
20. 3– 21. 4	Gray and green silicified skarn(?); 2–5 percent pyrite.
21. 4– 30. 2	Very hard green hornfels; local banding at 60° to core. Minor pyrite.
Hole 4	
0– 9. 4	No core.
9. 4– 23. 2	Tan silicified rhyolite porphyry with rounded to rectangular feldspar phenocrysts; color darker brown toward bottom of interval; trace of pyrite.
23. 2– 41. 7	Very hard siliceous green and black hornfels; subrounded to subangular white porphyroblasts. Trace of calcite, pyrite, and magnetite; silicified andesite porphyry(?).
41. 7– 49. 9	Magnetite with 5–20 percent pyrite; skarn(?), fine-grained. Pyrite in pods and stringers.
49. 9– 64. 4	Dense fine-grained magnetite with 5–15 percent pyrite and calcite gangue. Pyrite as disseminations, pods, and stringers.
64. 4– 66. 5	Very hard green hornfels, with local magnetite and pyrite.
66. 5– 72. 0	Dense fine- to medium-grained magnetite with 5–20 percent pyrite and calcite gangue. Green mineral, possibly epidote.

Interval (meters)	Description
Hole 4	
72.0–73.2	Alternating green hornfels and magnetite with pyrite and calcite.
73.2–79.3	Green and white very hard banded hornfels; bands at 40°–70° to core, but most at 60°–70° to core. Pyrite as disseminations, pods, and stringers.
Hole 5	
0–21.0	No core; chemical analysis of cuttings shows iron intersected from 1.5–16.7 m; average iron content as follows: 1.5–10.7 m, 51.2 percent Fe 10.7–16.7 m, 27.8 percent Fe
21.0–38.9	Gray and green hard silicified andesite(?); pyrite magnetite, and calcite. Calcite in veinlets.
38.9–43.5	Green weakly silicified to silicified andesite(?); local "blotched" texture due to inclusions of calcite and magnetite.
43.5–46.7	Green hard hornfels with white subangular to subrounded porphyroblasts; silicified andesite porphyry(?).
Hole 6	
0–27.5	White and green hard siliceous hornfels; some rectangular porphyroblasts. Local vague banding trends 60°–65° to core. Trace of mineralization; silicified andesite porphyry(?).
27.5–29.0	No core; cuttings show about 90 percent magnetite.
29.0–33.5	Green skarn(?) with irregular pods of magnetite, calcite, and pyrite. About 50 percent magnetite.
33.5–38.7	Banded magnetite, local banding 50°–70° to core; 5–15 percent pyrite as disseminations, pods, and stringers; calcite gangue.
38.7–45.7	Hard siliceous hornfels with rounded to rectangular white porphyroblasts. Local banding 80°–90° to core; silicified andesite porphyry(?).
Hole 7	
0–1.5	No core; overburden.
1.5–13.7	Massive hematite-magnetite with sugary texture and leached vugs after pyrite.
13.7–16.2	Massive magnetite with minor hematite and pyrite; leached cavities after pyrite.
16.2–20.1	Massive magnetite, somewhat friable, fine-grained; irregular pods and stringers of pyrite. Calcite gangue.
20.1–25.8	Same as from 16.2–20.1 m, but also includes few unmineralized intervals (5–20 cm thick) of green skarn(?).
25.8–28.6	Dark-green siliceous hornfels with subrounded to rectangular white porphyroblasts. Silicified andesite porphyry(?).
28.6–36.4	Massive magnetite alternating with soft green skarn(?). Irregular pods and stringers of pyrite and thin calcite stringers.
36.4–41.1	Green mottled skarn(?) and 2- to 13-cm pods of massive magnetite.
41.1–45.7	Same as interval 28.6–36.4 m.
45.7–49.8	Dense hard fine-grained magnetite with 5–15 percent pyrite in pods and stringers; trace of calcite. Local fragments of unmineralized rock.
49.8–51.6	Dark-green siliceous hornfels with subangular to subrounded white porphyroblasts. Silicified andesite porphyry(?).
51.6–55.3	Green locally silicified mottled skarn(?) with traces of magnetite and pyrite.
55.3–82.0	Friable dense to sugary-textured magnetite; irregular pods and stringers of pyrite as much as 2 cm thick. Few rock fragments (skarn?). banding from 61.3–64.2 m at 60°–70° to core.
82.0–87.7	Green, banded, hard siliceous hornfels; some pyrite and magnetite. Banding 55°–60° to core.
87.7–88.5	Contact zone; hornfels as from 82.0–87.7, pseudo-igneous texture becoming more prominent toward end of interval.
88.5–88.8	Contact zone; altered granodiorite; abundant plagioclase feldspar; some quartz and hornblende; some green hornfels.

Interval (meters)	Description
Hole 8	
0–6.4	Mainly hematite, little magnetite; leached vugs after pyrite(?) locally concentrated; porous texture; minor gangue is mostly quartz.
6.4–9.5	Mainly hematite and magnetite; some irregular pods of pyrite as much as 1 cm thick; many leached vugs; pyrite content increases toward bottom of interval.
9.5–11.0	Brittle vuggy hematite-magnetite and minor pyrite.
11.0–20.0	Dense fine-grained magnetite; 5–10 percent pyrite in irregular pods and stringers; rock fragments (skarn?) locally as much as 30 percent of core.
20.0–24.7	Friable dense sugary-textured magnetite and 3–10 percent pyrite in irregular pods as much as 5 mm thick; minor gangue.
24.7–30.0	Fine- to medium-grained dense partly friable magnetite; 5–20 percent pyrite as disseminations and irregular pods. Unreplaced rock fragments (skarn?) locally as much as 30 percent of core.
30.0–36.9	Dense fine-grained magnetite; 5–20 percent pyrite as disseminations, pods, and stringers; also irregular pods and stringers of calcite and unreplaced rock fragments (skarn?).
36.9–38.1	Magnetite and pyrite, alternating with intervals of partly silicified green skarn(?).
38.1–39.7	Dense fine- to medium-grained magnetite; irregu-pods and stringers of pyrite as much as 2 cm.
39.7–41.1	Green silicified skarn(?) with irregular pods and stringers of magnetite and pyrite; also disseminated pyrite.
41.1–46.7	Dense fine- to medium-grained magnetite; 5–15 percent pyrite as pods and stringers; also includes a few 15- to 25-cm intervals of skarn(?) with magnetite.
46.7–47.0	Green silicified skarn(?) with trace of pyrite.
47.0–56.3	Dense fine- to medium-grained magnetite; unmineralized intervals of green skarn(?) as much as 40 cm thick; 5–15 percent pyrite as disseminations and irregular pods and stringers.
56.3–56.9	Black silicified rock with white porphyroblasts. May be silicified andesite porphyry.
56.9–60.3	Fairly dense fine- to medium-grained magnetite; 5–10 percent pyrite in pods and thin stringers; local unreplaced rock fragments of skarn(?) and short intervals of skarn(?) with magnetite at 57.4–57.8 m, and from 58.2–58.4 m; minor calcite gangue.
60.3–61.5	Green mottled skarn(?) with 1- to 10-mm pods of massive magnetite and some pyrite; minor calcite gangue.
61.5–64.6	Hard green silicified skarn(?); thin pyrite and calcite stringers.
64.6–66.4	Very hard green siliceous hornfels; vague banding at 35°–45° to core.
Hole 9	
0–1.5	Overburden: soil and hematite-magnetite boulders.
1.5–6.1	Sludge: red-brown, sandy; hematite and trace of magnetite. No core.
6.1–12.8	Black and green hard siliceous hornfels.
12.8–18.6	Green and black hard siliceous hornfels with minor iron oxide staining.
18.6–20.7	Green locally banded hard hornfels; banding at 60°–70° to core and thin fractures at 20°–30° to core.
20.7–20.8	No core recovery and no sludge.
20.8–21.9	Hematite and minor magnetite and calcite gangue; leached vugs (after pyrite?).
21.9–23.8	Green vaguely banded hard hornfels; traces of iron oxide staining and pyrite.
23.8–24.8	Hematite and some magnetite and pyrite; dense but partly vuggy; leached vugs (after pyrite?).
24.8–27.9	Green hard siliceous hornfels and trace of pyrite.

Interval (meters)	Description
Hole 9	
27. 9– 37. 9	Green and white vaguely to distinctly banded hard siliceous hornfels; traces of pyrite as disseminations and stringers; banding at 55°–70° to core.
37. 9– 38. 0	Green soft metamorphic rock; considerable pyrite as pods, disseminations, and stringers (skarn?).
38. 0– 38. 3	No core recovery; no sludge.
38. 3– 39. 3	Green hard siliceous hornfels; minor pyrite.
39. 3– 39. 7	Fine-grained dense magnetite; pyrite pods and disseminations.
39. 7– 56. 4	Green and white vaguely to distinctly banded hard siliceous hornfels; traces of calcite and pyrite. Banding at 50°–75° to core but most is at 60°–70°.
56. 4– 57. 4	Magnetite with considerable calcite gangue and pyrite as pods, stringers, and disseminations.
57. 4– 65. 6	White and green vaguely to distinctly banded hard siliceous hornfels. Banding at 55°–70° to core. Breccia texture at end of interval.
65. 6 66. 6	Dense fine-grained magnetite; 5–15 percent pyrite as pods, disseminations, and stringers; minor calcite gangue.
66. 6– 72. 8	Green vaguely to distinctly banded hard siliceous hornfels; thin veinlets of calcite and traces of pyrite and magnetite(?). Banding at 60°–70° to core and veinlets at 20°–40° to core.
Hole 10	
0 – 7. 6	Mainly hematite boulders with little magnetite; porous; leached vugs after pyrite(?); minor noncalcareous gangue. At 5.5–6.4 m, altered granodiorite(?) (boulder?), mostly plagioclase feldspar; minor quartz and some hornblende.
7. 6– 9. 4	Black very hard siliceous hornfels with some pyrite as pods and irregular stringers.
9. 4– 11. 3	Black and green hard siliceous hornfels with minor pyrite; iron oxide staining along fractures.
11. 3– 12. 4	Green hard siliceous hornfels; minor pyrite; iron oxide staining along fractures.
12. 4– 14. 2	White and green hard siliceous hornfels; little magnetite; minor pyrite as pods, stringers, and disseminations.
14. 2– 16. 8	Green and white vaguely banded hard siliceous hornfels; minor pyrite; little magnetite; iron oxide staining along fractures.
16. 8– 18. 3	Green and white vaguely to distinctly banded hard siliceous hornfels; minor pyrite; banding 50°–60° to core; little magnetite.

PHU HIA DIAMOND-DRILL HOLE 1

By SANER PRAPASSORNKUL and H. S. JACOBSON

Interval [1] (meters)	Description
0 – 0. 7	No core.
. 7– 11. 9	Green sandstone and quartzite with weak iron oxide stain along fractures. Trace of disseminated pyrite. From 6.1–7 m, green shale or tuff(?).
11. 9– 15. 2	No core; sludge of sandstone with magnetite.
15. 2– 18. 6	Sandstone with hematite and magnetite. Magnetite increases toward bottom of interval.
18. 6– 21. 2	Magnetite and hematite with sand and clay gangue. Mostly crystalline magnetite with ½–1 mm crystals.
21. 2– 25. 3	Green limy clay rock (mudstone or tuff(?)); locally sandy. From 21.6–22 m, magnetite with pyrite and clay gangue; remainder of interval contains trace of pyrite.
25. 3– 25. 8	Magnetite with clay and calcite gangue (partly replaced limy mudstone or tuff).
25. 8– 35. 0	Massive dense fine-grained magnetite, with local crystalline magnetite (crystals 1–2 mm); calcite gangue less than 5 percent.
35. 0– 40. 9	Dense fine-grained magnetite, with variable amounts of gangue as much as 50 percent of core. Gangue is unreplaced limy mudstone or tuff. Local irregular pods and stringers of pyrite and calcite.
40. 9– 47. 8	Massive dense fine-grained magnetite; less than 5 percent carbonate gangue and few irregular pods and stringers of pyrite. At 47.8 m, sharp contact with limestone (below) trends 80°–90° to core axis.
47. 8– 61. 0	Dense gray and white fine-grained partly recrystallized limestone except from 51.1–51.4 m, which is green dense limy clay rock (argillite or tuff(?).

See footnote at end of table.

[1] Average core recovery 53 percent.

PHU HIA DIAMOND-DRILL HOLES 2-4

By NARIN PHOLPHAN

Interval (meters)	Description
Hole 2	
0 – 3. 0	Overburden; magnetite-hematite boulders.
3. 0– 6. 1	Tuff or shale, limonite-impregnated; local magnetite.
6. 1– 7. 6	Weathered massive magnetite-hematite.
7. 6–13. 8	Yellow altered tuff with minor limonite. Contains considerable magnetite from 11.0–11.9 m. Minor magnetite from 11.9–13.8 m.
13. 8–16. 1	Massive fine-grained magnetite-hematite; minor pyrite.
16. 1–17. 1	Medium-grained altered granite.
17. 1–41. 9	Green metasedimentary rock, mostly fine-grained quartzite with calcite stringers. (Gradational contact with granite above).
41. 9–70. 8	Dark-gray-green hornblende granite consisting of quartz, white and pink feldspar, and hornblende.
Hole 3	
0 – 4. 6	Overburden with magnetite-hematite boulders.
4. 6 – 5. 9	Fragments of magnetite and other iron oxides and yellow-brown clay.
5. 9 –12. 2	No core.
12. 2 –14. 9	Gray-green granite consisting of quartz, white feldspar, hornblende, green minerals, and some pyrite.
14. 9 –19. 2	No core.
19. 2 –21. 3	Green brecciated quartzite.
Hole 4	
0 – 0. 07	Iron oxide fragments, mostly magnetite.
. 07– 4. 57	No core.
4. 57– 9. 15	Massive, dense magnetite-hemitite; increasing hematite toward bottom of interval. Also, leached vugs increasing toward bottom.
9. 15–21. 04	No core.
21. 04–22. 57	White quartzite.
22. 57–35. 55	Gray-green fine-grained granitic rock composed of quartz, white and pink feldspar, and mafic minerals. Local calcite veinlets; probable contact zone.
35. 55–41. 04	Granite consisting mainly of quartz, feldspar, and hornblende, some pyrite.

PHU ANG DRILL HOLES 1–22

By Thawat Japakasetr, Boonmai Inthuputi, H. S. Jacobson, C. T. Pierson, and Narin Pholphan

Interval (meters)	Description
Hole 1	
0 – 5.1	No core; cuttings contain some hematite, magnetite, and clay.
5.1– 6.4	Core: 0.2 m of hematite-magnetite; cuttings: clay with some magnetite.
6.4– 16.8	No core; cuttings contain mainly clay.
16.8– 19.8	No core; cuttings contain a small amount of magnetite in clay.
19.8– 35.1	No core; cuttings contain clay.
35.1– 36.6	No sample.
36.6– 44.2	No core; cuttings contain clay and a small amount of magnetite.
44.2– 61.0	No core; cuttings contain clay.
61.0– 62.5	No core or cuttings.
Hole 2	
0 – 3.0	No core; cuttings contain hematite, magnetite, and lateritic soil.
3.0– 4.6	Core: 0.13 m of hematite-magnetite; cuttings contain magnetite and hematite.
4.6– 11.6	No core; cuttings contain clay with an appreciable amount of hematite and magnetite.
11.6– 16.8	Core: 0.5 m of hematite-magnetite-goethite showing some boxwork structure. Cuttings contain clay with an appreciable amount of hematite and magnetite.
16.8– 25.0	No core; cuttings contain clay with some hematite and magnetite.
25.0– 26.8	Core: 0.3 m of hematite-magnetite; some magnetite as octahedral crystals; cuttings contain clay with an appreciable amount of hematite and magnetite.
26.8– 28.0	No core or cuttings.
Hole 3	
0 – 3.0	Iron-ore body exposed by starting pit.
3.0– 14.9	Core: 2.7 m of hematite-magnetite-goethite; cuttings contain clay with a considerable amount of hematite and magnetite.
14.9– 16.3	No core; cuttings contain clay with an appreciable amount of hematite and magnetite.
16.3– 19.8	Core: 1.0 m of hematite-magnetite with some clay; cuttings contain a considerable amount of hematite and magnetite.
19.8– 21.3	No core; cuttings contain clay with an appreciable amount of hematite and magnetite.
21.3– 24.4	No core; cuttings contain clay with some hematite and magnetite.
24.4– 25.6	Core: 0.5 m of light-blue tuffaceous shale; bedding at 70° to core axis; cuttings contain clay and silt.
25.6– 27.4	No core; cuttings contain clay and silt.
27.4– 59.1	Core: 2.5 m of tuffaceous shale; cuttings contain clay and silt.
59.1– 67.1	Core: 0.3 m of laminated shale heavily impregnated with goethite; the laminations are parallel to the core axis; cuttings contain clay and silt.
67.1– 71.3	Core: 0.6 m of fine- to medium-grained brown sandstone; cuttings contain clay and silt.
71.3– 77.7	No core; cuttings contain clay and silt.
77.7– 85.4	No core; cuttings contain mineral grains of feldspar, ferromagnesian minerals, quartz and a small amount of magnetite. Material probably derived from igneous rock of dioritic composition.
85.4– 89.0	Core: 0.6 m of blue-gray silty clay; cuttings contain mineral grains probably derived from diorite.

