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Lead-zinc mineralization at Theingon Mine, Bawsaing, Southern Shan State, Burma: A Mississippi Valley-type deposit?

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ABSTRACT: The Theingon Pb-Zn deposit is located near Bawsaing, Southern Shan State, Burma. The Theingon deposit is comparable to the principal Mississippi-Valley-type deposits of Heyl *et al.*, (1974) in many respects such as host rock stratigraphy, structural setting of the orebody, mineralogy and ore metal zonation. The Theingon Pb-Zn mineralization occurs within the carbonate rocks of the Wunbye Formation (Lower to Middle Ordovician). The orebody is localised in a clay-filled solution channel along a limb of an east dipping small overturned anticline. The ore assemblages are essentially of galena with minor amounts of sphalerite, tetrahedrite-tennantite, digenite, chalcopyrite, covellite, argentite and pyrite. Following the crude mineralogical zonation in the Theingon Mine, quantitative picture of the ore elements (Pb Zn and Cu) contents in the carbonate host rocks within the orebody exhibited a broad, but distinct overlapping vertical zonation, the copper (more than 100 ppm) being commonly concentrated at the lower part of the orebody while zinc (more than 1000 ppm) and lead (more than 2000 ppm) restricted to the upper part of the orebody.

Present geologic, mineralogic and geochemical evidences combined with accumulation of ore minerals embedded in a yellow clay-filled channel in the carbonate rocks lend support to the conclusion that the Theingon Pb-Zn mineralisation is epigenetic in origin and can be explained by the combination of magmatic-and meteoric hydrothermal circulation (White, 1974).

Ore metals contents in the carbonate host rocks in the Theingon-Mine are found generally and progressively increased towards the mineralised zones. This ore elements variation suggests, though does not prove, that the ore constituents have been leached by ground water circulated relatively deep into the adjacent Sedimentary Paleozoic beds. Further isotopic studies are needed to ascertain the source and sources of ore metals and fluids.

INTRODUCTION

The Theingon Pb-Zn deposit is located at North Latitude 20° 57′ and East Longitude 96° 48′, about 2.4 kilometers SE of Bawsaing, north of Heho, in the Southern Shan State, Burma (Fig. 1). The mine area is characterised by karst topography with simple and compound sinks, and rounded to elongated hills with general elevations of 1350 meters.

History and production

The Theingon Mine area has long been a source of silver-bearing ore in Burma. Ancient Mining activities which date back to the 14th Century or earlier are indicated by numerous pits, extensive mine workings, and many lead slag piles. During 1920–30, Steel Brothers Limited was reported to have several exploration programmes in the

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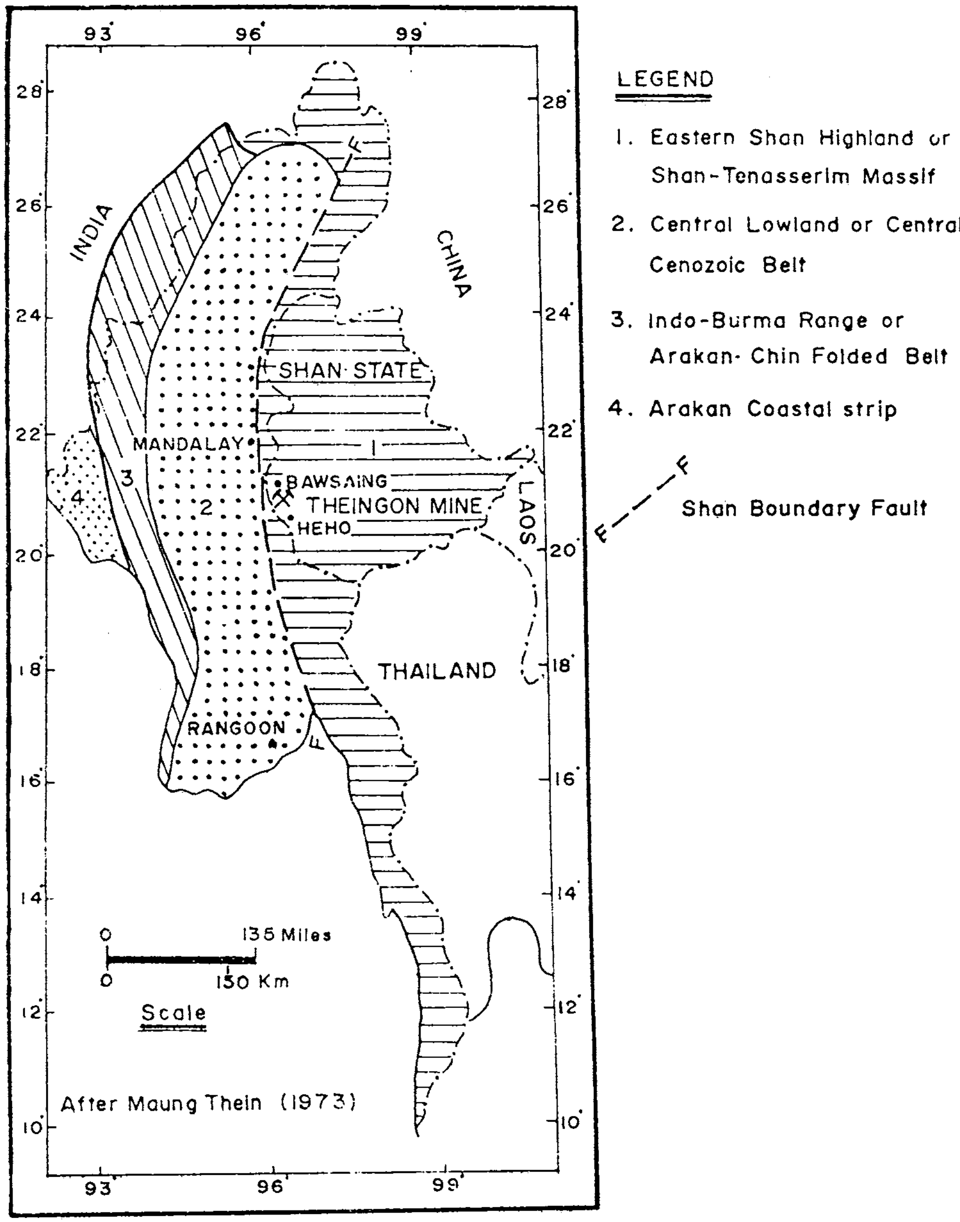