Interval (meters)	Description
Hole 4	
0 – 0.8	No core; cuttings contain a considerable amount of hematite and magnetite.
.8– 4.6	Core: 0.5 m of magnetite-hematite; some vugs after pyrite; cuttings contain magnetite and hematite.
4.6– 6.1	No core; cuttings contain magnetite and hematite.
6.1– 7.6	No core; cuttings contain brown clay, quartz, and calcite(?) as well as some magnetite and hematite.
7.6– 16.8	No core; cuttings contain brown clay with an appreciable amount of hematite, magnetite, and goethite.
16.8– 19.8	No core; cuttings contain brown clay and silt with some magnetite, hematite, and goethite.
19.8– 21.3	Core: 0.2 m of clay; cuttings contain clay and silt and a small amount of hematite and magnetite.
21.3– 26.4	No core; cuttings contain brown clay, silt, and some hematite and magnetite.
26.4– 26.5	Core: 0.1 m of brown clay, cuttings contain brown clay, silt, and some magnetite.
26.5– 31.7	No core; cuttings contain clay with a small amount of magnetite.
31.7– 32.0	Core: 0.2 m of blue clay, locally stained by iron oxide. Cuttings contain pinkish-brown clay.
32.0– 32.3	No core; cuttings contain clay with a small amount of magnetite and hematite.
32.3– 33.5	Core: 0.3 m of brown clay; cuttings contain clay with some magnetite.
33.5– 39.3	No core; cuttings contain pinkish-brown clay with a small amount of magnetite and hematite.
39.3– 39.6	Core: 0.1 m of brown clay; cuttings contain clay with a small amount of magnetite.
39.6– 45.4	No core; cuttings contain pinkish-brown clay.
45.4– 45.7	Core: 0.2 m of yellow clay with some grains of weathered quartz and feldspar. Cuttings contain clay.
45.7– 54.9	No core; cuttings contain light-colored clay with a small amount of magnetite, hematite, and pyrite.
54.9– 62.0	Core: 0.3 m of brown to gray, iron oxide-stained mudstone containing some pyrite. Cuttings contain light-gray clay and silt and a small amount of pyrite.
62.0– 65.5	No core; cuttings contain light-colored silty clay with a small amount of magnetite.
65.5– 70.1	Core: 0.3 m of yellow to white clay and mudstone. Cuttings contain light-gay clay with a small amount of magnetite.
70.1– 72.3	No core; cuttings contain light-gray silty clay with a small amount of magnetite.
72.3– 74.1	Core: 0.1 m of iron oxide-impregnated claystone. Cuttings contain light-gray silty clay with some magnetite.
74.1– 77.7	Core: 0.8 m of dense magnetite with small amounts of hematite and pyrite. Cuttings contain magnetite with some clay.
77.7– 78.4	No core; cuttings contain gray silty clay with some magnetite.
Hole 5	
0 – 6.1	No core or cuttings. Data from pit 18 indicate that surface ore body is 3.5 m thick.
6.1– 21.2	No core; cuttings contain clay.
21.2– 21.3	Core: 0.06 m of tan clay with white blotches.
21.3– 22.6	Core: 0.07 m of dense hematite-magnetite with sparse leached cavities (after pyrite?). Cuttings contain clay with a few grains of magnetite.
22.6– 25.9	Core: 0.19 m of porous vuggy hematite and goethite, having some cubic vugs after pyrite, and some irregular bands of quartz. Cuttings contain clay with a few grains magnetite.

Interval (meters)	Description
Hole 5	
25.9– 36.6	Core: 0.6 m of tan to blue-gray clay. Cuttings contain clay with some magnetite.
36.6– 38.4	Core: 0.3 m of clay and vuggy hematite-goethite. Cuttings contain clay with some magnetite.
38.4– 42.1	Core: 0.12 m of hematite-goethite with leached vugs (after pyrite?). No cuttings.
42.1– 42.8	No core or cuttings.
42.8– 47.3	Core: 0.51 m of softy vuggy hematite-goethite. No cuttings.
47.3– 49.1	Core: 0.45 m of iron oxide-impregnated clay. No cuttings.
49.1– 51.2	Core: 1.28 m of white and green pyritizied and silicified tuff. No cuttings.
51.2– 57.8	Core: 5.02 m of massive fine-grained magnetite with pyrite as irregular pods, stringers, and disseminated grains; some calcite gangue and country rock. No cuttings.
57.8– 61.8	Core: 1.09 m of silicified, vaguely banded mudstone(?); black and white bands trend 60°–80° to core axis; some vein quartz and pyrite occur at the bottom of the interval. No cuttings.
78.4– 85.4	Core: 0.2 m of gray to brown mudstone with small amounts of pyrite and iron oxides. Cuttings contain light-gray silty clay with some magnetite.
85.4– 86.9	Core: 0.2 m of iron oxide-impregnated clay. Cuttings contain light-gray silty clay with some magnetite.
86.9– 90.9	Core: 0.2 m of mudstone. Cuttings contain light-gray silt with some magnetite.
Hole 6	
0 – 1.5	No core; cuttings contain hematite, magnetite, and brown clay.
1.5– 3.0	Core: 0.25 m of massive hematite-magnetite with 1–7-mm diameter leached vugs, probably after pyrite. Cuttings contain hematite and magnetite, as well as some brown clay.
3.0– 6.1	No core; cuttings contain hematite and magnetite, as well as some brown clay.
6.1– 13.7	No core or cuttings.
13.7– 23.5	Core: 1.19 m of massive hematite-magnetite with some 1- to 8-mm diameter leached vugs. No cuttings from 13.7–19.8 m. Cuttings from 19.8 to end of interval contain mainly hematite and magnetite, with a small amount of brown clay.
23.5– 30.2	No core; cuttings contain clay, hematite, and magnetite.
30.2– 32.4	Core: 0.25 m of massive hematite-magnetite with leached vugs 1–8 mm in diameter. No cuttings.
32.4– 33.8	Core: 0.10 m of iron oxide-impregnated tuff; 0.02 m of hematite-magnetite. No cuttings.
33.8– 35.3	Core: 0.25 m of dark-gray tuff with some iron oxide. No cuttings.
35.3– 68.1	Core: 5.52 m of white to green tuff; between 62–67.5 m, bedding trends 75°–80° to core axis. Cuttings contain clay, and locally, a small amount of magnetite.
68.1– 74.5	Core: 6.25 m of green, locally pyritized limestone and dolomitic limestone: The pyrite occurs as veinlets and as irregular pods. Cuttings contain yellow-green calcareous fragments.
74.5– 78.0	Core: 3.50 m of green dolomitic limestone with 10- to 30-cm thick intervals containing considerable magnetite andsome pyrite. Cuttings contain gray calcareous rock and a considerable amount of magnetite.
78.0– 88.9	Core: 4.17 m of massive magnetite with irregular pods of pyrite as much as 10 cm long; a few 1- to 3-mm thick pyrite veinlets and calcite veinlets; local unmineralized intervals of green limestone. Cuttings from 77.8–82.3 m contain gray calcareous rock and some magnetite. No cuttings for remainder of interval.
Hole 6	
88.9– 89.5	Core: 0.86 m of gray and green vaguely banded limestone; considerable magnetite and pyrite; banding trends 80°–90° to core axis. No cuttings.
89.5– 91.9	Core: 1.86 m of mottled green and gray vaguely banded limestone with thin stringers of magnetite and pyrite, as well as thin veinlets of calcite. No cuttings.
91.9– 94.3	Core: 2.40 m of massive magnetite with local short intervals of green limestone; pyrite as irregular pods, stringers, and disseminations in magnetite. No cuttings.
94.3–100.5	Core: 5.38 m of irregularly banded dark-gray limestone with calcite veinlets and minor amounts of disseminated pyrite; banding trends 80°–90° to core axis. No cuttings.
100.5–102.6	Core: 2.01 m of green irregularly banded limestone; some of the bands are replaced by magnetite and pyrite; banding trends 80°–90° to core axis. No cuttings.
102.6–108.4	Core: 3.32 m of gray and green, locally mottled irregularly banded partly silicified limestone with pyrite as disseminations and as veinlets as much as 1 mm thick; calcite occurs in veinlets 1–3 mm wide. No cuttings.
Hole 7	
0 – 5.9	Core: 0.66 m of hematite-magnetite with 1–8-mm leached cavities (after pyrite); cuttings contain hematite and magnetite.
5.9– 11.1	Core: 0.13 m of yellow to white clay. Cuttings contain clay and silt with about 5 percent of magnetite in the interval 6.1–7.6 m.
11.1– 12.6	Core: 0.05 m of clay and hematite-magnetite; cuttings contain clay with considerable amount of magnetite.
12.6– 52.7	Core and (or) cuttings: clay, tuff, and shale; local minor iron oxide impregnations.
52.7– 76.1	Core: 18.03 m of green to gray andesite(?) porphyry; plagioclase and hornblende phenocrysts 1–3 mm long; aphanitic groundmass. Cuttings, 52.7–56.4 m, contain gray to brown unidentified rock fragments. No cuttings for remainder of interval.
76.1– 82.2	Core: 4.94 m of massive magnetite with pods and veinlets of pyrite and calcite as much as 20 mm thick. No cuttings.
82.2– 83.1	Core: 0.90 m of serpentine rock. No cuttings.
83.1– 84.6	Core: 1.47 m of massive magnetite with a considerable amount of pyrite. No cuttings.
84.6– 87.5	Core: 2.9 m of light-green to dark-green serpentine rock containing some pods and stringers of calcite and quartz, as well as some disseminations of pyrite and magnetite. No cuttings.
87.5– 87.7	Core: 0.20 m of magnetite with a small amount of pyrite. No cuttings.
87.7– 88.4	Core: 0.70 m of serpentine rock with some disseminated magnetite. No cuttings.
88.4– 90.8	Core: 2.40 m of massive magnetite with some irregular pods, stringers, and disseminations of pyrite; some serpentine rock. No cuttings.
90.8– 99.9	Core: 7.10 m of serpentine rock with some pyrite as disseminations and veinlets, and a small amount of disseminated magnetite. No cuttings.
99.9–102.9	Core: 3.00 m of serpentine rock with an appreciable amount of disseminated magnetite and pyrite; some pods and veinlets of calcite. No cuttings.
102.9–120.4	Core: 17.50 m of dolomitic limestone; some pyrite as disseminations and veinlets. No cuttings.
Hole 8	
0 – 3.0	Core: 0.33 m of hematite-magnetite; some leached vugs after pyrite. No cuttings 0–1.5 m; cuttings for remainder of interval contain hematite and magnetite, and a small amount of soil.
3.0– 9.1	No core; cuttings contain clay and soil with considerable magnetite.

Interval (meters)	Description
Hole 8	
9. 1– 24. 5	Core and (or) cuttings contain clay, locally with small amounts of iron oxides.
24. 5– 50. 6	Core and (or) cuttings: hornblende-biotite-granodiorite(?); some vein quartz locally.
50. 6– 51. 6	Core: 0.98 m of baked mudstone; no cuttings.
51. 6– 51. 8	Core: 0.20 m of massive magnetite with some pods and stringers of pyrite; calcite as thin veinlets as much as 1 mm thick. No cuttings.
51. 8– 53. 3	Core: 1.50 m of baked mudstone(?). No cuttings.
53. 3– 55. 0	Core: 1.70 m of granodiorite(?). No cuttings.
55. 0– 64. 9	Core: 9.90 m of dark-gray altered rock; some pyrite as pods and disseminations. No cuttings.
64. 9– 80. 5	Core: 15.6 m hornblende-biotite-granodiorite(?). No cuttings.
Hole 9	
0 – 8. 2	Core: 1.77 m of hematite with some goethite. Cuttings contain hematite with a little magnetite.
8. 2– 8. 8	Core: 0.30 m of pink clay. Cuttings containing hematite with a little magnetite.
8. 8– 11. 9	Core: 0.15 m of iron oxide-impregnated clay; small amount of massive hematite-magnetite. Cuttings contain hematite and clay.
11. 9– 18. 3	Core: 0.82 m of hematite-magnetite-goethite with some iron oxide-impregnated clay. Cuttings contain hematite and magnetite with some clay.
18. 3– 64. 0	Core: 4.37 m of yellow to gray tuff(?); some iron oxide impregnations. Cuttings contain clay with small amounts of hematite and magnetite.
64. 0– 76. 0	Core: 10.03 m of magnetite with pyrite as pods and stringers 1–8 mm thick and as disseminations. Cuttings 64.0–65.5 contain magnetite; no cuttings for remainder of interval.
76. 0– 76. 5	Core: 0.50 m of amphibolite(?). No cuttings.
76. 5– 78. 6	Core: 2.10 m of magnetite, pyrite, and amphibolite(?). No cuttings.
78. 6– 79. 4	Core: 0.08 m of amphibolite(?). No cuttings.
79. 4– 89. 5	Core: 12.01 m of magnetite and pyrite. No cuttings.
89. 5– 97. 8	Core: 6.03 m of amphibolite(?); some veinlets of quartz and some pods and disseminations of pyrite and magnetite. No cuttings.
97. 8– 98. 7	Core: 0.90 m of magnetite and pyrite; some chalcopyrite. No cuttings.
98. 7–124. 8	Core: 15.28 m of gray limestone, local pyrite and magnetite in small pods.
Hole 10	
0 – 3. 7	Core: 0.58 m of dense massive hamatite; small amount of magnetite; sparse leached cavities.
3. 7– 4. 9	No core; cuttings contain a considerable amount of hematite.
4. 9– 6. 1	Core: 0.33 m of massive hematite with a small amount of magnetite; some leached vugs.
6. 1– 8. 5	Core: 0.23 m of yellow clay.
8. 5– 9. 1	No core; cuttings contain a considerable amount of hematite and magnetite.
9. 1– 29. 7	Core and (or) cuttings: white to yellow claystone and tuff; some iron oxide staining.
29. 7– 31. 7	No core; cuttings contain magnetite with some clay.
31. 7– 33. 5	Core: 0.23 m of iron oxide-impregnated clay with some massive hematite-magnetite.
33. 5– 34. 5	Core: 0.15 m of light-brown weakly iron-stained tuff.
34. 5– 35. 0	Core: 0.10 m of iron oxide-impregnated clay.
35. 0– 54. 6	Core: 5.44 m of white to tan claystone and tuff.
54. 6– 86. 0	Core: 20.30 m of green and white dolomitic limestone; vague banding 80°–90° to core axis.
86. 0– 88. 0	Core: 1.78 m of alternating gray-green limestone and massive magnetite with irregular pods of pyrite (2mm–2 cm).
88. 0– 96. 3	Core: 7.20 m of green partly silicified massive limestone with paper-thin calcite stringers; traces of pyrite.
Hole 10	
96. 3– 97. 9	Core: 1.47 m of magnetite and pyrite with calcite gangue.
97. 9–171. 6	Core: 54.00 m of greenish-gray to white limestone and weakly mineralized intervals of magnetite-pyrite.
171. 6–173. 2	Core: 0.55 m of dense fine-grained magnetite; carbonate gangue and pyrite as disseminations and irregular pods.
173. 2–183. 7	Core: 6.77 m of greenish-gray to white irregularly banded limestone; banding trends 45°–50° to core axis.
183. 7–184. 9	Core: 0.94 m of dense magnetite; carbonate gangue and pyrite as disseminations and irregular stringers.
184. 9–206. 1	Core: 20.55 m of green and gray vaguely banded limestone; banding trends 35°–40° to core axis; minor pyrite locally.
Hole 11	
0 – 0. 6	Core: 0.12 m of massive hematite and minor magnetite; leached vugs (after pyrite?).
. 6– 1. 2	No core; cuttings contain hematite.
1. 2– 3. 0	Core: 0.13 m of hematite-magnetite with leached vugs (after pyrite?).
3. 0– 3. 7	No core; cuttings contain considerable hematite and a little magnetite.
3. 7– 4. 3	Core: 0.05 m of vuggy hematite with quartz gangue and a little brown clay.
4. 3– 4. 9	No core; cuttings contain brown clay, hematite, and magnetite.
4. 9– 5. 5	Core: 0.05 m of yellow and brown clay.
5. 5– 9. 8	Core: 0.13 m of white to brown clay rock. Cuttings contain clay, magnetite, and hematite.
9. 8– 12. 5	Core: 0.13 m of massive hematite and a little magnetite; leached vugs (after pyrite?). Cuttings contain brown clay with some magnetite.
12. 5– 52. 1	Core and (or) cuttings: brown to yellow clay and tuff; local minor iron oxide staining.
52. 1– 58. 5	Core: 0.81 m of massive to vuggy hematite; some magnetite and clay. Cuttings contain hematite and magnetite.
58. 5– 69. 3	Core and (or) cuttings contain white to light-brown clay rock and tuff.
69. 3– 71. 3	Core: 0.40 m of iron oxide-impregnated slightly calcareous clay rock with few grains of pyrite.
71. 3–105. 2	Core: 1.83 m of blue-gray to yellow mudstone(?) and tuff(?); bedding trends 60°–80° to core axis; some pyrite. Cuttings contain clay.
Hole 12	
0 – 4. 6	Core: 0.89 m of massive hematite-magnetite with numerous leached vugs (after pyrite?); traces of calcite. Cuttings contain hematite, goethite, and magnetite; some soil and silt.
4. 6– 7. 0	No core; cuttings contain hematite and magnetite.
7. 0– 8. 2	Core: 0.04 m of massive hematite-magnetite. No cuttings.
8. 2– 10. 4	Core: 0.20 m of white to pink clay. No cuttings.
10. 4– 12. 2	Core: 0.06 m of massive hematite-magnetite and traces of calcite. Cuttings contain magnetite and clay.
12. 2– 15. 2	No core; cuttings contain clay with some magnetite.
15. 2– 50. 0	Core and (or) cuttings: white to buff clay rock and tuff.
50. 0– 80. 8	Core and (or) cuttings: white to dark-gray tuff, and mudstone; 0.10 m of yellow-green calcareous sinter at base of interval; pyrite locally as thin stringers and disseminations.
80. 8– 86. 9	Core: 3.62 m of white to light-gray recrystallized limestone; 2–5 percent pyrite as pods and stringers. No cuttings.
86. 9– 88. 4	Core: 0.08 m of partly silicified, strongly fractured, fine-grained dolomite(?); some pyrite. No cuttings.