Fig. 1. Location map of the Theingon Mine, Bawsaing, Southern Shan State, Burma.

area. In 1928, development of the Theingon Mine began and lead ore was produced sporadically thereafter. During World War II Japanese occupied the mine and probably extracted ore from it. From 1947 to 1965 a local miner worked the upper part of the Theingon orebody and peak production apparently was achieved in 1951. In 1965, mining activity came under the direction of DGSE (Directorate of Geological Survey and Exploration), formerly called Mineral Development Corporation. In 1969, the mine was nationalised and controlled by No. 1 Mining Corporation. Annual production of the Theingon Mine in 1970 was 600 tons of lead concentrates averaging 60% Pb. Brown (1930) estimated the ore reserves of the Theingon Mine to be 185,400 tons averaging more than 7% lead.

Previous investigations

The Theingon Mine area was extensively studied by Fedden (1864), Jones (1837), Middlemiss (1900), Clegg (1926), Rundall (1927), Brown (1930), Brown and Sondhi (1933), and Soe Win (1967). A systematic study of regional geology and Pb-Zn deposits of the Theingon Mine area was made by Myint Lwin Thein *et al.* (1972) and Myint Lwin Thein (1973 and 1979). Geologic studies and exploration activities in the vicinity of the Theingon Mine area by postgraduate students in the Applied Geology Department, Arts and Science University, Rangoon were recently reported by Nackowski, Khin Zaw, and Aung Myint Thein (1977). Detailed geological mapping of selected Pb-Zn prospects in the Bawsaing area was also conducted by postgraduate students (Myint Lwin, 1975; Tin Lin, 1975; Zaw Minn *et al.*,; 1977). Most recently, Goossens (1978) in his contribution on the metallogeny of Burma, reported on the general characteristics of Pb-Zn and Ba mineralization in Southern Shan State, including the Theingon deposit.

REGIONAL GEOLOGY

Burma is broadly divided into four north-south trending composite physiographic and tectonic belts (Fig. 1). These are, from east to west, the Eastern Shan Highlands or Shan-Tenasserim Massif, The Central Lowlands or Central Cenozoic Belt, the Indo-Burma Range or Arakan-Chin Folded Belt, and the Arakan Coastal Strip. The Theingon Mine area is in the western part of the Shan Highlands which is separated from the Central Lowlands by the Shan Boundary Fault system (Fig. 1).

Stratigraphy

The generalised stratigraphy in the vicinity of the Theingon Mine is shown in table 1. The following brief summary of lithologic descriptions are based on the authors' own field examinations and on the more complete studies of Myint Lwin Thein *et al.* (1972) and Mying Lwin Thein (1973 and 1979). The regional geology of the Theingon Mine is shown in Fig. 2.

The oldest unit in the Theingon Mine area is the Hsinmango Formation (Molohein Group) of Upper Cambrian age which is exposed in the Hethin Taung, two kilometers north of Heho, where it forms a faulted anticline bordered by Ordovician Siltstones. The Hsinmango Formation is a slightly metamorphosed sedimentary sequence mainly of micaceous sandstones, reddish feldspathic sandstone and grits.

TABLE 1

GENERALISED STRATIGRAPHIC COLUMN IN THE VICINITY OF THE THEINGON MINE, BAWSAING, SOUTHERN SHAN STATE, BURMA.
(modified after Myint Lwin Thein *et al.*, 1972; Myint Lwin Thein 1973; 1979)

Stratigraphic Units	Lithology	Age
Alluvium and lacustrine deposits	insoluble, residual terra rossa soil and alluviated valleys	Quarternary to Recent
Unconformity	--------------------	
Plateau Limestone Group	highly brecciated dolomites, dolomitic limestones, cherty limestones and micritic limestones.	Upper Carboniferous to Triassic
Unconformity	--------------------	
Lime Formation (Mibayataung Group)	phacoidally-textured limestones, mudstones and graptolitic shales	Lower Silurian
Nan-on Formation (Pindaya Group)	yellow siltstones, mudstones and argillaceous limestones	Upper Ordovician
Wunbye Formation (Pindaya Group)	limestones, dolomitized limestones, siltstones and dolomites	Lower to Middle Ordovician
Lokepyin Formation (Pindaya Group)	essentially of siltstones with minor mudstones and buff to greenish marls	Lower to Middle Ordovician
Hsinmango Formation (Molohein Group)	dominantly of micaceous sandstones with minor grits, limestones and dolomites.	Upper Cambrian

These Upper Cambrian rock are conformably overlain by the Lokepyin and Wunbye Formations (Lower to Middle Ordovician), and Nan-on Formation (Upper Ordovician) all of the Pindaya Group. The Lokepyin Formation is dominantly composed of siltstones with minor mudstones and buff to greenish marl.