Interval (meters)	Description
Hole 13	
0 – 6. 1	No core; cuttings contain clay and hematite with some magnetite of probable detrital origin.
6. 1– 25. 3	Core: 15.06 m of brown to buff-colored altered tuff and porphyry. Cuttings 6.1–7.6 m contain clay. No cuttings for remainder of interval.
25. 3– 30. 5	Core and (or) cuttings contain clay.
30. 5– 75. 3	Core: 5.78 m of white to greenish-gray limestone and recrystallized limestone; a little magnetite occurs in some of the cuttings.
Hole 14	
0 – 0. 6	No core or cuttings.
. 6– 4. 6	Core: 0.78 m of hematite-magnetite and iron oxide-impregnated clay. Cuttings 1.5–4.6 m contain hematite and magnetite with some soil.
4. 6– 6. 1	Core: 1.40 m of white to brown iron oxide-stained clay. Cuttings contain hematite and magnetite.
6. 1– 7. 6	No core or cuttings.
7. 6– 16. 2	Core: 2.94 m of hematite-magnetite with numerous leached vugs (after pyrite?). Cuttings 7.6–9.2 m contain hematite and magnetite. No cuttings for remainder of interval.
16. 2– 17. 1	No core or cuttings.
17. 1– 48. 2	Core: 21.28 m of buff-colored highly altered tuff.
48. 2– 53. 7	Core: 0.75 m of moderately altered diorite(?). No cuttings 48.2–51.8 m; cuttings at 51.8–54.2 m do not contain iron oxides. No cuttings 54.2 to end of interval.
53. 7– 55. 2	Core: 1.02 m of skarn containing 5–15 percent magnetite. No cuttings.
55. 2– 59. 1	Core: 1.95 m of gray limestone and a small amount of magnetite; some pyrite as pods and disseminations. No cuttings 55.2–58.0 m; cuttings for remainder of interval contain silt with a few grains of pyrite.
59. 1– 89. 0	Core: 7.34 m of gray volcanic rock. Cuttings 59.1–59.5 m contain silt and a few grains of pyrite; no cuttings 59.5–61.0 m. Cuttings at 61.0–74.6 m contain greenish-gray silt with minor pyrite and magnetite. No cuttings 74.6 m to end of interval.
89. 0– 99. 8	Core: 9.80 m of magnetite with some pyrite, chalcopyrite, noncalcareous gangue, serpentine, and calcite. No cuttings.
99. 8–102. 9	Core: 0.75 m of greenish-gray limestone with some pyrite as pods, disseminations, and veinlets. No cuttings.
102. 9–105. 9	Core: 2.70 m of magnetite with some pyrite, chalcopyrite, noncalcareous gangue, serpentine, and calcite; calcite veinlet trends 50° to core axis. No cuttings.
105. 9–112. 8	Core: 4.03 m of gray, banded limestone with 1–3 percent magnetite; pyrite as irregular pods and thin stringers; banding trends 55°–65° to core axis. No cuttings.
112. 8–115. 4	Core: 1.53 m of altered clayey limestone or altered mafic igneous rock; some pyrite and calcite; 5–15 percent magnetite between 113.1–115.4 m. No cuttings.
115. 4–122. 0	Core: 1.82 m of greenish-gray, banded limestone; minor pyrite as pods, disseminations, and stringers; banding trends 55°–65° to core axis No cuttings.
Hole 15	
0 – 3. 3	Core: 0.85 m of hematite-magnetite with some leached cavities (after pyrite?); minor noncalcareous gangue. Cuttings contain hematite, goethite, magnetite, and quartz.
3. 3– 4. 8	Core: 0.80 m of iron oxide-impregnated tuff. Cuttings contain hematite, goethite, magnetite and quartz.
4. 8– 6. 4	Core: 0.22 m of claystone with about 10 percent magnetite. Cuttings at 4.8–6.4 m contain hematite, goethite, magnetite, and quartz.
Hole 15	
6. 4– 10. 8	Core: 3.51 m of brown iron-oxide stained tuff?. Cuttings 6.4–7.6 m contain hematite, goethite, magnetite, and clay. No cuttings 7.6 m to bottom of interval.
10. 8– 14. 8	Core: 0.48 m of hematite-magnetite with leached cavities (after pyrite?). Cuttings contain hematite, magnetite, goethite, and quartz.
14. 8– 15. 5	No core; cuttings contain magnetite and hematite.
15. 5– 17. 1	Core: 0.41 m of hematite-magnetite. Cuttings contain magnetite and hematite.
17. 1– 17. 7	No core; cuttings contain magnetite and hematite.
17. 7– 21. 3	Core: 0.90 m of hematite-magnetite. Cuttings 17.7–18.3 m contain magnetite and hematite. No cuttings 18.3 m to end of interval.
21. 3– 22. 0	No core or cuttings.
22. 0– 29. 6	Core: 2.47 m of buff-colored clay and tuff(?). No cuttings.
29. 6– 31. 1	No core or cuttings.
31. 1– 38. 1	Core: 2.62 m of massive hematite-magnetite with many leached vugs. No cuttings at 31.1–32.0 m. Cuttings 32.0–33.6 m contain magnetite with some hematite and a little pyrite. No cuttings 33.6 m to bottom of interval.
38. 1– 39. 3	No core or cuttings.
39. 3– 55. 0	Core: 2.96 m of white to yellow tuff and mudstone. No cuttings at 39.3–51.8 m; cuttings 51.8 m to bottom of interval contain yellow clay with a few magnetite grains.
55. 0– 57. 5	Core: 0.25 m of altered andesite porphyry. Cuttings contain brown silt with a few magnetite grains.
57. 5–106. 7	Core: 6.40 m of gray tuff and mudstone. Cuttings 57.5–100 m contain gray to brown clay and silt and a few magnetite or pyrite grains. No cuttings 100 m to bottom of interval.
106. 7–117. 4	Core: 0.42 m of greenish-gray altered andesite(?) porphyry; some pyrite. No cuttings.
117. 4–122. 0	Core: 0.25 m of gray mudstone; traces of pyrite. No cuttings.
Hole 16	
0 – 0. 6	No core; cuttings contain magnetite, hematite, and soil.
. 6– 2. 1	Core: 0.20 m of hematite-magnetite with minor carbonate gangue. Cuttings contain magnetite, hematite, and soil.
2. 1– 3. 1	Core: 0.13 m of tuff. Cuttings contain magnetite, hematite, and soil.
3. 1– 12. 2	Core: 5.83 m of reddish-brown altered tuff. Cuttings contain brown clay and silt with small amounts of magnetite and quartz.
12. 2– 16. 8	No core; cuttings contain clay and silt.
16. 8– 18. 3	No core; cuttings contain magnetite with some clay and quartz.
18. 3– 19. 8	Core: 0.12 m of hematite-magnetite. Cuttings contain magnetite with some clay and quartz.
19. 8– 23. 5	Core: 3.3 m of tuff and skarn with some magnetite; cuttings contain magnetite and clay.
23. 5– 27. 1	Core: 0.89 m of magnetite-hematite with about 10 percent tuff. Cuttings contain magnetite and silt.
27. 1– 35. 1	Core: 2.17 m of yellow to brown skarn. Cuttings contain silt with some magnetite.
35. 1– 38. 1	Core: 0.50 m of gray to green slightly pyritized porphyry. Cuttings contain silt with some magnetite.
38. 1– 38. 7	Core: 0.40 m of skarn with magnetite and some pyrite. Cuttings contain silt with some magnetite.
38. 7– 39. 3	No core; cuttings contain silt with some magnetite.
39. 3– 40. 6	Core: 0.80 m of gray to green altered brecciated porphyry with some magnetite, pyrite, and epidote. Cuttings contain silt with some magnetite.

Interval (meters)	Description
Hole 16	
40. 6– 47. 3	Core: 3.77 m of brown to green porphyry; locally, small amounts of iron oxides and pyrite. Cuttings contain silt with some magnetite.
47. 3– 58. 3	Core: 3.49 m of mudstone with a little pyrite and epidote. Cuttings contain silt with traces of pyrite.
58. 3– 58. 9	Core: 0.20 m to gray to brown skarn. Cuttings contain silt with traces of pyrite.
58. 9– 72. 9	Core: 4.24 m of mudstone. Cuttings contain silt; local traces of magnetite and pyrite.
72. 9– 74. 1	Core: 0.35 m of granitic rock with some pyrite. Cuttings contain silt with traces of magnetite and pyrite.
74. 1– 82. 0	Core: 2.12 m of gray to green mudstone with some pyrite. Cuttings 74.1–77.8 m contain silt with traces of magnetite and pyrite. No cuttings at 77.8–79.4 m. Cuttings at 79.4–80.8 m contain gray to brown silt. No cuttings for remainder of interval.
82. 0– 85. 3	Core: 0.72 m of gray to green porphyry with about 5 percent disseminated magnetite and some pyrite. No cuttings.
85. 3– 96. 0	Core: 2.45 m of magnetite and pyrite in porphyry and mudstone. No cuttings at 85.3–94.5 m. Cuttings at 94.5–96.0 contain magnetite and pyrite.
96. 0– 97. 6	Core: 0.02 m of mudstone. Cuttings contain silt, magnetite, and pyrite.
97. 6– 99. 1	Core: 0.08 m of magnetite-pyrite. Cuttings contain magnetite, pyrite, and silt.
99. 1–100. 6	Core: 0.32 m of light-gray mudstone. Cuttings contain silt, magnetite, and pyrite.
100. 6–110. 7	Core: 0.53 m of light-gray mudstone. Cuttings at 100.6–102.1 m contain silt with some magnetite. No cuttings for remainder of interval.
Hole 17	
0 – 0. 6	No core; cuttings contain hematite and magnetite.
. 6– 1. 2	Core: 0.11 m of hematite-magnetite. Cuttings contain hematite and magnetite.
1. 2– 1. 8	No core; cuttings contain hematite and magnetite.
1. 8– 8. 5	Core: 1.55 m of hematite-magnetite with leached vugs after pyrite.
8. 5– 9. 2	No core; cuttings contain hematite and magnetite.
9. 2– 10. 7	Core: 1.15 m of reddish-brown clay with local thin (6–10 cm) intervals of iron oxides. Cuttings contain magnetite and hematite.
10. 7– 14. 6	Core: 2.46 m of hematite-magnetite with leached vugs after pyrite(?). Cuttings contain magnetite and hematite, with some clay and quartz.
14. 6– 16. 1	No core; cuttings contain clay, magnetite, and hematite.
16. 1– 16. 2	Core: 0.14 m of low-grade iron ore.
16. 2– 22. 9	Core: 2.45 m of iron oxide-impregnated tuff. Cuttings 16.2–19.8 contain clay with about 20 percent of iron oxides. No cuttings for remainder of interval.
22. 9– 25. 8	Core: 0.07 m of vuggy magnetite-hematite. Cuttings 23.2–25.8 contain magnetite and hematite with some quartz and silt.
25. 8– 49. 1	Core: 4.42 m of tuff and mudstone; some iron oxide impregnation and pyrite. Cuttings contain silt and clay.
Hole 18	
0 – 1. 2	Core: 0.30 m of magnetite with some goethite and white gangue mineral. Cuttings contain magnetite, hematite, and soil.
1. 2– 2. 1	No core; cuttings contain magnetite, hematite, and soil.
2. 1– 4. 3	Core: 0.22 m of magnetite-hematite. Cuttings contain magnetite and hematite.
4. 3– 6. 1	No core; cuttings contain magnetite and hematite.
6. 1– 11. 0	No core; cuttings contain clay with 50 percent estimated iron oxide content.
11. 0– 12. 8	No core; cuttings contain magnetite and hematite with some clay.

Internal (meters)	Description
Hole 18	
12. 8– 15. 2	Core: 1.50 m of hematite with about 2 percent gangue. Cuttings contain magnetite, hematite, and clay.
15. 2– 18. 3	No core; cuttings contain magnetite, hematite and clay.
Hole 19	
0 – 4. 3	Core: 1.35 m of hematite-magnetite. Cuttings contain hematite, magnetite, and clay.
4. 3– 6. 1	No core; cuttings contain clay with an estimated 20 percent iron oxide content.
6. 1– 6. 7	Core: 0.03 m of hematite-magnetite. Cuttings contain clay with an estimated 10 percent iron oxide content.
6. 7– 18. 3	No core; cuttings contain light-brown to tan clay and silt with an estimated iron oxide content of less than 5 percent.
Hole 20	
0 – 0. 6	Core: 0.10 m of magnetite-hematite with vugs after pyrite. Cuttings of magnetite, hematite, and soil.
. 6– 1. 2	No core; cuttings of magnetite, hematite, and soil.
1. 2– 3. 7	Core: 0.70 m of hematite-goethite with some vugs after pyrite. Cuttings contain magnetite, hematite, and soil.
3. 7– 4. 3	No core; cuttings contain magnetite and hematite with a small amount of clay.
4. 3– 10. 4	Core: 3. 46 m of magnetite-hematite with local white gangue mineral. Cuttings contain magnetite, hematite, and clay.
10. 4– 11. 6	Core: 0.51 m of white altered tuff. Cuttings contain magnetite, hematite, and clay.
11. 6– 12. 2	No core; cuttings contain an estimated iron oxide content of 40 percent.
12. 2– 13. 4	Core: 0.16 m of hematite-magnetite and white tuff. Cuttings contain magnetite, hematite, and clay.
13. 4– 18. 6	No core; cuttings contain magnetite, hematite, and clay.
18. 6– 19. 2	Core: 0.12 m of iron oxide-impregnated tuff. Cuttings contain magnetite, hematite, and clay.
19. 2– 20. 4	No core; cuttings contain magnetite, hematite, and clay.
20. 4– 21. 0	Core: 0.20 m of iron oxide-impregnated tuff. Cuttings contain magnetite, hematite, and clay.
21. 0– 21. 6	Core: 0.25 m of magnetite and iron oxide-impregnated tuff. Cuttings contain magnetite, hematite, and clay.
21. 6– 24. 7	Core and (or) cuttings: tuff and iron oxide impregnated tuff; cuttings contain an estimated 18 percent iron oxide content.
Hole 21	
0 – 0. 3	No core; cuttings contain magnetite, hematite, and soil.
. 3– . 6	Core: 0.22 m of magnetite-hematite with some vugs after pyrite. Some iron oxide-impregnated tuff. Cuttings contain magnetite, hematite, and soil.
. 6– 1. 0	No core; cuttings contain magnetite, hematite, and soil.
1. 0– 4. 9	Core: 1.73 m of hematite-magnetite; cuttings contain magnetite, hematite, and clay.
4. 9– 7. 3	No core; cuttings contain clay with an estimated 30 percent iron oxide content.
7. 3– 7. 9	Core: 0.03 m of magnetite-hematite. Cuttings contain clay with an estimated 35 percent iron oxide content.
7. 9– 8. 5	Core: 0.05 m of gray, altered tuff. Cuttings contain clay with an estimated 30 percent iron oxide content.
8. 5– 9. 8	No core; cuttings contain clay with an estimated 20 percent iron oxide content.
9. 8– 17. 1	No core; cuttings contain clay.
17. 1– 30. 4	No core; cuttings contain clay with an estimated 20 percent iron oxide content.

Interval (meters)	Description
Hole 22	
0 – 2.0	No core; cuttings contain hematite, magnetite, and soil.
2.0– 2.4	Core: 0.15 m of hematite-magnetite. Cuttings contain hematite, magnetite, and soil.
2.4– 5.5	No core; cuttings contain hematite, magnetite, and clay.
5.5– 15.2	Core: 4.23 m of tuff and iron oxide-impregnated tuff. Cuttings contain clay with an estimated 20 percent iron oxide content.
15.2– 30.5	Core: 3.84 m of tuff and iron oxide-impregnated tuff. Cuttings contain clay with an estimated 17 percent iron oxide content.
30.5– 39.6	Core: 2.86 m of tuff and iron oxide-impregnated tuff. Cuttings contain clay with an estimated 12 percent iron oxide content.