The Wunbye Formation conformably overlies the Lokepyin Formation and is the main ore host in the district. All known exploitable Pb-Zn mineralization in the Theingon Mine area occurs within the Wunbye Formation, which forms more than 50 percent of the outcrops in the district and consists principally of limestone, dolomitized limestones, and dolomites, all containing minor amounts of siltstones. The limestones are thick-bedded, exhibit burrow and pelletal structures, and are styolitic. Limestones comprise more than half of the Wunbye Formation and are commonly interbedded with dolomites and siltstones. The dolomites are thick-bedded to massive, finely crystalline, usually oolitic or sub-oolitic,, and strongly jointed. The siltstones are commonly micaceous, locally marly, medium to thick-bedded, and subindurated. Petrologic characteristics of the Wunbye Formatin are described later in this paper.

The Nan-on Formation (Upper Ordovician) comformably overlies the Wunbye Formation and is composed largely of buff-yellow siltstones, light-grey mudstones,

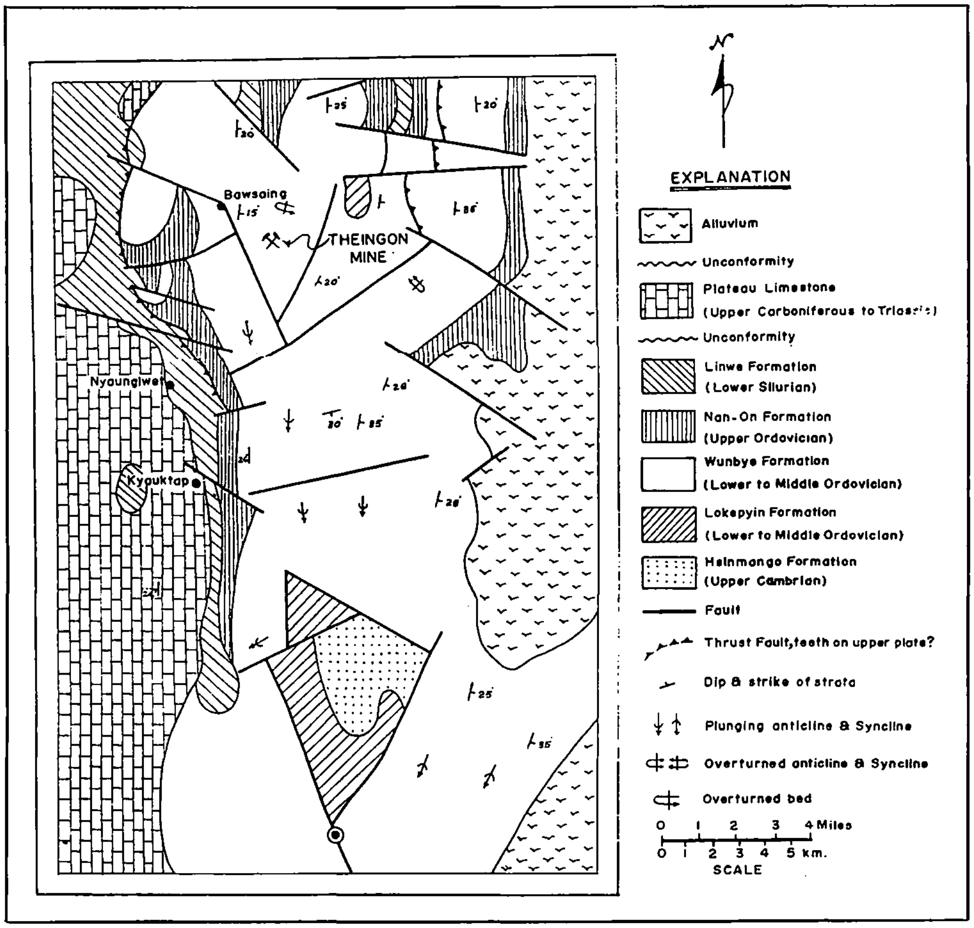

Fig. 2. Regional geologic setting of the Theingon Mine area, Bawsaing, Southern Shan State, Burma (After M.L. Thein, 1979)

and argillaceous limestones.The Nan-on Formation is conformably overlain by the Linwe Formation (Lower Silurian) of the Minbayataung Group, which includes sequences of phacoidally textured limestones, calcareous mudstones, and graptolitic shales.

The youngest unit exposed in the Theingon Mine area is a thick carbonate sequence of the Plateau Limestone Group (Carboniferous to Triassic), which rests unconformably on the Silurian rocks. The Plateau Limestone Group shows extreme lithologic variation from massive, micritic, and cherty limestones, to thick-bedded dolomitic limestones and highly brecciated dolomites.

Structure

The Theingon Mine lies in the Bawsaing-Hethin Mountain range, a north-south trending anticlinorium. Repeated overturned folds accompanied by thrusting are common. Folds trend approximately N-S and are overturned either to the east or west. Most of the overturned folds plunge southward, but north-plunging folds occur locally. Faults in the Theingon Mine area include thrusts and steep-dipping normal, reverse or transcurrent faults. Thrust faults trend N-S and dip east or west. Steeply dipping, high angle faults in the mine area include conjugate sets trending NE-SW and NW-SE, and a presumably related extensional set trending E-W. Detailed discussion of the structural evolution of the area was presented by Myint Lwin Thein *et al.*, (1972).

MINE GEOLOGY

Stratigraphy

Major lithologies exposed in the mine area are limestones, dolomitized limestones, dolomites, and siltstones of the Wunbye Formation (Lower to middle Ordovician age). Lead-Zinc mineralization is almost exclusively confined to the carbonate rocks of the Wunbye Formation. Myint Lwin Thein *et al.*, (1972) used underground exposures in the Theingon Mine to divide these carbonates and silstones into several sub-units.

Myint Lwin (1975), recently conducted detailed outcrop mapping at a scale of 1:4000 in the mine area. As shown in Fig. 3, the major lithologies, listed in random order, are burrowed limestones, bedded limestones, siltstones, dolomitized limestones, and dolomites of the Wunbye Formation.

Burrowed limestones (unit BrL) are grey to bluish grey, massive, compact, and finely crystalline, with pink, buff, or yellow-coloured silty materials. Bedded limestones (unit BL) are thin to thick-bedded with regularly interstratified siltstones. Siltstones (unit Si) are commonly micaceous, locally calcareous, medium to thick-bedded, yellow to light grey, and soft to indurated.

Dolomitized limestones (unit DL) and dolomites (unit D) are well-exposed in the vicinity of the mine. They are medium-grained, commonly oolitic, highly jointed in criss-cross patterns, and buff to blue grey in color. The oolites are sub-rounded to elongated, 1 to 0.5 mm long and commonly dolomitic.

Structure

The structural setting of the Theingon orebody was described by Brown (1930), Soe Win (1967), and Myint Lwin Thein *et al.*, (1972). The mine is on the eastern limb of an overturned south-plunging anticline, which represents one of the of many small folds of the Bawsaing-Hethin anticlinorium. The orebody occupies a wide irregular fissure-controlled solution channel that trends N 20° W oblique to the strike of the enclosing rocks, which trend northeasterly and dip 30°–60° SE. The mineralised zone trends N-S, pitches 18°–25° to the south, and dips almost vertically.

Description of the orebody

The orebody was encountered in both the Bawsaing and the Theingon shafts (see

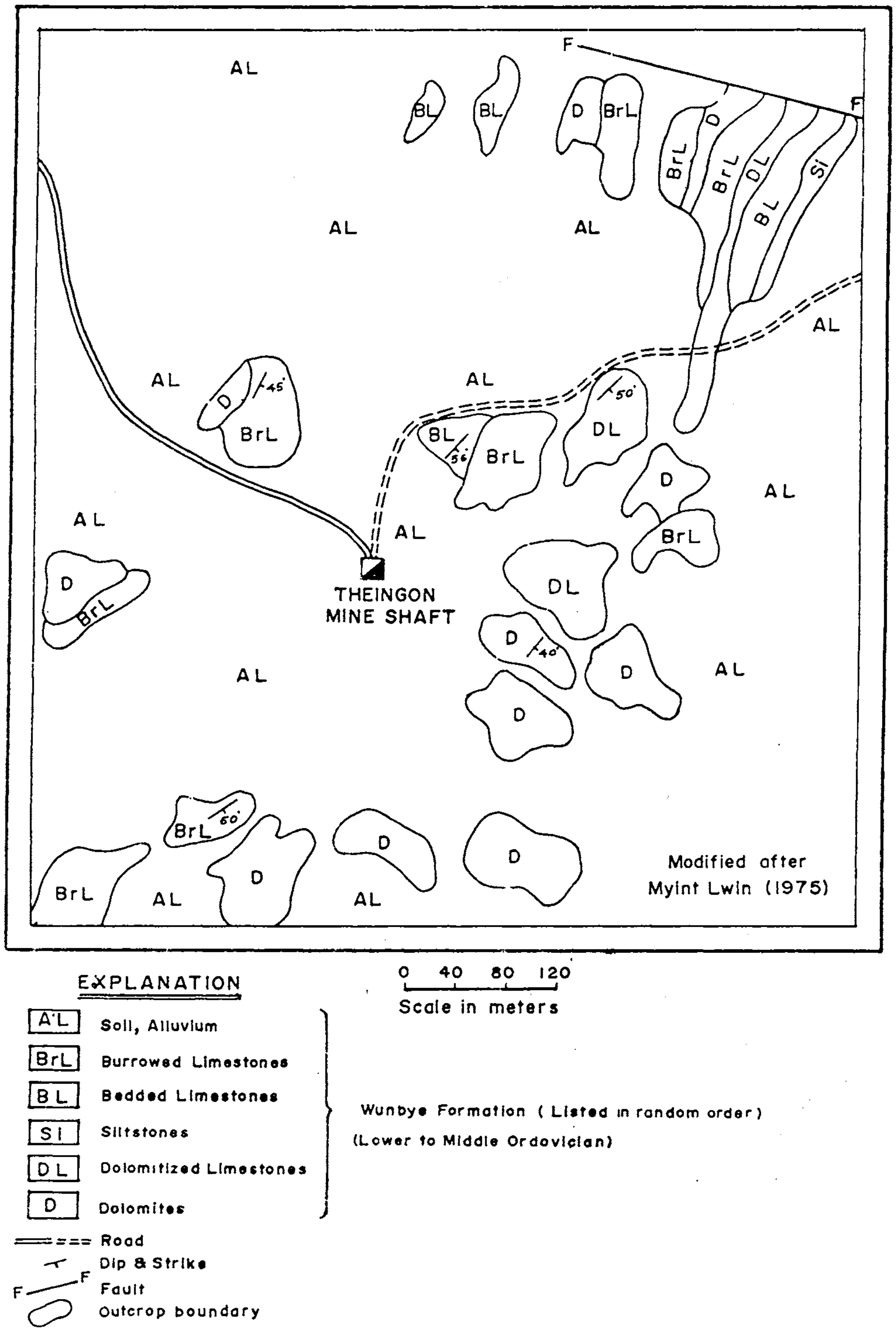

Fig. 3. Outcrop Geologic Map of the Theingon Mine, Bawsaing, Southern Shan State.