WANG SAPHUNG ANHYDRITE-GYPSUM DEPOSIT

WANG SAPHUNG GYPSUM DRILL HOLES 1 AND 2

By Thawat Japakasetr

Interval (meters)	Description
Hole 1 [1]	
0 – 1.5	No core.
1.5– 11.5	Light-brown to brown and white clay and shale. Iron staining on fracture surfaces.
11.5– 36.6	Gray to green calcareous mudstone and shale with pyrite crystals locally along fractures; calcite veinlets.
36.6– 78.2	Green dolomitic limestone, fine-grained, partly dense. Calcite and gypsum along fractures; disseminated pyrite. Thin, short interbedded intervals of gray mudstone and limestone.
78.2– 87.9	Gray and gray-green mudstone and interbedded dolomitic limestone. Calcite, quartz, and gypsum and anhydrite along fractures.
87.9– 98.9	White crystalline anhydrite and gypsum; sugary texture in part. Few interbedded black calcareous shale beds 1 to 80 cm thick. Mostly gypsum from 94.2 to 97.2 m.
98.9–107.7	Gray to black calcareous mudstone and shale with 1- to 5-mm stringers and veinlets of gypsum and anhydrite.
107.7–110.3	White to gray sugary anhydrite. Few local patches of gray mudstone.
110.3–113.2	Same as interval 98.9 to 107.7 m.
113.2–125.9	White to gray sugary anhydrite.
Hole 2 [2]	
0 – 4.6	No core.
4.6– 18.9	Gray to brown clay with iron oxide stain; noncalcareous.
18.9– 24.4	Greenish-gray dense limestone. Calcite filling vugs and as veinlets. Local 16- to 70-cm thick intervals of interbedded tan calcareous shale.
24.4– 31.8	Gray to green partly calcareous mudstone with 10- to 25-cm intervals of green dolomitic limestone.
31.8– 38.1	Green to gray sandy-textured dolomitic limestone. Few pyrite grains; 2 approximately 1 m intervals of interbedded gray-green calcareous mudstone.
38.1– 44.2	Gray-green calcareous mudstone with calcite veinlets and stringers.
44.2– 45.8	Dark-gray limestone.
Hole 2	
45.8– 54.0	White crystalline gypsum with as much as 5 percent interbedded gray mudstone and lime stone.
54.0– 59.7	Interbedded gray-green limestone and mudstone (poor core recovery).
59.7– 61.3	White to gray crystalline gypsum.
61.3– 64.6	No core.
64.6– 71.0	Interbedded gray-green limestone and mudstone (poor core recovery).
71.0– 76.5	White to gray crystalline and sugary gypsum.
76.5– 95.1	Anhydrite and local interbedded short intervals of gray-green limestone, green mudstone, and gypsum. (28 cm gypsum at 87.5 m; 80 cm gypsum at 94.5 m).
95.1–100.6	Gray to black partly calcareous mudstone and shale with occasional calcite veinlets.
100.6–104.3	Gray to white recrystallized anhydrite. Local sugary-textured gypsum. (35 cm gypsum at 101 m; 79 cm gypsum at 104 m).
104.3–106.4	Gray to black partly calcareous shale and mudstone.
106.4–108.6	White to gray sugary gypsum and anhydrite; black shale interbedded.
108.6–125.5	Gray-green calcareous shale and interbedded black shale, gypsum, and anhydrite; calcite pods and stringers. Gypsum and anhydrite as follows: 15 cm gypsum at 108.8 m 70 cm gypsum at 113 m 20 cm gypsum at 115.6 m 150 cm gypsum at 117 m 125 cm gypsum and anhydrite at 122 m (Contact between gypsum and anhydrite 45° to core axis.)
125.5–146.5	Interbedded brown or glassy crystalline anhydrite and white to gray sugary anhydrite. Local shale fragments (5–10 percent) in anhydrite.
146.5–152.9	Green and yellow noncalcareous mudstone and anhydrite veinlets and stringers. 20 cm anhydrite at 149 m 15 cm anhydrite at 151 m 30 cm anhydrite at 152 m
152.9–201.8	White and gray sugary anhydrite. Locally, few centimeters of shale. Interbedded gray-green mudstone or shale as follows: 85 cm mudstone at 188 m 45 cm mudstone at 189 m 8 cm mudstone at 191 m 10 cm mudstone at 195 m (Shale makes 45° angle to core axis.)
201.8–211.2	Dark-gray-green and black mudstone and shale. Bedding 45° to core axis. Locally, sandy mudstone. Gypsum and mudstone interbedded from 202.2–203.97 m. Gypsum and anhydrite from 206.35–209.95 m.
211.2–212.5	Gray-green sandstone or tuffaceous(?) sandstone, with 1- to 3-mm gypsum or anhydrite veinlets.
212.5–235.5	Interbedded white and gray gypsum or anhydrite and dark-gray or black noncalcareous shale; few calcite stringers in shale. Gypsum or anhydrite intervals and local shale and limestone are: 212.5–213.7 anhydrite 214.5–216.9 gypsum and anhydrite 217 15 cm anhydrite or gypsum 218.4–222.4 anhydrite or gypsum 229.7–230.6 anhydrite and gypsum 231.0–235.5 anhydrite and gypsum.
235.5–242.9	Green-mottled soft rock with porphyritic appearance (coarse tuff or porphyry?); thin stringers of quartz-calcite or gypsum-anhydrite; 30 cm of white sugary anhydrite and gypsum at 238 m.

See footnotes at end of table.

Interval (meters)	Description
Hole 2	
242. 9–259. 9	White sugary anhydrite and gypsum and interbedded green mudstone, and black shale; bedding 45°–60° to core. Local short intervals of limy silica-bearing mudstone, anhydrite, and gypsum intervals: 242.9–243.8 Gypsum or anhydrite 243.8–244.5 Gypsum or anhydrite and about 40 percent mudstone 247.0–253.8 Gypsum and anhydrite 257.17–259.08 Gypsum
259. 9–260. 9	Green-gray, soft, locally limy tuff(?) or porphyry(?).

[1] Average core recovery 62 percent.
[2] Core recovery: 0–75.6 m, 24 percent; 75.6–125.88 m, 85 percent.

CHAIYAPHUM SALT DEPOSIT

CHAIYAPHUM HOLES 1–5

By Thawat Japakasetr

Interval (meters)	Description
Hole 1	
0 – 6. 1	Sand, yellow to brown, fine to medium.
6. 1 – 25. 4	Clay, reddish-brown; some pods of green sandy clay; locally, gray and green clay; about 0.5 percent gypsum.
25. 4 – 33. 5	Clay, greenish-gray, locally sandy.
33. 5 – 38. 9	Gypsum, white, brown, and gray, sugary. About 2 percent irregular bands (2–5 mm wide) of glassy crysyalline gypsum, some stringers of impure gypsum; bands and stringers make 30°–90° angle to core.
38. 9 – 57. 0	Clay, reddish-brown, slightly sandy; some pods of green sandy clay (30 percent).
57. 0 – 57. 91	Gypsum, white, sugary; about 50 percent of irregular dark impure gypsum.
57. 91–107. 95	Halite, glassy; about 1–20 percent of unit 1,[1] and 1–2 percent of unit 2.
107. 95–108. 02	Gypsum white, sugary; about 50 percent is irregular dark impure gypsum.
108. 02–112. 77	Halite, mostly glassy; about 2–5 percent of unit 1, and 1–2 percent of unit 2.
112. 77–136. 55	Halite, mostly glassy; about 5 percent of unit 2 and 1–5 percent of unit 3.
136. 55–166. 06	Halite, mostly glassy; about 0.2–1 percent of unit 1, 5 percent of unit 2, and 1–5 percent of unit 3.
166. 06–167. 05	Anhydrite, gray to white; some irregular stringers (3 mm wide) of dark impurities.
167. 05–167. 41	Sandstone, gray to greenish-gray, very fine grained, hard.
167. 41–169. 52	Sandstone, reddish-brown, very fine grained, hard.
169. 52–171. 70	Sandstone, reddish-brown, very fine grained, hard; local pods of light-brown fine-grained sand and pods of dark-brown mudstone.
171. 70–171. 91	Conglomeratic sandstone, light-brown; pebbles are brown mudstone and sandstone. About 0.5 percent pods of white gypsum, cemented by clay.
171. 91–175. 00	Sandstone, reddish-brown, very fine grained, hard.
175. 00–177. 82	Conglomeratic sandstone, brown to light-brown; fine-grained sandstone and dark-brown mudstone. Number and sizes of pebbles decrease with depth.

[1] Unit 1 Thin irregular bands (1-10 mm wide) of white sugary gypsum(?) or anhydrite.
2 Milky halite, white, dense; harder than glassy halite.
3 Smoky halite, brown to black; has a petroleum odor when broken.

Interval (meters)	Description
Hole 2	
0 – 9. 14	Sand, yellowish-brown to brown, fine to coarse.
9. 14– 34. 44	Clay, reddish-brown; locally, gray to green sandy clay.
34. 44– 40. 36	Clay, gray, sandy.
40. 36– 45. 31	Gypsum, white, gray to brown, sugary; some irregular bands of glassy crystalline gypsum (2–10 mm wide) and some dark impure stringers; both bands and stringers make 30°–90° angle to core.
45. 31– 63. 27	Clay, reddish-brown; 2–5 percent round pods of green sandy clay, and 1–5 percent of thin bands (2–5 mm wide) of glassy gypsum (45°–90° angle to core).
63. 27– 63. 58	Clay, white to gray and green; some traces of gypsum.
63. 58– 64. 54	Anhydrite, white to gray, sugary; some stringers of dark impurities.
64. 54– 90. 52	Halite, mostly glassy; about 1 percent of unit 1, 2 percent of unit 2, and 0–50 percent of unit 3 (increasing to 5 percent at 74 m and to 50 percent at 89 m).
90. 52– 90. 60	Gypsum, white to gray, sugary; some dark impurities.
90. 60–100. 58	Halite, mostly glassy; about 1 percent of unit 1, 5 percent of unit 2, and 30–50 percent of unit 3.
100. 58–135. 03	Halite, mostly glassy; about 15 percent of unit 2 and 10–30 percent of unit 3.
135. 03–154. 23	Halite, mostly glassy; about 1 percent of unit 1, 15 percent of unit 2, and 30–50 percent of unit 3.
154. 23–164. 46	Halite, glassy; about 10 percent of unit 2, and 30–70 percent of unit 3.
164. 46–165. 53	Anhydrite, white to gray, sugary; some irregular stringers of dark impurities.
165. 53–166. 06	Sandstone, gray, very fine grained, hard.
166. 06–167. 33	Sandstone, reddish-brown, very fine grained, hard.
Hole 3	
0 – 21. 34	Sand, yellow to brown and reddish-brown medium; with 5 percent gravel of quartz and laterite; some clay.
21. 34– 26. 95	Clay, reddish-brown, slightly sandy.
26. 95– 32. 31	Clay, gray, sandy, some muscovite.
32. 31– 35. 91	Gypsum, white, gray to brown, sugary; some irregular bands (2–5 mm wide) of glassy crystalline gypsum and some stringers of dark-brown impure gypsum.
35. 91– 56. 39	Clay, reddish-brown; 3 percent thin bands (1–10 mm wide) of glassy gypsum; 2 percent round green pods of sandy clay.
56. 39– 57. 30	Clay, gray, sandy.
57. 30– 58. 06	Anhydrite, white to gray, sugary; some stringers of dark-brown impure anhydrite.
58. 06– 61. 87	Halite, glassy; about 10 percent of unit 1, and 5 percent of unit 3.
61. 87– 70. 71	Halite, glassy; about 5 percent of unit 1, 10–5 percent of unit 2 (decreasing), and 5–10 percent of unit 3 (increasing).
70. 71– 87. 17	Halite, glassy; about 1 percent of unit 1, 5–15 percent of unit 2, and 15 percent of unit 3.
87. 17–158. 80	Halite, glassy; about 2–20 percent of unit 1, 10–5 percent of unit 2, and 15–5 percent of unit 3.
158. 80–168. 45	Halite, glassy; about 1 percent of unit 1, 3 percent of unit 2, and 10 percent of unit 3.
168. 45–169. 54	Anhydrite, white to gray, sugary; about 5 percent stringers of dark impurities.
169. 54–169. 97	Sandstone, gray, very fine grained, hard.
169. 97–171. 60	Sandstone, reddish-brown, very fine grained, hard.

Interval (meters)	Description
Hole 4	
0 - 12. 19	Sand, yellowish-brown to brown, fine- to coarse.
12. 19- 35. 97	Clay, reddish-brown; locally sandy; some round pods of green sandy clay.
35. 97- 43. 76	Clay, gray, sandy; some muscovite.
43. 76- 45. 42	Gypsum, white gray to brown, sugary; about 70 percent irregular stringers of dark impure gypsum and about 5 percent of thin irregular bands (1–8 mm wide) of glassy crystalline gypsum.
45. 42- 64. 92	Clay, reddish-brown; locally sandy; some round pods of green sandy clay, about 3–5 percent thin bands (1–3 mm wide) of glassy gypsum; bands trend 45°–80° to core.
64. 92- 65. 23	Clay, gray, slightly sandy.
65. 23- 67. 51	Gypsum, white and gray, sugary; about 50 percent of irregular stringers of dark impure gypsum decreasing to 2 percent toward bottom of interval.
67. 51- 87. 48	Halite, glassy; about 2–1 percent of unit 1, 25–15 percent of unit 2, and 30–20 percent of unit 3.
87. 48–119. 18	Halite, glassy; about 0.5 percent of unit 1, 10 percent of unit 2, and 5–15 percent of unit 3.
119. 18–146. 91	Halite, glassy; about 1 percent of unit 1, 2–5 percent of unit 2, and 10–20 percent of unit 3.
146. 91–158. 80	Halite, glassy; about 0.5 percent of unit 1, 2 percent of unit 2, and 30–80 percent of unit 3.
158. 80–162. 03	Halite, glassy; about 0.5 percent of unit 1, 1–2 percent of unit 2, and 30–5 percent of unit 3.
162. 03–163. 04	Anhydrite, white, gray and brown, sugary; about 5 percent irregular stringers of dark impurities.
163. 04–163. 47	Sandstone, gray, very fine grained, hard.
Hole 5	
0 - 16. 76	Sand, yellow to brown, fine to medium.
16. 76- 30. 48	Clay, reddish-brown, sandy.
30. 48- 31. 65	Clay, gray, sandy; some pods of white sand and muscovite.
31. 65- 36. 27	Gypsum, white, gray and brown, sugary. About 70 percent dark-brown impure gypsum stringers (1–5 mm wide) and about 5 percent thin irregular bands (1–10 mm wide) of glassy crystalline gypsum.
36. 27- 56. 46	Clay, reddish-brown; some round green pods of sandy clay (1–5 mm diameter); about 2 percent thin bands of glassy gypsum (1–3 mm wide).
56. 46- 58. 01	Gypsum, about 50 percent white sugary gypsum with 30 percent gray sugary gypsum and 20 percent dark-gray stringers of impure gypsum.
58. 01- 86. 26	Halite, mostly glassy; about 5 percent of unit 1, 20 percent of unit 2, and 10 percent of unit 3.
86. 26- 95. 96	Halite, mostly glassy; about 2 percent of unit 1, 20 percent of unit 2, and 5 percent of unit 3.
95. 96- 96. 04	Gypsum, white to gray, sugary.
96. 04–125. 27	Halite, mostly glassy; about 2 percent of unit 1, 20 percent of unit 2, and 5 percent of unit 3.
125. 27–162. 35	Halite, mostly glassy; about 1 percent of unit 1, 10–2 percent of unit 2, and 5 percent of unit 3.
162. 35–163. 42	Anhydrite, white, gray, sugary; about 10 percent thin irregular stringers of dark impurities.
163. 42–163. 93	Sandstone, gray, very fine grained, hard.
163. 93–166. 42	Sandstone, reddish-brown, very fine grained. Some dark-reddish-brown mudstone pebbles.

CHEMICAL ANALYSES

The chemical analyses were all performed by the Royal Thai Department of Mineral Resources Laboratory, Bangkok, Thailand, except as indicated. Additional analytical data for samples from trenches, pits, and outcrops are included in the text.

Samples herein listed were taken in feet because drilled intervals were measured in feet. Average analyses (previously given) are in meters, and some do not correspond exactly to sampled intervals.

BASE-METAL DEPOSITS

PHU HIN LEK FAI BASE-METAL DEPOSIT, DRILL HOLES 1 AND 2

Interval (feet)—		Percent		
From	To	Copper	Zinc	Lead
Drill hole 1 core samples				
11. 0	17. 0	0 75	2. 24	None
56. 0	57. 0	1. 17	2. 40	------
77. 1	86. 0	2. 44	------	------
108. 0	108. 3	. 08	. 30	------
141. 5	150. 0	------	5. 65	None
150. 0	160. 0	------	7. 10	None
183. 0	193. 0	. 12	------	------
193. 0	203. 0	. 05	------	------
203. 0	213. 0	. 09	------	------
213. 0	223. 0	. 05	------	------
223. 0	232. 0	. 05	------	------

From	To	Copper
Drill hole 2 core samples		
0. 0	4. 0	------
4. 0	6. 0	0. 47
6. 0	7. 0	. 28
7. 0	11. 0	------
11. 0	16. 0	. 23
16. 0	21. 0	. 27
21. 0	26. 0	. 37
26. 0	31. 0	. 42
31. 0	33. 0	. 30
33. 0	36. 0	. 73
36. 0	41. 0	. 26
41. 0	46. 0	. 11
46. 0	51. 0	. 13
51. 0	66. 0	------
66. 0	71. 0	. 50
71. 0	75. 2	. 12
75. 2	80. 2	. 07
80. 2	87. 0	. 03
87. 0	92. 0	. 05
92. 0	94. 0	------
94. 0	95. 7	. 72
95. 7	100. 0	------
100. 0	103. 0	. 81
103. 0	105. 0	. 16
105. 0	107. 0	. 66
107. 0	110. 0	. 85
110. 0	112. 0	1. 35
112. 0	114. 0	------
114. 0	119. 0	1. 33
119. 0	123. 0	------
123. 0	127. 2	. 60
127. 2	138. 2	. 27
138. 2	152. 0	. 76
152. 0	167. 0	0. 56
167. 0	176. 0	. 10
176. 0	185. 0	. 14
185. 0	195. 0	. 19
195. 0	198. 0	1. 12
198. 0	202. 0	2. 61
202. 0	208. 0	. 99
208. 0	212. 0	3. 11
212. 0	215. 6	1. 37
215. 6	220. 0	------
220. 0	223. 0	. 75
223. 0	227. 0	. 25
227. 0	230. 0	4. 86
230. 0	235. 0	3. 24
235. 0	237. 5	. 27
237. 5	246. 0	. 75
246. 0	248. 7	. 13
248. 7	264. 0	. 09
264. 0	272. 0	. 03
272. 0	276. 6	. 59
276. 6	295. 0	. 56
295. 0	301. 0	. 11
301. 0	322. 7	1. 19
322. 7	326. 0	. 46
326. 0	331. 0	. 61
331. 0	337. 0	. 90
337. 0	364. 4	. 44
364. 4	385. 0	2. 24
385. 0	401. 0	. 86
401. 0	417. 4	. 87
417. 4	424. 0	1. 75
424. 0	434. 5	1. 13

PHU THONG DAENG COPPER DEPOSIT, DRILL HOLES 1–3 AND PHU KHOK TRENCH 1

Interval (feet)— From	To	Copper (percent)	Interval (feet) From	To	Copper (percent)
Drill hole 1 core samples			*Drill hole 1 core samples*		
10.0	20.0	0.30	197.0	201.0	------
20.0	30.0	.39	201.0	211.0	0.20
30.0	40.0	------	211.0	217.0	------
40.0	51.0	.30	217.0	218.0	1.16
51.0	54.0	.87	218.0	223.0	------
54.0	58.0	------	223.0	234.0	.17
58.0	68.0	.21	234.0	237.0	------
68.0	77.0	.23	237.0	240.0	.87
77.0	88.0	.35	240.0	250.0	.26
88.0	97.0	.35	250.0	260.0	.19
97.0	103.0	.11	260.0	270.0	.19
103.0	112.0	------	270.0	280.0	.31
112.0	120.0	.23	280.0	290.0	.24
120.0	123.0	.58	290.0	300.0	1.49
123.0	127.5	------	300.0	310.0	.96
127.5	130.0	.87	310.0	311.0	------
130.0	139.5	.09	311.0	312.0	8.70
139.5	150.0	.11	312.0	318.0	------
150.0	160.0	.30	318.0	320.0	3.19
160.0	169.0	2.08	320.0	334.0	------
169.0	180.0	.11	334.0	345.0	.35
180.0	190.0	.27	345.0	355.0	.68
190.0	191.5	------	355.0	358.0	.60
191.5	197.0	.25	358.0	380.0	------
Drill hole 2 core samples			*Drill hole 2 core samples*		
0.0	11.0	------	200.0	204.0	------
11.0	20.5	0.34	204.0	212.0	0.44
20.5	30.0	.09	212.0	219.0	------
30.0	40.0	.45	219.0	224.0	5.36
40.0	45.0	------	224.0	239.0	------
45.0	55.0	.20	239.0	247.0	1.62
55.0	63.0	.15	247.0	250.0	------
63.0	67.0	------	250.0	260.0	1.21
67.0	78.0	.08	260.0	269.0	1.90
78.0	107.0	------	269.0	280.0	1.39
107.0	117.0	.29	280.0	288.0	.89
117.0	127.0	.13	288.0	290.0	------
127.0	136.0	.38	290.0	301.0	.56
136.0	147.0	.30	301.0	312.0	.31
147.0	155.0	.35	312.0	321.0	.47
155.0	165.0	.33	321.0	330.0	.18
165.0	169.0	.16	330.0	333.0	------
169.0	174.0	------	333.0	338.0	.25
174.0	179.0	.44	338.0	345.0	------
179.0	192.0	------	345.0	354.0	.13
192.0	200.0	1.76	354.0	360.0	.12

Depth (feet)	Representative chip for interval	Copper (percent)	Depth (feet)	Representative chip for interval	Copper (percent)
Drill hole 3			*Drill hole 3*		
100	98–103	0.12	235	220–252	None
129	127–130	.23	295	285–314	.50
151	145–154	.12	320	319–322	.17
171	175–180	.29	324	322–334	.03
189	180–196	1.86	339	334–350	.22
198	196–201	.93			

Channel sample	Position in trench [1] (meters)	Percent SiO₂	Cu	Fe	Mn	Pb	Zn
Phu Khok trench 1							
P45A	0–3	5.34	0.20	50.74	1.85	None	2.07
B	3–6	5.16	.18	51.63	1.61	None	1.76
C	6–9	5.78	.25	51.92	2.19	None	2.45
D	9–12	3.62	.19	54.72	2.18	None	1.56
E	12–15	5.36	.17	49.66	2.76	None	1.53
F	15–18	3.70	.25	51.91	2.29	None	1.79
G	18–21	4.30	.24	52.76	3.99	None	1.98
H	21–24	5.32	.24	50.79	3.37	None	2.60
I	24–27	3.78	.27	52.76	3.97	None	2.74
J	27–30	7.26	.29	51.07	2.74	None	3.42
K	30–33	6.82	.26	52.20	3.24	None	4.31

[1] Beginning from west end of trench.

IRON DEPOSITS

PHU YANG IRON DEPOSIT, DRILL HOLES 1–10

Interval (feet)— From	To	Percent Iron	Sulphur	Interval (feet)— From	To	Percent Iron	Sulphur
Drill hole 1 core samples				*Drill hole 1 core samples*			
20.4	21.2	52.07	0.09	70.2	75.6	60.61	3.33
21.2	22.4	58.55	.10	75.6	80.6	60.05	5.14
22.4	23.5	57.67	.13	80.6	85.5	61.18	3.87
23.5	24.8	62.72	.12	85.5	89.4	61.74	3.53
24.8	25.6	59.49	.27	89.4	92.8	62.86	1.88
25.6	26.5	62.29	1.18	92.8	95.5	60.05	2.75
26.5	30.2	64.54	1.06	95.5	100.5	66.44	2.87
30.2	35.2	66.68	.09	100.5	103.0	64.54	4.09
35.2	37.2	61.08	.92	103.0	108.5	61.74	3.73
37.2	40.0	57.97	1.25	108.5	112.7	62.92	4.23
40.0	43.2	61.92	3.41	112.7	115.5	66.23	3.19
43.2	45.5	56.96	4.42	115.5	117.7	67.35	2.65
45.5	50.5	58.86	3.77	117.7	121.7	62.23	4.52
50.5	53.4	55.17	4.12	121.7	126.7	Missing	------
53.4	55.4	53.05	5.38				
55.4	60.4	56.69	4.08	126.7	130.5	58.30	5.14
60.4	63.2	60.05	4.73	130.5	136.2	57.74	2.07
63.2	64.6	56.12	4.45	186.6	197.4	38.96	8.12
64.6	70.2	59.77	5.14				
Drill hole 2 core samples				*Drill hole 2 core samples*			
0.0	4.5	61.95	0.15	110.8	115.8	53.26	------
4.5	15.8	65.05	.11	115.8	120.8	52.70	2.98
15.8	28.2	68.40	.26	120.8	125.8	59.99	2.61
28.2	34.2	62.54	.07	125.8	131.0	53.26	4.60
34.2	38.8	55.84	.66	131.0	136.0	57.74	2.07
38.8	45.5	67.28	.22	136.0	141.0	52.70	2.31
45.5	50.5	63.91	2.03	141.0	146.0	64.47	2.59
50.5	55.9	58.59	2.94	146.0	151.0	65.59	2.86
55.9	60.5	56.06	4.66	151.0	156.0	64.19	3.83
60.5	65.5	63.07	4.71	156.0	161.0	66.15	2.28
65.5	69.5	60.18	4.00	161.0	166.0	57.46	6.95
69.5	74.1	56.24	4.36	166.0	171.0	51.58	4.33
74.1	79.9	53.82	3.05	171.0	175.4	40.37	1.25
79.9	85.3	56.75	4.37	175.4	181.0	47.93	2.16
85.3	90.7	58.17	2.21	181.0	186.0	61.11	4.65
90.7	95.7	56.31	3.42	186.0	191.0	62.37	3.92
95.7	100.8	53.52	2.88	191.0	197.0	30.83	.13
100.8	105.8	Dolomite	------	238.4	241.0	38.68	4.80
				241.0	251.0	37.56	2.96
105.8	110.8	36.92	2.30	251.0	260.0	54.94	3.24

Interval (feet)— From	To	Percent Iron	Sulphur
Drill hole 3 core samples			
15	20	67. 84	0. 16
20	25	62. 79	. 12
25	30	69. 52	0. 17
Drill hole 4 core samples			
105. 0	107. 4	54. 86	2. 03
136. 7	137. 9	59. 34	2. 13
137. 9	140. 9	0	0
140. 9	141. 9	41. 98	5. 58
141. 9	143. 2	0	0
143. 2	146. 1	55. 98	5. 13
146. 1	151. 1	50. 38	2. 54
151. 1	156. 1	52. 06	3. 04
156. 1	158. 6	64. 56	4. 72
158. 6	163. 1	0	0
163. 1	164. 1	No sample?	No sample?
164. 1	176. 0	0	0
176. 0	181. 0	58. 69	3. 85
181. 0	185. 5	58. 69	4. 98
185. 5	190. 5	64. 56	3. 66
190. 5	195. 5	60. 45	4. 58
195. 5	200. 9	54. 39	23. 63
200. 9	206. 0	48. 86	21. 42
206. 0	211. 0	45. 17	5. 06
211. 0	217. 8	0	0
217. 8	226. 0	60. 87	3. 21
226. 0	231. 0	59. 75	3. 48
231. 0	236. 0	60. 74	1. 65
236. 0	241. 0	45. 47	3. 62
241. 0	246. 0	21. 13	3. 25
Drill hole 5 core samples			
5. 0	10	58. 75	NA[1]
15. 0	20	49. 47	NA
25. 0	30	50. 60	NA
30. 0	35	47. 22	NA
Drill hole 6 sludge samples			
20	25	45. 75	0. 15
25	30	19. 51	. 12
30	35	15. 25	. 11
35	40	20. 74	0. 05
40	45	17. 94	. 13
45	50	11. 21	. 15
Drill hole 6 core samples			
90	95	57. 75	2. 82
95	100	44. 82	1. 77
100	105	53. 40	3. 41
105	110	47. 54	4. 77
110	115	52. 82	5. 25
115	120	58. 10	7. 35
120	125	57. 51	6. 78
125	127	56. 93	6. 83
Drill hole 7 core samples			
0. 0	5. 0	29. 34	0. 08
5. 0	10. 0	63. 97	. 11
10. 0	15. 0	66. 32	. 08
15. 0	20. 0	65. 14	. 06
20. 0	25. 0	62. 80	. 17
25. 0	30. 0	61. 04	. 14
30. 0	35. 0	No data	No data
35. 0	40. 0	61. 14	. 29
40. 0	45. 0	No data	No data
45. 0	53. 0	67. 49	. 72
53. 0	60. 0	61. 48	3. 25
60. 0	68. 0	63. 21	2. 09
68. 0	70. 0	61. 03	2. 47
70. 0	78. 5	51. 71	1. 61
78. 5	84. 3	49. 30	1. 41
84. 3	94. 0	0	0
94. 0	100. 0	49. 42	1. 94
100. 0	105. 0	48. 84	1. 07
105. 0	110. 0	60. 91	1. 60
110. 0	115. 0	55. 15	2. 20
115. 0	119. 6	49. 59	2. 26
119. 6	125. 5	23. 77	. 88
Drill hole 7 sludge samples			
125. 5	130. 0	39. 32	1. 36
130. 0	135. 0	29. 93	1. 28
135. 0	140. 0	56. 02	1. 92
140. 0	145. 0	61. 48	1. 52
145. 0	150. 0	55. 17	3. 17
150. 0	155. 0	59. 30	3. 84
155. 0	159. 5	50. 64	2. 69
159. 5	164. 0	50. 41	2. 50
164. 0	167. 0	0	0
167. 0	169. 5	62. 06	2. 57
169. 5	181. 5	0	0
181. 5	188. 0	52. 78	2. 53
188. 0	192. 0	61. 08	1. 81
192. 0	202. 0	55. 15	2. 86
202. 0	211. 0	57. 52	3. 39
211. 0	215. 0	52. 82	3. 32
215. 0	225. 0	54. 58	3. 53
225. 0	230. 0	55. 75	3. 07
230. 0	240. 0	58. 71	2. 35
240. 0	250. 0	53. 37	3. 62
250. 0	260. 0	56. 93	5. 72
260. 0	269. 0	54. 56	6. 27
273. 0	275. 6	31. 69	9. 58

Interval (ft) From	To	Percent Iron	Sulphur
Drill hole 8 core samples			
0. 0	5. 3	No data	No data
5. 3	10. 4	64. 37	0. 23
10. 4	15. 0	55. 20	. 26
15. 0	20. 0	58. 58	. 28
20. 0	25. 5	55. 80	. 55
25. 5	31. 0	53. 51	3. 66
31. 0	36. 0	59. 73	. 15
36. 0	44. 7	53. 26	4. 36
44. 7	52. 5	46. 62	1. 37
52. 5	56. 0	46. 74	2. 61
56. 0	61. 0	46. 02	3. 24
61. 0	65. 7	41. 88	3. 50
65. 7	71. 0	46. 91	5. 22
71. 0	76. 0	56. 96	2. 45
76. 0	81. 0	47. 46	2. 62
81. 0	86. 0	37. 72	3. 16
86. 0	90. 0	35. 58	2. 93
90. 0	95. 0	40. 09	5. 70
95. 0	98. 4	39. 61	4. 26
98. 4	101. 8	0	0
101. 8	105. 0	43. 17	3. 52
105. 0	110. 0	39. 38	3. 67
110. 0	115. 0	40. 80	3. 34
115. 0	121. 0	37. 24	3. 02
121. 0	125. 0	36. 06	4. 29
125. 0	130. 3	42. 22	6. 76
130. 3	134. 9	2[illegible]. 47	4. 34
134. 9	140. 0	44. 36	3. 34
140. 0	145. 0	39. 61	2. 46
145. 0	150. 0	36. 06	3. 60
150. 0	155. 8	39. 14	2. 86
155. 8	160. 0	39. 85	1. 87
160. 0	166. 0	31. 79	2. 24
166. 0	171. 3	42. 70	2. 45
171. 3	176. 0	34. 63	2. 43
176. 0	181. 0	39. 85	4. 58
181. 0	184. 8	56. 54	2. 10
184. 8	186. 7	0	0
186. 7	191. 5	45. 23	3. 19
191. 5	197. 8	62. 68	3. 28
Drill hole 9 core samples			
0	5	12. 44	0. 04
5	10	11. 55	. 05
10	15	10. 47	0. 03
15	20	10. 29	. 05
Drill hole 10 core samples			
0	[2]17. 9	59. 19	None
21	[2]25. 0	61. 89	0. 39
0	5. 0	39. 09	. 44
5	10. 0	46. 90	. 34
10	15. 0	45. 23	None
15	20. 0	37. 41	7. 70
20	25. 0	3[illegible]. 09	None

PHU HIA IRON DEPOSIT, DRILL HOLES 1–4

Interval (feet)— From	To	Percent Iron	Sulfur
Drill hole 1 core samples			
50. 0	61. 0	32. 87	0. 10
61. 0	69. 7	60. 65	. 14
69. 7	83. 0	-----	-----
83. 0	84. 5	31. 74	. 73
84. 5	91. 6	66. 31	. 82
91. 6	97. 0	69. 71	. 26
97. 0	103. 6	68. 58	. 89
103. 6	109. 3	68. 01	. 11
109. 3	114. 9	6[illegible]. 31	0. 18
114. 9	120. 0	53. 28	9. 71
120. 0	126. 5	62. 35	. 37
126. 5	134. 0	49. 88	. 25
134. 0	141. 2	62. 91	. 19
141. 2	147. 0	62. 35	. 25
147. 0	153. 5	59. 51	2. 38
153. 5	156. 7	6[illegible]. 35	14. 62
Drill hole 2 core samples			
0. 0	10. 0	68. 31	None
10. 0	12. 0	63. 08	0. 01
12. 0	20. 0	-----	-----
20. 0	25. 0	69. 57	None
25. 0	36. 0	-----	-----
36. 0	39. 0	55. 79	None
39. 0	46. 3	-----	-----
46. 3	53. 0	65. 47	0. 11
Drill hole 3 core samples			
0. 0	6. 7	69. 15	0. 06
6. 7	8. 3	-----	-----
8. 3	15. 0	6[illegible]. 58	0. 11
15. 0	19. 3	60. 08	. 11

[1] NA, not analyzed.
[2] Sludge sample.