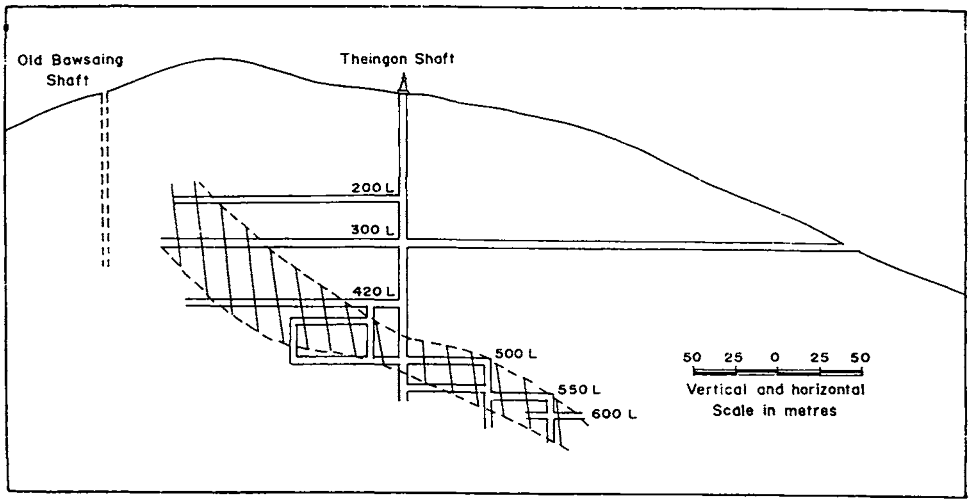

Fig. 4. Longitudional section (looking east) of the Theingon orebody, Bawsaing, Southern Shan State, Burma. Dashed line indicates outline of the ore zone.

Fig. 4). The orebody varies from 15 to 61 meters in thickness, has a maximum width of 21 meters, and a length that exceeds 305 meters and is still open to the south.

Five main levels have been developed in the Theingon Mine, the 200, 300, 400–420–450, 500–550, and the 600. Active workings are in the eastern part of the mine on the 420–450 levels. The ore zone is in a solution channel filled with yellow, soft and plastic clay in which galena is irregularly distributed, occuring as disseminations, stringers, nodules, or blocks embedded in the silty and sandy clay matrix.

FIELD AND LABORATORY METHODS

Representative underground and surface rock samples were collected in the Theingon Mine area for petrographic and geochemical study. Underground rock sampling was conducted with an average sample interval of 10–15 meters. Ninety samples were collected underground, including 14 from the 200 level, 16 from the 300 level, 23 from the 420 level, 9 from the 450 level, 13 from 500 level, 7 from the 550 level, and 8 from the 570 level. Fifty-five samples were also collected from surface exposures at and from within several kilometers of the mine site, including all major lithologic units in the area. Many of the samples used in this study were collected by U Khin Zaw and U Thet Aung Zan during the summer 1977.

Forty-five thin sections were made for petrographic study. Calcite and dolomite were distinguished by staining with Alizarin Red (Friedman, 1959; Dickson, 1965). Underground rock samples were analysed for lead, zinc, and copper using a Varien Tectron atomic absorption spectrophoto-meter Model M-1000. The hot aqua regia extraction method of Foster (1971) was used to obtain complete digestion.

HOST ROCK PETROGRAPHY AND PETROLOGY

Petrographic studies emphasizing the textural features of essential and some accessory minerals were conducted on the carbonate host rocks to investigate their depositional environment and its relationship to the localization of ore minerals.

Calcite is the most abundant mineral in the carbonate host rocks and occurs as: (1) microcrystalline (micritic) matrix, (2) clear sparry crystals and (3) secondary calcite. Microcrystalline calcite is interstitial to the coarser, euhedral calcite crystals which typically display polysynthetic twinning and distinct rhombohedral cleavage.

Dolomite is the second most abundant mineral. It occurs as (1) euhedral crystals and (2) microcrystalline dolomite matrix. Large dolomite crystals have sharp boundaries and euhedral form. Some contain darker micritic interiors, which may represent relic crystallized turbid calcites. Polysynthetic twins cross cut the short diagonal of the dolomite rhombs.

Zoning of iron (Fe^{++}) is common in dolomite crystals, with zone boundaries presumably parallel to (1011) rhombohedral crystal faces. Zoning has occurred where the growing dolomited crystals have progressively encroached on adjacent patches of iron oxides. Resultant roughly spherulitic aggregates of dolomite crystals give the rock a macroscopic, oolitic appearance (Fig. 5). Similar ferroan dolomites are reported in shallow-marine carbonate rocks of the Illinois Basin (Choquette, 1971).

Quartz is the third most abundant mineral after calcite and dolomite. It is predominantly of detrital origin and sporadically occurs interstitial to calcite and dolomite. Quartz grains also form as a vein filling along brecciated cracks. Overgrowths of quartz on calcite and dolomite was seen in some samples. Quartz grains are 0.02 mm in diameter and are well rounded.

Flakes of white mica occur as calcite grains intimately associated with quartz, and are commonly interstitial to the carbonate minerals (Fig. 6).

Opaque minerals commonly occur as accessory minerals disseminated in the carbonate rocks. Goossens (1978) reported microscopic galena disseminated in carbonate rocks in the Theingon Mine area.

Depositional environment

Deposition of the carbonate rocks exposed near the Theingon occurred in agitated, warm, shallow-seas as indicated by the presence of oolitic textures, and "Orthis Brachiopods". Association of limestones and dolomites with detrital quartz and mica also reflects the nonuniformity of the depositional environment.

The presence of interbedded thin siltstone in the Theingon carbonate rocks suggests at least local transgression and regression of the marine environment.