Interval (feet)— From	To	Percent Iron	Sulphur	Interval (feet)— From	To	Percent Iron	Sulphur
Drill hole 4 core samples				*Drill hole 4 core samples*			
0	3.0	71.41	0.12	15	22.0	70.28	0.15
3	15.0	------	------	22	30.0	69.71	.12
Drill hole 3 sludge samples				*Drill hole 3 sludge samples*			
0	5	65.75	0.12	10	15	69.15	0.06
5	10	65.75	.11				
Drill hole 4 sludge samples				*Drill hole 4 sludge samples*			
0	5	69.75	0.05	20	25	66.75	0.04
5	10	69.55	None	25	30	62.91	.05
10	15	69.74	.05	30	35	68.03	None
15	20	69.03	.01	35	40	55.65	.03

PHU ANG IRON DEPOSIT, DRILL HOLES 2–12, 14–22

Interval (feet)— From	To	Percent Iron	Sulphur	Interval (feet)— From	To	Percent Iron	Sulphur
Drill hole 2 core samples				*Drill hole 2 core samples*			
45.0	50.0	61.14	None	82.0	85.0	63.15	0.15
50.0	52.0	61.06	0.05	85.0	88.0	62.75	.12
52.0	55.0	62.17	.02				
Drill hole 3 core samples				*Drill hole 3 core samples*			
10.0	15.0	65.11	------	34.0	38.0	62.86	------
15.0	20.5	65.67	------	38.0	43.6	67.19	------
20.5	25.0	66.23	------	43.6	49.0	65.44	------
25.0	29.0	65.67	------	53.5	58.5	48.21	------
29.0	34.0	63.42	------	58.5	65.0	66.87	------
Drill hole 4 core samples				*Drill hole 4 core samples*			
2.5	5.0	68.66	0.42	243.0	248.4	59.86	1.52
5.0	10.0	69.25	.16	248.4	255.0	53.33	1.15
10.0	15.0	66.90	.41				
Drill hole 5 core samples				*Drill hole 5 core samples*			
70.0	85.0	51.78	0.12	172.6	176.0	55.42	14.43
126.0	138.0	60.18	.21	176.0	180.4	58.22	14.83
140.4	155.0	59.62	.29	180.4	188.0	54.58	13.20
168.0	172.6	52.06	22.16	188.0	189.5	51.78	8.07
Drill hole 6 core samples				*Drill hole 6 core samples*			
5.0	10.0	68.67	0.19	270.0	277.0	61.67	7.09
45.0	59.0	67.78	None	277.0	282.0	61.08	8.22
59.0	67.5	67.05	.06	282.0	286.4	58.71	13.08
67.5	77.0	66.16	.05	286.5	291.5	54.56	17.41
99.0	106.0	64.12	None	291.5	294.0	21.35	9.37
106.0	111.0	52.23	.18	301.5	305.0	41.51	7.60
244.4	256.0	33.21	6.40	305.0	309.8	56.34	12.19
256.0	264.0	56.93	3.88	329.5	336.5	29.65	17.75
264.0	270.0	52.78	6.66				
Drill hole 7 core samples				*Drill hole 7 core samples*			
0.0	5.0	67.03	0.02	265.0	269.7	61.72	9.50
5.0	9.0	59.78	.16	272.7	277.5	57.49	20.95
9.0	15.3	56.77	.13	287.0	287.8	63.05	1.67
15.3	19.2	50.22	.22	290.0	297.8	56.81	2.83
250.0	255.0	58.67	2.59	327.8	332.6	40.56	3.92
255.0	260.0	63.28	3.26	332.6	337.6	36.41	3.22
260.0	265.0	65.82	4.03				

Interval (feet)— From	To	Percent Iron	Sulphur	Interval (feet)— From	To	Percent Iron	Sulphur
Drill hole 8 core samples				*Drill hole 8 core samples*			
0.0	6.0	62.09	0.13	169.3	170.0	52.05	0.55
6.0	10.0	62.32	.11				
Drill hole 9 core samples				*Drill hole 9 core samples*			
0.0	6.0	60.21	None	235.0	240.0	45.41	22.33
6.0	10.0	61.63	None	240.0	245.0	56.40	20.64
10.0	16.0	63.92	None	245.0	249.4	56.53	11.09
16.0	20.0	64.20	None	251.0	252.4	56.95	6.03
20.0	25.0	63.06	None	254.0	257.7	58.68	21.28
25.0	29.0	52.22	None	260.4	265.0	62.10	29.39
29.0	39.0	53.93	None	265.0	270.0	60.89	8.07
50.0	55.0	63.06	0.17	270.0	275.0	59.24	15.50
55.0	60.0	56.69	.34	275.0	280.0	55.42	17.64
210.0	215.0	39.34	7.61	280.0	285.0	57.59	17.65
215.0	220.0	56.98	5.79	285.0	290.0	60.95	8.36
220.0	225.0	61.32	3.00	290.0	293.7	49.79	12.69
225.0	230.0	53.80	18.52	320.7	323.6	46.99	24.73
230.0	235.0	55.25	9.41				
Drill hole 10 core samples				*Drill hole 10 core samples*			
0.0	7.0	68.48	0.19	282.2	288.6	44.93	1.59
7.0	12.0	47.37	None	316.0	321.2	40.07	10.62
16.0	20.0	67.34	.17	563.0	568.0	57.87	2.42
104.0	110.0	53.07	.23	602.5	606.5	41.04	6.58
113.0	114.0	54.83	3.23				
Drill hole 11 core samples				*Drill hole 11 core samples*			
0.0	2.0	65.63	None	178.0	183.0	60.49	0.39
4.0	10.0	13.69	None	189.5	191.8	67.34	.38
32.0	41.0	67.34	None	227.4	234.0	22.69	1.69
171.0	178.0	12.90	0.09				
Drill hole 12 core samples				*Drill hole 12 core samples*			
0.0	15.0	66.26	0.17	34.0	40.0	67.11	0.41
23.0	27.0	66.22	.17				
Drill hole 14 core samples				*Drill hole 14 core samples*			
2.0	15.0	60.29	0.03	291.8	308.6	51.63	3.04
25.0	35.0	66.26	.16	310.6	322.0	56.41	4.09
35.0	44.0	57.60	.06	322.0	327.5	46.86	3.04
44.0	53.0	61.19	.19	337.5	347.2	54.32	3.91
Drill hole 15 core samples				*Drill hole 15 core samples*			
0.0	2.0	65.64	0.01	62.2	64.0	62.59	0.12
2.0	4.0	64.72	.06	64.0	66.0	61.72	.08
4.0	6.0	58.72	.02	66.0	68.0	62.59	.09
6.0	11.0	65.98	.01	68.0	70.0	59.41	.07
11.0	16.0	58.84	.09	102.0	105.0	63.74	.05
35.5	40.0	56.53	.18	105.0	106.7	65.76	.06
40.0	45.0	64.61	.12	106.7	108.0	64.89	.08
45.0	47.0	68.64	.09	108.0	110.0	65.18	.06
47.0	49.0	64.61	.10	110.0	113.0	69.65	None
51.0	54.0	65.18	.05	113.0	115.0	66.19	.11
54.0	56.0	61.14	.08	115.0	117.0	60.85	.22
58.0	58.5	58.84	.06	117.0	119.0	68.93	None
58.5	59.3	68.07	.04	119.0	121.0	65.76	None
59.3	61.0	63.45	.05	121.0	123.0	62.87	.10
61.0	62.2	64.32	.09	123.0	125.0	60.85	None
Drill hole 16 core samples				*Drill hole 16 core samples*			
2.0	4.0	67.24	0.10	126.0	127.0	42.89	2.16
4.0	7.0	69.55	.04	279.9	300.0	52.58	4.89
60.0	65.0	52.17	.06	300.0	303.2	29.51	3.27
77.0	82.0	59.12	.10	303.2	315.0	55.57	6.75
82.0	89.0	62.60	.21	320.0	325.0	53.31	4.02
125.0	126.0	34.91	.72				

Interval (feet)—		Percent	
From	To	Iron	Sulphur
Drill hole 17 core samples			
2.0	4.0	66.66	0.12
6.0	8.0	67.82	.14
8.0	10.0	68.98	.12
10.0	12.0	68.40	.12
12.0	14.0	66.66	.12
14.0	16.0	67.82	.12
16.0	18.0	67.24	.19
18.0	20.0	68.40	.18
20.0	22.0	65.50	.21
22.0	24.0	66.66	0.23
24.0	25.5	65.50	.41
25.5	28.0	65.50	.33
35.0	38.0	67.34	.30
38.0	43.0	68.48	.36
43.0	48.0	68.48	.06
75.0	76.0	69.05	.07
76.0	80.0	67.34	.07
80.0	85.0	67.34	.10
Drill hole 18 core samples			
0.0	2.0	68.48	0.09
2.0	4.0	64.50	.10
7.0	9.0	63.47	.18
9.0	12.0	68.16	.06
12.0	14.0	59.40	0.01
42.0	44.0	60.92	.01
44.0	48.0	64.42	.01
48.0	50.0	58.47	.01
Drill hole 19 core samples			
0.0	4.0	67.54	0.08
4.0	6.0	67.56	.06
6.0	8.5	68.20	.07
8.5	10.0	68.15	.10
10.0	12.0	67.42	0.05
12.0	14.0	68.54	.08
20.0	22.0	67.13	.18
Drill hole 20 core samples			
0.0	2.0	66.38	0.04
4.0	8.0	66.81	.04
8.0	10.0	65.15	.09
10.0	12.0	67.25	.05
14.0	16.0	66.61	None
16.0	18.0	66.08	None
18.0	20.0	67.25	None
20.0	22.0	66.23	None
22.0	24.0	64.35	.04
24.0	26.0	64.31	0.03
26.0	28.0	62.03	None
28.0	30.0	68.19	.01
30.0	32.0	68.79	None
32.0	34.0	69.34	None
40.0	42.0	59.97	.01
42.0	44.0	55.50	.05
69.0	71.0	43.38	.01
Drill hole 21 core samples			
1.0	2.0	65.53	0.04
3.2	4.7	61.40	.04
4.7	8.0	63.25	.04
8.0	10.0	65.53	.03
10.0	12.0	64.39	0.01
12.0	14.0	69.52	.02
14.0	16.0	67.81	.02
24.0	26.0	63.25	.01
Drill hole 22 core samples			
6.7	8.0	63.82	0.01
Drill hole 2 sludge samples			
0	5	55.65	------
5	10	60.71	------
10	15	53.65	------
15	20	38.51	------
20	25	53.41	------
25	30	45.50	------
30	35	57.06	------
35	40	53.12	------
40	45	56.18	------
45	50	51.99	------
50	55	56.21	------
55	60	32.58	------
60	65	27.26	------
65	70	21.08	------
70	75	16.85	------
75	80	27.51	------
80	85	35.42	------
85	88	46.06	------
Drill hole 3 sludge samples			
10	15	49.95	------
15	20	60.05	------
20	25	62.29	------
25	30	63.42	------
30	35	61.18	------
35	40	61.74	------
40	45	60.02	------
45	50	61.84	------
50	55	36.53	------
55	60	48.73	------
60	65	63.04	------
65	70	36.92	------

Interval (feet)—		Percent	
From	To	Iron	Sulphur
Drill hole 4 sludge samples			
0	5	53.52	0.16
5	10	42.09	.29
10	15	53.88	.27
15	20	34.80	.27
25	30	28.06	None
30	35	20.21	.01
35	40	44.90	.09
40	45	45.46	.02
45	50	47.71	.01
50	55	46.11	.01
60	65	22.99	0.03
75	80	14.15	.01
105	110	7.99	None
125	130	7.59	None
235	240	10.54	3.11
240	245	11.66	3.97
245	250	21.19	2.69
250	255	11.32	1.49
255	260	9.98	1.26
275	280	9.87	1.31
Drill hole 5 sludge samples			
45	50	7.86	None
60	65	11.79	None
65	70	8.42	None
70	75	13.57	.52
75	80	12.67	.23
80	85	14.35	.44
85	90	13.68	.12
90	95	17.83	0.01
95	100	16.71	.32
100	105	12.91	None
105	110	9.54	None
110	115	7.29	None
115	120	7.06	.06
120	125	11.66	.01
Drill hole 6 sludge samples			
10	15	53.26	0.07
15	20	41.96	.01
75	80	61.92	None
80	85	51.06	None
Drill hole 8 sludge samples			
10	15	36.98	0.07
15	20	37.89	.20
20	25	40.97	0.30
25	30	39.60	.12
Drill hole 9 sludge samples			
45	50	62.19	0.21
Drill hole 10 sludge samples			
10	15	58.89	0.19
25	30	52.32	.54
100	105	46.03	0.72
Drill hole 11 sludge samples			
0	5	61.41	0.11
10	15	50.61	.12
15	20	41.28	.10
20	25	39.36	.12
25	30	40.99	.13
30	35	58.89	0.09
35	40	22.79	.11
40	45	19.09	.06
185	190	57.32	.16
Drill hole 12 sludge samples			
15	20	44.70	0.19
35	40	49.78	.17
40	45	53.83	0.11
Drill hole 14 sludge samples			
5	10	56.40	0.14
10	15	60.83	.09
15	20	50.54	0.12
25	30	62.03	.17
Drill hole 15 sludge samples			
0	5	41.17	0.11
5	10	53.75	.10
10	15	54.32	.09
15	20	58.32	.07
20	25	37.74	.06
35	40	60.04	.09
40	45	53.40	0.22
45	50	57.80	.07
50	55	56.30	.09
55	60	55.49	.11
105	110	65.30	.20

Interval (feet)— From	Interval (feet)— To	Percent Iron	Percent Sulphur
Drill hole 16 sludge samples			
0	5	45.93	0.03
5	10	59.08	.03
55	60	53.14	.11
60	65	54.18	.11
65	70	48.34	.23
70	75	50.01	.24
75	80	54.02	.30
Drill hole 16 sludge samples			
80	85	48.50	0.24
85	90	40.64	.22
310	315	58.40	3.46
315	320	21.05	2.60
320	325	55.09	5.43
325	330	19.18	2.89
Drill hole 17 sludge samples			
0	5	57.68	0.04
5	10	54.65	.05
10	15	60.86	.03
15	20	61.43	.03
20	25	64.61	.23
25	30	69.22	.23
Drill hole 17 sludge samples			
30	35	66.91	0.23
35	40	65.76	.21
40	45	54.22	.07
45	50	55.95	.15
76	80	63.45	.11
80	85	55.95	.22
Drill hole 18 sludge samples			
0	15	61.92	0.24
15	20	61.25	.26
36	44	47.78	.04
Drill hole 18 sludge samples			
44	50	60.61	0.03
50	55	60.63	.18
55	60	52.54	.20
Drill hole 19 sludge samples			
0	14	58.77	1.12
Drill hole 20 sludge samples			
0	2	51.93	0.14
2	4	57.64	.08
4	6	58.78	.07
6	8	38.24	.08
8	10	31.96	.11
10	12	66.77	.11
12	14	66.45	.03
14	16	66.80	.09
16	18	66.11	.10
18	20	67.95	.15
20	22	67.37	.04
22	24	66.34	.03
24	26	66.91	None
26	28	66.11	.05
28	30	68.29	.27
30	32	68.86	.34
32	34	60.58	.06
Drill hole 20 sludge samples			
34	36	62.12	0.12
40	42	55.00	.10
42	44	60.02	1.18
44	46	63.94	1.62
46	48	65.63	.06
48	50	63.35	.07
50	52	63.35	.07
52	54	65.63	.10
54	56	65.63	.04
56	58	65.63	.10
58	60	63.97	.04
60	63	58.97	.05
63	65	58.73	.01
65	67	60.11	.04
67	69	54.46	.06
69	71	53.73	.07
Drill hole 21 sludge samples			
0	2	42.67	0.08
2	4	56.47	.02
6	8	63.84	.02
8	10	53.80	.02
Drill hole 21 sludge samples			
10	12	51.65	0.05
12	14	50.68	.06
14	16	52.77	.08
16	18	51.09	.05
Drill hole 22 sludge samples			
0	2	66.09	None
2	4	65.53	None
4	6	59.83	None
6	8	58.12	None
8	10	55.84	None
Drill hole 22 sludge samples			
10	12	62.11	None
12	14	56.98	None
14	16	60.97	None
16	18	59.83	None

PHA BAEN LIMESTONE DEPOSIT

Composition of grab sample

[Analysis by U.S. Geol. Survey]

	Percent		Percent		Percent
SiO_2	0.19	CaO	55.00	TiO_2	0.02
Al_2O_3	.27	Na_2O	.05	P_2O_5	.02
Fe_2O_3	.11	K_2O	.02	MnO	.05
FeO	.12	H_2O-	.03	CO_2	43.30
MgO	.50	H_2O+	.16		100

WANG SAPHUNG ANHYDRITE-GYPSUM DEPOSIT DRILL HOLES 1 AND 2

Interval (feet)— From	Interval (feet)— To	Composition (percent) CaO	SO_3	H_2O+
Drill hole 1				
288.6	299.0	38.81	53.88	5.64
299.0	309.0	37.90	54.70	2.28
309.0	319.0	35.43	47.84	14.52
319.0	323.0	41.56	56.06	1.04
351.5	360.8	42.41	55.80	.60
370.8	380.8	43.45	56.44	.20
380.8	390.8	43.21	56.28	None
390.8	400.8	42.42	55.94	None
400.8	413.0	44.29	54.70	None
Drill hole 2				
150.3	170.0	32.34	45.72	20.56
170.0	177.0	32.62	41.82	18.64
195.0	201.0	32.82	44.84	20.20
233.0	251.0	34.70	48.26	16.36
251.0	257.7	39.46	55.02	4.92
262.5	280.0	41.46	56.14	.98
280.0	286.3	40.94	57.99	.72
286.1	287.0	33.02	47.10	19.16
287.0	308.8	41.14	56.58	.92
308.8	310.4	32.98	45.54	20.16
331.1	332.4	34.98	43.88	19.68
332.4	339.7	40.42	42.64	1.44
339.7	342.3	34.18	47.38	16.52
349.3	351.8	34.70	37.98	18.04
351.8	356.4	39.90	51.96	1.40
357.6	362.0	40.10	53.84	.64
362.0	362.4	32.26	46.44	18.52
365.8	370.2	32.77	42.66	17.08
371.1	372.0	33.44	40.90	17.80
383.9	386.2	36.60	40.00	17.08
398.9	399.9	30.84	39.08	15.24
399.9	400.9	38.96	52.20	4.80
400.9	401.8	26.02	34.18	12.28
401.8	402.6	39.94	54.20	3.32
402.6	403.0	26.82	36.38	13.80
410.4	411.6	33.06	39.38	16.76
411.6	422.0	40.18	56.60	.56
422.0	433.3	40.61	55.76	1.76
438.5	445.3	40.52	55.22	.32
448.0	449.8	31.61	40.60	.20
440.8	457.0	40.56	54.25	.96
457.2	467.0	41.28	56.82	.12
467.0	471.3	40.36	56.56	.20
471.3	472.5	34.92	39.78	.24
472.5	480.2	39.46	56.38	.12
491.0	491.9	40.30	57.48	.60
493.0	494.5	40.86	55.82	.28
496.7	497.7	35.66	49.38	.52