Dolomitization and mineralization

Dolomitic limestone and dolomites in the Theingon Mine area seem to be largely

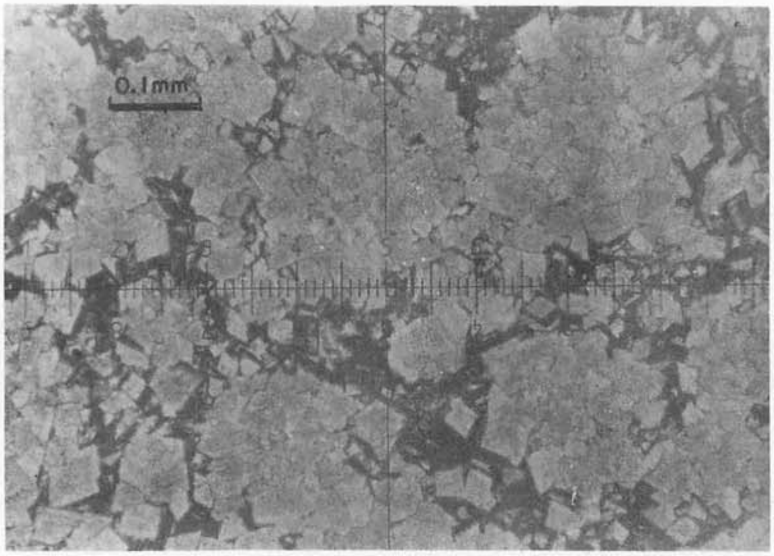

Fig. 5. Photomicrograph showing concentric, oolitic growth textures; note iron-stained zoned boundaries indicating direction of growth of dolomite crystals during progressive infilling of voids; plane-polarised transmitted light; Location, 570 level; sample no. 570–6.

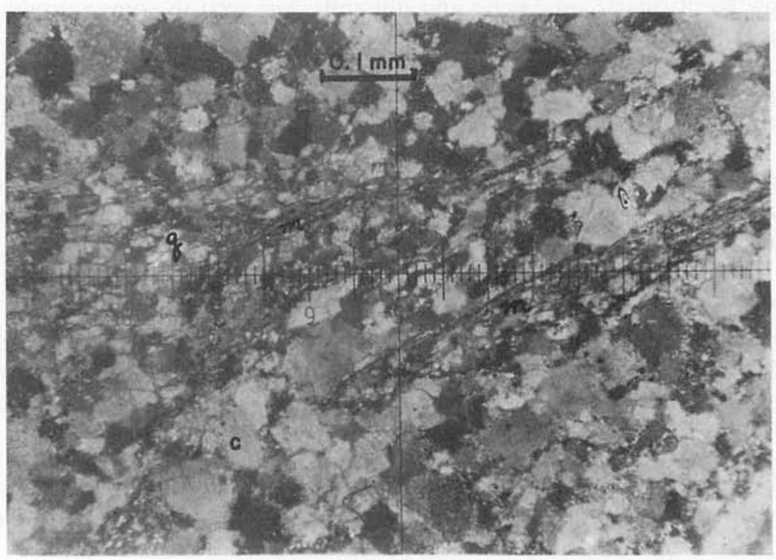

Fig. 6. Photomicrograph showing clastic grains of white mica (m) and quartz (q) intimately associated with carbonates (c); X-nicols, plane-polarised transmitted light; Location, 200 level; sample no. 200–5.

of diagenetic origin as suggested by (1) their heterogeneous texture and relatively large variation in grain size, (2) presence of dolomite rhombs with cloudy centers and clear rims, (3) presence of detrital quartz, and (4) occurrence of incompletely dolomitized fossil fragments. Dolomitization of limestone can result in increased porosity, provided that a solid framework remains to minimize the effect of subsequent compaction (Chilingar *et al.*, 1967, p., 288). Chilingar and Terry (1954) demonstrated that replacement of calcite by dolomite causes a 12 to 13 percent increase in porosity as a result of the reaction:

$$2CaCO_3 + Mg^{2+} \rightleftarrows CaMg\,(CO_3)_2 + Ca^{2+}$$

Porosity formed during dolomitization is common in the carbonate rocks of the Theingon Mine area. Ooliths are composed of dolomitized calcite grains, and sulfide mineralization commonly occurs in the oolitic dolomitized limestones presumably because of the increased porosity that accompanied dolomitization. Consequently, ore-bearing fluids may have gained entrance to, and migrated through, the porous dolomitized carbonate rocks to deposit ore in the more favourable fissure-type solution channel. Thus, sulfide mineralization at the Theingon Mine post-dated dolomitization.

ORE MINERALOGY

The ore mineralogy of the Theingon Mine is simple and in part comparable to that of Mississippi Valley-type Pb-Zn deposits. The principal ore mineral is galena, but minor amounts of sphalerite, tetrahedrite-tennantite, chalcopyrite, digenite, covellite, pyrite, and argentite are present. Although barite is associated with galena in mineral showings near the TheingonMine, none is reported in association with the Theingon ores. Fluorite is conspicuously absent. The gangue minerals are mainly calcite and quartz. Conformable relations between ore and host rock were not observed either on megascopic or microscopic scales. No recrystallization nor remobilization was seen in the Theingon ores. Several ore samples were taken from each level of the mine and were studied under an ore microscope.

Galena forms irregular patches to massive aggregates. Galena crystals are characterized by high reflectivity, numerous triangular pits, and light gray colour (Fig. 7). In some samples, galena is smeared along fractures and interstices of gangue minerals, indicating that the ore zone was subjected to at least minor post-mineralization movement. In some samples, galena is rimmed by clusters of tiny cerussite crystals giving a net texture (Fig. 8), and indicating that galena has undergone some post-ore oxidation.

Sphalerite forms rounded, isolated grains up to 1 mm in diameter (Fig. 7). No zoning or twinning is visible. Sphalerite is grayish white to medium gray under the ore microscope suggesting moderate variation, between crystals, of Fe concentration in solid solution.