Interval (feet)—		Composition (percent)		
From	To	CaO	SO_3	H_2O+
Drill hole 2				
502. 1	505. 8	40. 18	56. 32	0. 08
506. 3	508. 2	37. 18	52. 32	. 08
511. 0	524. 0	41. 14	56. 04	. 08
524. 0	543. 8	41. 62	56. 49	. 14
543. 8	561. 5	41. 54	57. 72	. 13
561. 5	584. 9	41. 22	57. 95	. 18
584. 9	587. 4	34. 32	33. 94	. 76
587. 4	598. 0	41. 27	52. 97	1. 66
598. 0	602. 8	41. 25	57. 73	. 13
603. 4	615. 6	41. 67	57. 26	. 14
618. 3	619. 4	41. 59	57. 30	. 23
620. 8	625. 6	41. 42	57. 18	. 12
626. 3	632. 1	41. 28	49. 54	. 35
632. 6	644. 2	41. 57	58. 08	. 09
644. 2	660. 8	41. 26	57. 48	. 13
660. 8	661. 8	36. 32	48. 96	14. 42
674. 3	681. 1	41. 11	56. 55	1. 25
681. 1	682. 3	33. 76	44. 00	14. 80
Drill hole 2				
697. 2	701. 0	39. 79	54. 50	4. 93
704. 3	707. 4	41. 91	57. 11	. 36
707. 4	711. 0	36. 27	43. 40	16. 53
731. 8	733. 3	32. 78	46. 76	20. 43
733. 3	747. 1	41. 49	55. 97	. 97
747. 1	750. 2	37. 25	47. 55	8. 54
753. 6	755. 6	41. 10	54. 20	2. 43
755. 6	756. 6	34. 09	45. 81	18. 81
757. 8	758. 4	32. 88	46. 74	20. 13
758. 4	772. 1	41. 38	57. 56	. 83
772. 1	772. 8	34. 57	48. 17	17. 25
810. 7	812. 0	30. 73	40. 60	17. 53
812. 0	816. 4	38. 47	51. 32	1. 49
817. 6	820. 0	31. 11	34. 30	3. 56
820. 8	831. 0	40. 08	36. 74	2. 27
831. 0	833. 3	35. 33	28. 87	11. 25
843. 7	850. 3	35. 69	38. 91	16. 44

CHAIYAPHUM SALT DEPOSIT

COMPOSITION OF COMPOSITE DRILL-CORE SAMPLES

	Drill holes (Analysis, in percent, by U.S. Geol. Survey)			
	2	3	4	5
SiO_2	0. 09	0. 09	0. 08	0. 05
MgO	. 033	. 033	. 033	. 033
CaO	1. 06	1. 27	1. 25	. 85
Na_2O	51. 49	50. 93	51. 36	51. 63
K_2O	. 024	. 036	. 009	. 008
SO_3	1. 52	1. 77	1. 77	1. 24
H_2O	<. 01	<. 01	<. 01	<. 01
R_2O_3	<. 01	<. 01	<. 01	<. 01
Cl	58. 25	58. 61	58. 54	59. 14
Br	<. 01	<. 01	<. 01	<. 01
CO_2	. 14	. 026	. 042	. 034
Subtotal	112. 61	112. 74	113. 12	112. 95
Less 0=Cl	−13. 14	−13. 22	−13. 21	−13. 34
Total	99. 47	99. 52	99. 91	99. 61

ANALYSIS OF CORE SAMPLES

[Leaders indicate no sample]

Interval (feet)		Percent							
From	To—	CaO	Na_2O	K_2O	SO_3	Cl	Total	Less O=Cl	Total
Drill hole 2									
212. 0	230. 8	3. 30	48. 3	0. 05	4. 70	55. 0	111. 35	12. 3	99. 1
230. 8	249. 2	1. 58	50. 8	. 04	2. 30	58. 2	112. 92	13. 2	99. 7
249. 2	268. 4	1. 25	50. 6	. 04	1. 75	58. 2	111. 84	13. 1	98. 7
268. 4	282. 5	1. 82	50. 6	. 04	2. 62	56. 9	111. 98	13. 1	98. 9
282. 5	301. 7	1. 75	50. 6	. 04	2. 50	57. 8	112. 69	13. 1	99. 6
301. 7	320. 6	1. 08	51. 7	. 02	1. 50	58. 4	112. 70	13. 4	99. 3
320. 6	340. 2	1. 08	51. 8	. 03	1. 50	59. 0	113. 41	13. 4	100. 0
340. 2	358. 6	. 87	52. 1	. 03	1. 20	59. 3	113. 50	13. 5	100. 0
358. 6	375. 9	. 43	52. 4	. 03	. 65	59. 4	112. 91	13. 5	99. 4
375. 9	394. 9	. 64	52. 4	. 02	. 95	59. 4	113. 41	13. 5	99. 9
394. 9	415. 7	. 62	51. 6	. 02	. 88	59. 2	112. 32	13. 3	99. 0
415. 7	437. 7	. 58	51. 9	. 03	. 80	59. 0	112. 31	13. 4	98. 9
437. 7	457. 0	. 70	51. 9	. 01	1. 05	59. 2	112. 86	13. 4	99. 5
457. 0	479. 3	. 82	52. 2	. 01	1. 20	59. 4	113. 63	13. 5	100. 1
479. 3	497. 9	. 54	52. 2	. 01	. 80	59. 2	112. 75	13. 5	99. 3
497. 9	512. 9	. 60	51. 8	. 03	. 90	59. 2	112. 53	13. 4	99. 1
512. 9	532. 0	. 59	52. 0	. 01	. 88	59. 4	112. 88	13. 4	99. 5
532. 0	539. 6	. 54	51. 8	. 02	. 86	59. 0	112. 22	13. 4	98. 8

Interval (feet)		Percent							
From	To—	CaO	Na_2O	K_2O	SO_3	Cl	Total	Less O=Cl	Total
Drill hole 3									
190. 5	212. 6	3. 30	49. 0	0. 04	4. 60	55. 4	112. 34	12. 6	99. 7
212. 6	232. 3	2. 02	50. 8	. 04	2. 80	57. 6	113. 26	13. 2	100. 1
232. 3	251. 8	1. 02	51. 8	. 04	1. 45	59. 0	113. 31	13. 4	98. 9
251. 8	270. 3	1. 13	51. 7	. 01	1. 65	58. 9	113. 39	13. 4	100. 0
270. 3	286. 2	1. 30	51. 2	. 02	1. 85	58. 4	112. 77	13. 3	99. 5
286. 2	304. 7	1. 70	51. 4	. 03	2. 40	57. 6	113. 13	13. 3	98. 8
304. 7	323. 0	1. 45	51. 5	. 01	2. 10	58. 0	113. 06	13. 4	99. 7
323. 0	342. 3	1. 26	51. 6	. 02	1. 85	58. 6	113. 33	13. 4	99. 9
342. 3	361. 6	1. 75	50. 8	. 02	2. 50	57. 7	112. 77	13. 2	99. 6
361. 6	380. 7	. 32	52. 6	. 02	. 45	59. 9	113. 29	13. 7	99. 6
380. 7	399. 5	. 72	51. 8	. 02	1. 08	59. 1	112. 72	13. 4	99. 3
399. 5	419. 1	. 48	52. 4	. 02	. 75	59. 7	113. 35	13. 7	99. 7
419. 1	438. 8	. 95	52. 0	. 03	1. 40	58. 4	112. 78	13. 5	99. 3
438. 8	457. 0	. 72	52. 3	. 03	1. 08	59. 4	113. 53	13. 7	99. 8
457. 0	474. 3	. 51	51. 8	. 03	. 76	59. 3	112. 40	13. 4	99. 0
474. 3	484. 0								
484. 0	502. 0	. 65	51. 8	. 02	1. 02	58. 9	112. 39	13. 4	99. 0
502. 0	521. 0	. 96	51. 8	. 03	1. 36	58. 8	112. 95	13. 4	99. 6
521. 0	538. 8	. 72	51. 8	. 01	1. 02	59. 2	112. 75	13. 4	99. 6
538. 8	552. 6	. 70	51. 8	. 02	1. 04	59. 0	112. 56	13. 4	99. 2

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES

The semiquantitative spectrographic analyses were performed by the U.S. Geological Survey. The results are reported, in percent, to the nearest number in series: 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc., which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value about 30 percent of the time. In addition to the elements herein listed the following elements were looked for, but not detected in any of the samples: As, Au, B, Cd, Ce, Ge, Hf, Hg, In, La, Li, Pd, Pt, Re, Sb, Ta, Te, Th, Tl, U, and W.

Element	Samples											
	1	2	3	4	5	6	7	8	9	10	11	12
Si	5	M[1]	5	3	M[1]	1	5	7	5	3	7	0. 015
Al	1	1	1. 5	. 001	5	. 3	. 3	. 2	. 7	. 7	1	. 001
Fe	M[1]	M[1]	M[1]	M[1]	1. 5	M[1]	M[1]	M[1]	M[1]	M[1]	M[1]	
Mg	. 07	. 02	. 3	. 07	. 5	. 5		. 02	1. 5	1. 5	. 7	. 03
Ca	. 07	. 03	2. 0	. 07	. 5	. 01	. 005	. 005	1. 0	1. 5	3. 0	5. 0
Na					. 5				. 1	. 15		M[1]
K	. 2									. 3	. 3	
Ti	. 1	. 07	. 05	. 001	. 3		. 015	. 007	. 05	. 03	. 1	
P						. 5						
Mn	. 07	. 007	2. 0	. 7	. 02	. 03	. 15	. 002	. 07	. 03	. 05	
Ag		. 02		. 001	. 0005			. 0015				
Ba	. 5	. 002	. 002	. 005	. 003	. 01	. 001	. 001	. 015	. 003	. 002	. 0003
Be					. 0001	. 0015	. 0005					
Bi								. 007				
Co		. 001	. 003	. 007		. 005	. 007	. 0015	. 007	. 007	. 01	
Cr	. 02	. 001	. 0007	. 001	. 003	. 0015	. 005		. 003	. 003	. 002	. 0003
Cu	. 02	. 3			3. 0	3. 0	. 3	7	. 1	. 1	. 05	<. 0001
Ga	. 0015	. 0001	. 0007	. 001	. 0015	. 001	. 001	. 001	. 001	. 001	. 002	
Mo	. 0015	. 0015	. 0005	. 007		. 002	. 003	. 0007	. 001	. 001	. 0015	
Nb						. 005						
Ni							. 005		. 003	. 003		
Pb		. 003	. 003		. 01	. 001	. 003		. 002	. 0007		
Sc		. 0007	. 0003		. 0007		. 0003					
Sn	. 003	. 003		. 001	. 0015	. 003	. 001	. 001	. 005	. 003	. 003	. 003
Sr	. 001				. 007				. 0007	. 003		. 02
V			. 002		. 01		. 002	. 002				
Y					. 003	. 015						
Yb					. 0003	. 0015						
Zn			. 3	. 5	. 07	. 7	. 1					
Zr	. 015	. 015			. 005	. 015			. 015	. 015	. 015	

[1] M, major constituent, quantity not determined.

1 Phu Han-Phu Sang prospect gossan.
2 Phu Hin Lek Fai gossan.
3 Phu Hin Lek Fai drill hole 2, 36 ft; core.
4 Phu Hin Lek Fai drill hole 2, 228 ft; core.
5 Phu Hin Lek Fai drill hole 2, 430 ft; core.
6 Phu Thong Daeng gossan.
7 Phu Thong Daeng drill hole 1; 35–40 ft; core.
8 Phu Thong Daeng drill hole 1; 311 ft; core.
9 Phu Yang drill-hole 2 composite; 0–260 ft; core.
10 Phu Yang drill-hole 4 composite; 105–246 ft; core.
11 Phu Hia drill-hole 1 composite; 88–156 ft; core.
12 Chaiyaphum drill-hole composite; salt core.

PETROGRAPHIC ANALYSES

By G. W. Leo, U.S. Geological Survey

INTRUSIVE ROCKS (PERMIAN OR TRIASSIC)

Sample T31, 19 km southeast of Chiengkarn:

Megascopic: Clean unaltered even-grained granitic rock, average grain size 3–5 mm; quartz, plagioclase, hornblende, and biotite.

Microscopic: Hypidiomorphic verging on panidiomorphic texture, with subhedral to euhedral plagioclase and interstitial mortared quartz and some potassium feldspar, latter estimated 5–10 percent of total quartz + feldspar. Green hornblende and red-brown biotite about 5 percent each, both partly altered to green chlorite along cleavages, with some exsolution of sphene. Plagioclase (An_{30-60}) is sporadically sericitized, but shows conversion to epidote. Some carbonate associated with plagioclase and hornblende.

Observed: A hornblende-biotite quartz diorite (approaching granodiorite in composition). If this rock has been subjected to metamorphism, the effects are not evident.

Sample J13 (Phu Kwai Ngoen), 8 km east of Chiengkarn:

Megascopic: Mesocratic granitic rock, uniform fine grain, 2–5 mm; recognizable plagioclase, quartz, potassium feldspar, hornblende, and biotite.

Microscopic: Granitic rock with hypidiomorphic granular texture, little alteration. Overall appearance comparable to T31, except for higher proportion of potassium feldspar (estimated 10–12 percent of total feldspar + quartz). Green hornblende and olive-green biotite about 5 percent each.

Observed: Hornblende-biotite granodiorite, generally similar to T31.

Sample J73 (Phu I Thao), 24 km northeast of Loei:

Megascopic: Fine-grained homogeneous granitic rock with recognizable quartz, feldspar, and biotite.

Microscopic: Good hypidiomorphic texture, with quartz, plagioclase (An_{33-60}), and potassium feldspar (estimated 5–10 percent of total quartz + feldspar). Plagioclase but not notably saussuritized, little or no epidote. Mafic minerals are partly chloritized biotite and pale-green hornblende, total about 10 percent.

Observed: Slightly altered quartz diorite, which does not show evidence of low-grade metamorphism.

Sample J90, 13 km north of Loei:

Megascopic: Medium-grained rock of a granodioritic appearance.

Microscopic: Good hypidiomorphic texture, little alteration (even less than in J73). Potassium feldspar probably in excess of 10 percent, although the thin section too small for an accurate estimate. Red-brown biotite and green hornblende. Plagioclase=An_{42-52}.

Observed: From available section this can be called a hornblende-biotite granodiorite.

Sample J92 (Phu Mon), 5 km east-southeast of Chiengkarn:

Megascopic: Fine-grained granitic rock; green color of mafic minerals suggest alteration. Some suggestion of gneissic banding.

Microscopic: Blotchy heterogeneous texture verging on allotriomorphic, with much patchy interstitial quartz; looks like a magmatic rock. Plagioclase sericitized and mottled; generally has normal zoning; no composition obtainable. Red-brown biotite and green hornblende. Blobby sphene associated with plagioclase.

Observed: Rock is a fine-grained quartz diorite. No evidence of metamorphism.

UNDIFFERENTIATED INTRUSIVE ROCKS

Sample T28, 21 km east-southeast of Loei:

Megascopic: Fine-grained highly porphyritic rock, punky and altered, with recognizable hornblende and plagioclase; total phenocrysts about 50 percent.

Microscopic: Ground mass is dirty clay-feldspar-quartz mixture, thoroughly recrystallized. Plagioclase (An_{53-55}) forms fairly uniform and idiomorphic phenocrysts. Some saussuritization. About 10 percent hornblende, little altered, opaques reflect black.

Observed: Rock is dacite-rhyodacite.

Sample J71, 24 km east-northeast of Loei:

Megascopic: Light-gray highly porphyritic rock with aphanitic groundmass and phenocrysts of quartz, feldspar, and biotite. No rock fragments or evidence of tuffaceous origin.

Microscopic: Thoroughly recrystallized groundmass of quartz granules in altered feldspar, clay, and other minerals. Amount of potassium feldspar indeterminate, not positively identified. Phenocrysts are plagioclase (AN_{47-57}), quartz, and chloritized biotite. Little saussuritization or indication of the green-schist metamorphism observed in other volcanic rocks.

Observed: Rock can be called quartz latite.

VOLCANIC ROCKS (TRIASSIC)

Sample T6, 15 km northwest of Loei:

Megascopic: Dark fairly dense rock with aphanitic groundmass, about 20 percent small plagioclase phenocrysts, some apparent flow alinement.

Microscopic: Rock is much more altered than external appearance suggests. Groundmass completely recrystallized, with patches and veinlets of quartz, calcite replacement of plagioclase, hornblende, and pyroxene(?) phenocrysts, An_{38}.

Observed: A clear-cut volcanic porphyry, flow or shallow instrusive; estimated composition, quartz latite. Does not look metamorphosed.

Sample T22, 13 km southwest of Wang Saphung:

Megascopic: White dense completely bleached rock with scattered phenocrysts and angular fragments, apparently of feldspar.

Microscopic: Texture shows some definite signs of tuffaceous origin. Groundmass is recrystallized aggregate of quartz-clay-feldspar. Few unaltered phenocrysts of idiomorphic resorbed quartz. Irregular patches of quartz mosaic which look like (a) cavities and (b) relict rock fragments. Latter also represented by cloudy clay-carbonate aggregates. Local vague suggestion of compressed pumice fragments, scattered relicts of ferromagnesian minerals

Observed: The rock is definitely a tuff, could be a slightly welded tuff. Original composition probably quartz latite-rhyolite. No evidence of metamorphism.

Sample J61B, 18 km southwest of Loei:

Megascopic: Highly porphyritic rock with dense red-brown matrix, feldspar phenocrysts estimated 30 percent, scattered hornblende and biotite. No rock fragments or other indications of tuffaceous origin.

Microscopic: Groundmass is thoroughly recrystallized quartz-feldspar aggregate; potassium feldspar not evident, may be occult. Plagioclase shows incipient alteration to sericite and epidote. Biotite converted to chlorite with expelled sphene. Scattered euhedral and partly resorbed quartz phenocrysts.

Observed: Rock is probably a quartz latite, and shows effects of low-grade metamorphism.

Sample J100, 23 km west-northwest of Loei:

Megascopic: No specimen.

Microscopic: Rock rather altered, but shows intergranular texture defined by web of plagioclase laths (An_{38-46}). Scattered pseudomorphs of chlorite, which suggest original pyroxene. Some calcite patches and quartz aggregates.

Observed: Rock is volcanic or hypabyssal. Texture suggests diabase, but plagioclase suggests a less mafic composition (andesite or rhyodacite). Alteration appears hydrothermal.