Age relations between galena and sphalerite are unclear. Galena is locally found in fractures in the ore zone, whereas, similar occurrences of sphalerite are rare. Sphalerite

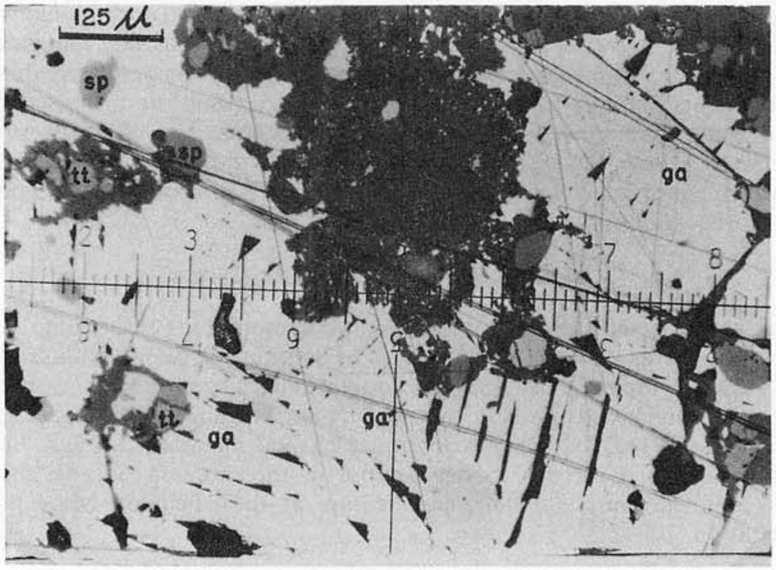

Fig. 7. Photomicrograph showing galena (ga) with triangular pits, and showing associated sphalerite (sp), tetrahedrite-tennatite (tt) and gangue (unlettered). Plane-polarised reflected light; location, 420 level; sample no. 420–3.

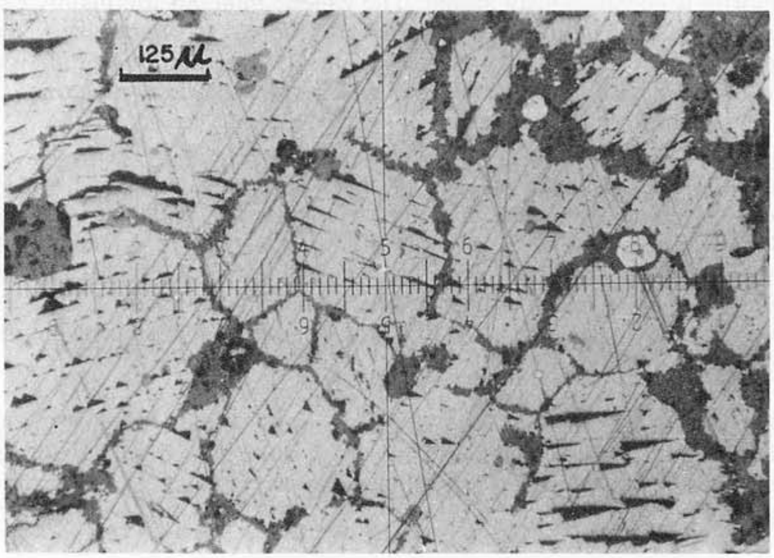

Fig. 8. Photomicrograph showing galena altered to cerussite along grain boundaries to give a net texture. Plane-polarised reflected light; location, 420 level; sample no. 420–5.

locally rims galena and is therefore younger than the galena. Studies of ore samples collected along different levels in the Theingon Mine demonstrate that galena and sphalerite are more abundant in the upper portion of the ore zone.

Tetrahedrite-tennantite is a widespread but minor constituent of the ore, and is commonly intergrowth with sphalerite. It has a distinct olive-yellow tint, moderate reflectivity, and internatl reflection (Fig. 7).

Tetrahedrite-tennantite is found as randomly distributed, equidimentional, rounded crystals up to 1 mm in diameter. Presence of smooth regular contacts between sphalerite and tetrahedrite-tennantite are interpreted to indicate simultaneous crystallization.

Digenite is a minor constituent occurring as subhedral grains up to 1 mm in diameter (Fig. 9). Most are grayish blue in colour, isotropic, and have relatively low reflectivity. Digenite was identified only in samples collected from the lower levels of the Theingon Mine.

Chalcopyrite is present in small amounts in many of the ore samples. Crystals of chalcopyrite average 0.5 mm in diameter and are intimately associated with galena, sphalerite, and gangue. No exsolution textures involving sphalerite and chalcopyrite were observed. Sharp embayed boundaries suggest that chalcopyrite replaced sphalerite and galena.

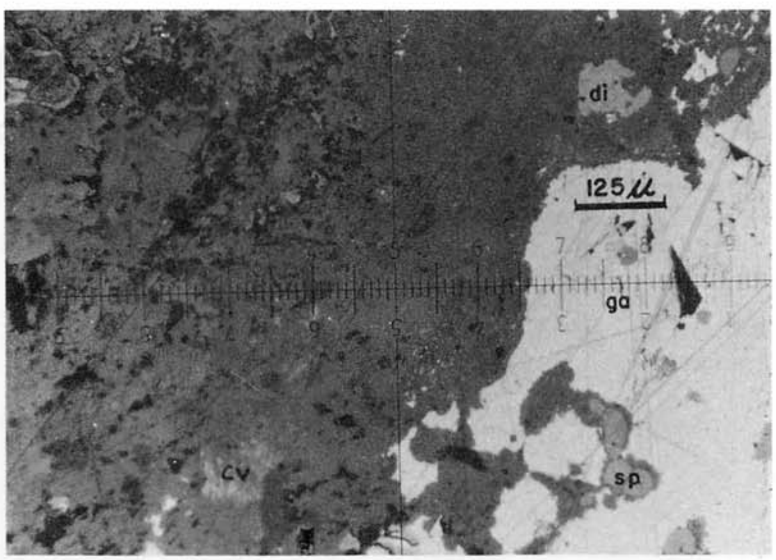

Fig. 9. Photomicrograph showing greyish blue, subhedral grain of digenite (di) at the upper right corner, and thin lammellar grains of covellite (cv) at the lower left corner, associated with galena (ga), sphalerite (sp) and gangue (unlettered); plane-polarised reflected light; location, 570 level; sample no. 570–10.