MINERAL-DEPOSIT HOST ROCKS AND WALLROCKS

PHU HIN LEK FAI BASE-METAL DEPOSIT

Sample J126:

Megascopic: Gray to buff granular carbonate rock with sugary aspect, distinct though irregular planar element. Does not look like normal limestone or marble, but this impression may not be applicable to the field occurrence.

Microscopic: Aggregate of pure carbonate, rounded grains, clearly recrystallized rock. Uniaxial or slightly biaxial (—). Reaction with dilute HCl.

Sample J131:

Megascopic: Whitish-brown mottled rock, slightly porous, obviously silicified. Shows faint indication of clastic or porphyritic texture.

Microscopic: Former phenocrysts of plagioclase(?) replaced by cryptocrystalline quartz, in a finely crystalline quartz groundmass; also irregular patches of sutured quartz, evidently a late filling. Appearance is of a completely silicified volcanic rock, probably hypabyssal or flow; no clear evidence for tuffaceous origin. Composition indeterminate, but in view of the preponderance of "plagioclase," probably intermediate.

Sample J273A:

Megascopic: Green dense faintly fragmental or brecciated-appearing rock, obviously altered. One pod of carbonate and a large euhedral hornblende prism are visible; faint suggestion of plagioclase phenocrysts.

Microscopic: Poor section. Rock is certainly a microbreccia, possibly tuff breccia, latter idea supported by apparent plagioclase phenocrysts largely replaced by carbonate.

Sample J282B:

Megascopic: Sandstone consisting mostly of subangular quartz grains with ferruginous cement.

Microscopic: Besides quartz, about 20 percent thoroughly kaolinized feldspar grains, and few quartzite fregments.

Observed: Rock could be called an arkose.

Sample J367:

Megascopic: Brown-gray fairly well-sorted cemented sandstone, apparently consisting mostly of quartz. Cut surfaces show some distinct tabular feldspar(?) and some rock fragments.

Microscopic: Many small equant quartz grains wind around highly altered feldspar tablets. Alteration is largely to clay, abundant carbonate patches, but little or no epidote. No identifiable shards or rock fragments.

Observed: Rock is apparently a tuff, although evidence is sparse. It is posible that the apparently clastic quartz grains are a thoroughly recrystallized groundmass, although the appearance of the rock in hand specimen is distinctly clastic. Evidence for low-grade metamorphism is indistinct; alteration may be nonmetamorphic.

Sample J377:

Megascopic: Gray, obviously recrystallized groundmass with scattered idiomorphic or angular feldspar phenocrysts and clusters of biotite grains; total phenocrysts, 30–35 percent.

Microscopic: Groundmass is fine quartz aggregate. Plagioclase phenocrysts are unaltered, estimated composition andesine. Biotite is chloritized. Rock is traversed by quartz veinlet.

Observed: Rock is silicified, but apparently unaffected by the low-grade regional metamorphism. Original composition estimated at rhyodacite or quartz latite.

Sample J384:

Megascopic: Medium-grained well-sorted sandstone consisting mostly of quartz, perhaps some feldspar, with ferruginous cement, fairly porous. No indication of tuffaceous origin.

Microscopic: Besides quartz, interstitial patches consisting mostly of muscovite, in part fairly coarse. Some of these may be altered plagioclase, but there are no other breakdown products.

Observed: Apparently a straightforward quartz-muscovite sandstone, although of somewhat unusual appearance. There has probably been some recrystallization of muscovite, but this does not look like a metamorphic rock.

Sample J389:

Megascopic: Lght-gray highly altered rock, chalky groundmass and barely distinguishable feldspar phenocrysts and hornblende prisms. Looks generally similar to previously described porphyries.

Microscopic: Thoroughly recrystallized groundmass; tabular plagioclase altered but clearly recognizable. Hornblende thoroughly chloritized. No phenocrysts of quartz or potassium feldspar, but quartz is disseminated and in irregular patches.

Observed: Rock probably is a latite or rhyodacite. Alteration due to weathering and hydrothermal activity, not metamorphic.

Sample J394:

Megascopic: Buff to limonite-brown very fine grained powdery rock that could be siltstone or tuff. Nothing directly identifiable.

Microscopic: Aggregate of fine quartz and white mica, with interspersed granules of iron oxide. Latter concentrated in bands, apparently parallel to bedding planes.

Observed: Little doubt about this being a sedimentary rock, but little else can be said.

Sample J401:

Megascopic: Breccia consisting of angular weathered fragments as much as 2.5 cm long in ferruginous matrix. Fragments are soft, highly altered, and apparently reduced to clay.

Microscopic: Fragments are fine aggregates of quartz and clay, show little internal structure. Movement during or after deposition is shown by shattering of some fragments. Much disseminated iron oxide.

Observed: There is little to say about this rock, except that it is sedimentary in origin.

PHU THONG DAENG COPPER DEPOSIT

Sample J162:

Megascopic: Silicified-looking rock, vuggy, with traces of brecciation, and finely crystallized aggregates of hematite(?), also deep-brown iron stain. Magnetism very weak.

Microscopic: Section seems to be from fragment other than available hand specimen. Is about half red-brown isotropic mineral, goethite or hematite; iron oxide has eaten into, and locally replaced, angular quartz fragment for which it forms a matrix. Quartz itself appears to be original, as from quartzite; brecciated effect could have been caused largely by introduction of and replacement by the iron oxide.

Sample J163:

Megascopic: Grayish-green rock, punky and altered, iron stained. Abundant shadowy gray-green feldspar phenocrysts are clearly preserved and indicate hypabyssal or flow rock of intermediate composition.

Microscopic: Groundmass is coarsely recrystallized quartz, giving superficial aspect of sandstone. Phenocrysts are completely kaolinized. Some possible rock fragments, including pumice fragments, but this very tentative.

Observed: Rock is certainly volcanic, and might be a tuff. However, in hand specimen the rock fragments are inconspicuous, whereas phenocrysts are obvious. Composition appears to be intermediate to silicic, that is, rhyodacite to quartz latite. Not metamorphosed.

Sample P46 (trench 1):

Megascopic: Brown-gray-green mottled compact granular rock; sawed surface shows phenocrysts of highly altered feldspar and a faint suggestion of pumice fragments.

Microscopic: Fragmental character is very evident, although pumice fragments doubtful; most clasts(?) are elongated laths of altered plagioclase. Entire rock is quartz-sericite aggregate, no indication of appreciable metamorphic recrystallization.

Observed: Probably intermediate tuffaceous rock, but some chance of being a volcanic porphyry. Texture and condition of rock allow for either interpretation.

Sample P51 (trench 1):

Megascopic: Buff chalky rock with chalky rounded to tabular phenocrysts in a fine-grained matrix.

Microscopic: An agglomeration of sericitic blobs in a sericitic matrix. Texture is very peculiar, and may have been largely obliterated by intense alteration. Rock is probably fragmental.

Observed: Probably an ash tuff of intermediate composition, deeply weathered but unmetamorphosed.

PHU ANG IRON DEPOSIT

Sample J133 (DDH 1, depth, 13 m):

Megascopic: Gray-brown flinty rock, very fine grained and homogeneous, distinctly metasedimentary in appearance.

Microscopic: Extremely fine and uniform aggregate, apparently all quartz and white mica.

Observed: Apparently a recrystallized quartz-clay (sericite) rock, thus an argillite. Degree of metamorphism may correspond to upper greenschist facies, possibly higher.

Sample P41:

Megascopic: Compact buff silty rock, generally comparable to P40.

Microscopic: Microaggregate of quartz sericite, and clay, with disseminated limonite patches. No clues to origin, except that it is sedimentary.

PHU YANG IRON DEPOSIT

Sample P58:

Location: Drill hole 1, depth, 40 m.

Megascopic: Dark-green rock with discernible acicular amphibole, disseminated pyrite, and patches of a black opaque mineral. The latter must be magnetite, as rock is strongly ferromagnetic.

Microscopic: Rock is a coarse felt of acicular to prismatic very pale green amphibole, interstitial patches of carbonate (about 5 percent), and patchy or disseminated magnetite and pyrite. Amphibole is definitely monoclinic, untwinned, with (—) $2V$ large, N_z close to 1.623. These properties fit tremolite-actinolite with about 25 percent of the Fe end member.

This assemblage strongly suggests a metamorphosed siliceous magnesian limestone. The unoriented texture of the rock is indicative of more or less static thermal metamorphism, and the absence of diopside or forsterite suggests that the temperature was moderate—maybe on the order of 200°–300° C.

Sample J599A:

Location: Drill hole 7, depth, 88.4 m.

Megascopic: Granitic rock, fine- to medium-grained; pinkish to white slightly chalky feldspar, gray-green hornblende, sphene, chalcopyrite, pyrite. Rock is weakly ferromagnetic and hence contains magnetite.

Microscopic: Rock consists dominantly of potassium feldspar, plagioclase (An_{34-38}) (less than 10 percent), and pale hornblende and clinopyroxene (about 20 percent), traces of quartz. Blebby black-reflecting opaque mineral (probably magnetite), irregularly disseminated, mostly within mafic minerals. Texture is hypidiomorphic, grading to allotriomorphic. Some ragged pale-brown biotite, locally replaced by prehnite(?).

Feldspar is very cloudy and evidently kaolinized, but certainly not recrystallized or even moderately saussuritized. Pyroxene and hornblende show a peculiar poikiloblastic intergrowth, generally with hornblende in disseminated optically oriented blebs within subhedral to euhedral pyroxene crystals; hornblende may also dominate within a given crystal. This texture is not the result of normal reaction relations, but rather suggests growth under "metamorphic" conditions, where pyroxene was being gradually converted to hornblende and perhaps water was insufficient for complete conversion. Perhaps this could result from a prolonged period of sustained high temperature following emplacement. Certainly, the rock has not been completely recrystallized, as shown by the feldspar; it should not be called a metamorphic rock.

Based on the mineral proportions in this small section, the rock is an augite-hornblende syenite. If additional larger sections show plagioclase to be relatively more abundant. it might then be better called a monzonite. The hand specimen contains very little quartz.

Sample J599B:

Location: Drill hole 1, depth, 46.9 m.

Megascopic: Very dense fine-grained rock, light-gray to gray-green; faint banding defined by parallel zones of dark minerals, some crosscutting veinlets of similar dark minerals, disseminated pyrite.

Microscopic: Fine mosaic of quartz with interstitial shreds and granules of epidote, pale-green actinolitic amphibole, and scattered prisms of dark-blue-green tourmaline. Pods of epidote, a dark-green hornblende, quartz and pyrite several millimeters across. Veinlets consisting dominantly of a uniaxial negative colorless mineral with slight negative relief (sodium-rich scapolite?).

Observed: A hornfels formed by thermal metamorphism of an impure quartz sandstone. Specimen is very close to P58 in the same hole, and certainly fits as an associated metamorphic rock. Scapolite identification is doubtful.

Sample J599C:

Location: Drill hole 4, depth, 11.0 m.

Megascopic: Pink igneous rock; fine crystalline ground mass, tabular feldspar phenocrysts, and prismatic hornblende.

Microscopic: Finely granular allotriomorphic groundmass, marked by patchy feldspar and micromosaic of quartz; gives the impression of a highly devitrified siliceous glass. Phenocrysts are cloudy prismatic plagioclase (An_{30-38}) 10–15 percent, scattered prisms of pale-green hornblende, and one rounded quartz grain. Rock shows incipient alteration to clay and sericite (notably the plagioclase), but texture is clear-cut magmatic. It could be called a quartz latite, possibly rhyodacite.

Sample J599D:

Location: Drill hole 6, depth, 22.9 m.

Megascopic: Grayish-green, fine-grained, homogeneous, and dense rock of diabasic aspect.

Microscopic: Rock consists of plagioclase (An_{20-50}), 55 percent; hornblende, 30 percent; and clinopyroxene, 15 percent; and a little corroded brown biotite. Plagioclase is strongly zoned, normal and reverse, and slightly altered, with inclusions of clay and sericite; no real saussuritization. Hornblende is pale grass green at margins and green brown at cores. Disseminated sphene and magnetite (rock is weakly ferromagnetic). Good subophitic texture.

Observed: This rock is a shallow intrusive or flow rock, either a microdiorite or hornblende diabase.

Sample J599E:

Location: Drill hole 4, depth, 29.3 m.

Megascopic: Dense dark-gray rock, finely crystalline groundmass, tabular feldspar phenocrysts.

Microscopic: Felted groundmass, about equal proportions plagioclase and pale-green to green-brown hornblende, intergranular or micro-ophitic texture. Scattered slightly altered plagioclase phenocrysts; only one determination possible, on indifferently oriented grain, gives An_{27-33} (true composition may be somewhat more calcic). Scattered sphene and magnetite (rock is slightly ferromagnetic). No pyroxene detected.

Observed: Except for absence of pyroxene, this rock is fairly similar to J599D, appears to be a related flow or shallow intrusion—a microdiorite.

Sample J599F:

Location: Drill hole 7, depth, 87.8 m.

Megascopic: Fine-grained granitic rock, slightly altered appearance, abundant visible disseminated pyrite; slight ferromagnetism indicates presence of magnetite.

Microscopic: General similarity with J599A. Principal minerals are potassium feldspar, plagioclase (An_{54}), clinopyroxene, and pale hornblende. Ratio of pottassium feldspar to plagioclase estimated at 2:1; so the rock is about on the boundary between syenite and monzonite. Large anhedral potassium feldspar grains surround euhedral to subhedral plagioclase laths with some (but not extensive) replacement. Clinopyroxene is more abundant than hornblende; clinopyroxene, estimated 10 percent; hornblende, 2 percent. Clinopyroxene forms subhedral to euhedral prisms, some practically pure, others intergrown with blebby hornblende.

Observed: Feldspar textures suggest late growth of potassium feldspar, possibly some potassium metasomatism. Except for the noted differences, all remarks about J599A apply to this rock also.

Sample J599G:

Location: Drill hole 2, depth, 50.6 m.

Megascopic: Gray-green fine-grained rock with slickensided serpentinized fracture surfaces. Subparallel bands of white mineral suggest sedimentary layers. Strongly ferromagnetic.

Microscopic: Most of the rock is a fine-grained felt of pale-green-brown biotite and subordinate colorless optically negative clinoamphibole, probably tremolite-actinolite. Texture is decussate, without preferred orientation. Disseminated opaque mineral reflects black and is presumably magnetite. Bands of white mineral: formless grains, incipient alteration to sericite (or talc?), local faint and indistinct lamellar twinning, index of refraction very close to 1.54, (−) 2*V* about 60°. These properties fit cordierite.

Observed: This is a thermally metamorphosed potassium- and magnesium-rich sedimentary rock. Metamorphic grade is intermediate (no specific guides to temperature range here) and appears to be compatible with the conditions that produced P58 and TS–B.

OTHER PROSPECTS

Sample J36 (Huai Muang manganese prospect):

Megascopic: Fragments of buff-colored quartzite cemented into a breccia by black dull conchoidally fracturing metallic mineral, not magnetite; appearance suggests manganese oxide.

Microscopic: Fragments are quartzite; metallic mineral reflects black.

Sample J50 (Khum Thong copper prospect):

Megascopic: Fine-grained homogeneous mesocratic rock, about 1:1 plagioclase and pyroxene in well-developed diabasic texture; scattered patches of pyrite and possibly chalcopyrite.

Microscopic: Plagioclase and augitic pyroxene in well-developed subophitic texture. Persistent green low birefringent chlorite and epidote, indicating greenschist facies metamorphism. Evenly distributed, skeletal or graphic semiopaque crystals; no pyrite and chalcopyrite seen in hand specimen.

Observed: Rock is a diabase or fine-grained gabbro.

Sample J5 (Phu Lek (Chiengkarn) iron deposit):

Megascopic: Dense silicified-appearing rock, gray with green mottling, irregular aggregates of green prismatic hornblende.

Microscopic: Intergrowth of dirty potassium feldspar(?) and green hornblende, latter with some cores of colorless clinopyroxene. Texture for the most part hypidiomorphic. Patches of calcite and large irregular grains of sphene. No obvious evidence of silicification or other metasomatic replacement or metamorphism.

Observed: Rock could be called a syenite (hornblende syenite); it is unique in the collection submitted.

Sample J65 (Phu Kaeo Yai iron prospect):

Megascopic: Pink fine-grained rock consisting dominantly of potassium feldspar, with evenly distributed quartz in a subgraphic texture, few larger plagioclase phenocrysts.

Microscopic: Graphic texture; rock is clearly the product of eutectic crystallization. Potassium feldspar is very cloudy but shows no other breakdown or alteration. Small amount of albitic plagioclase.

Observed: Rock is an aplite or micrograniite, the product of end-stage crystallization, and apparently unaffected by metamorphism.

Sample J198 (Phu Khok-Phu Khum Thong iron prospect):

Megascopic: Brown, rusty rock consisting dominantly of pale-brown garnet.

Microscopic: The garnet has a distinctive birefringence, estimated 0.005, supposedly restricted to andradite garnet series. Index of refraction close to 1.83, suggesting composition of An_{60}, Gr40. Associated minerals are quartz and black-reflecting opaque mineral, very slightly magnetic, possibly magnetite.

Observed: Apparently a contact-metamorphic rock.

Sample J75A (Phu Lek (Ban Mak Bit) iron prospect):

Megascopic: Cluster of oxidized garnet, some distinct dodecahedral crystals, extensively limonitized.

Microscopic: Light-pinkish-brown isotropic garnet oxidized along fracture. Index of refraction of garnet determined as 1.78–1.88; this almost certainly makes it a grossular-andradite, close to the andradite end (about 90 percent An if no other components are assumed).

Observed: Garnet of this composition suggests a skarn derived by contact metamorphism from an impure limestone, probably with some addition of iron.

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