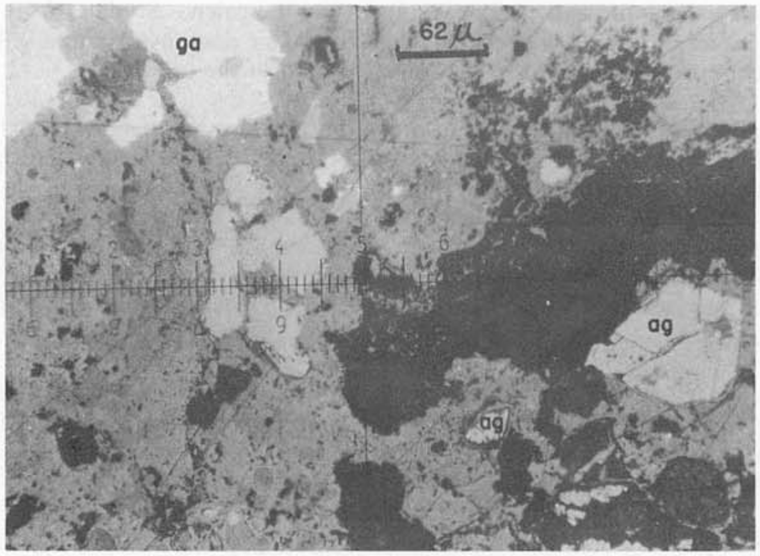

Fig. 10. Photomicrograph showing subhedral crystals of argentite (ag) at the right centre, associated with galena (ga) and gangue (unlettered). Plane-polarised reflected light; location, 450 level, sample no. 450–3.

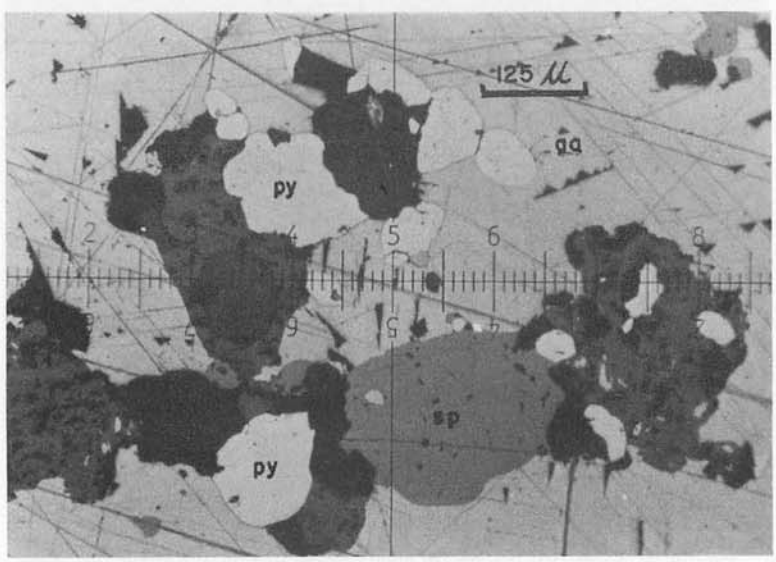

Fig. 11. Photomicrograph showing rounded to elliptical pyrite (py) associated with galena (ga), sphalerite (sp) and gangue (unlettered). Tiny pyrite grain enclosed in sphalerite at upper centre. Plane-polarised reflected light; location, 450 level; sample no. 450–7.

Covellite occurs as rare, isolated blue patches in some polished sections. It has a distinct deep blue colour with a pale violet tone and strong bireflectance. Some patches are composed of thin laminae (Fig. 9). Covellite is almost entirely restricted to the lower part of the ore zone. Argentite occurs as irregular anhedral crystals up to 0.5 mm long (Fig. 10) and sometimes it was found in oxidized galena. No exsolution or zoning was observed in these crystals.

Pyrite forms rounded to elliptical crystals up 3 mm long. Some tiny, isolated crystals are found as inclusion in sphalerite (Fig. 11). Pyrite locally occurs in spheroidal aggregates but without concentric zoning.

DISTRIBUTION OF LEAD, ZINC AND COPPER

Geochemical analyses were made of samples collected on several levels of the Theingon Mine in order to investigate the distribution of lead, zinc, and copper in the carbonate host rocks and within the Theingon orebody.

Distribution of these ore metals in the Theingon Mine has been studied by Thet Aung Zan (1977).

Variations of lead, zinc, and copper contents with proximity to the ore zone along the 200, 300 and 500 levels are illustrated in Figs. 12 to 14 respectively. In general, lead and zinc contents of the carbonate host rocks tend to increase with increasing proximity to the ore zones on the 300 and 500 levels. However, copper values are highly erratic, although the concentration of copper in the carbonate rocks seems to increase somewhat toward the ore zone on the 300 and 500 levels.

During the microscopic examination of ore samples from different levels of the Theingon Mine, it became apparent that copper minerals (covellite, digenite, and chalcopyrite) are more common in the deeper levels, whereas lead and zinc minerals (galena and sphalerite) are more concentrated in the upper portions of the orebody. Geochemical studies also reveal that the distributions of copper, lead and zinc generally conform with this mineralogical zonation. In order to evaluate the possibility of extentions of the Theingon orebody at depth (Aung Pwa, 1979), and to obtain a quantitative picture of suspected metal zonation, lead, zinc, and copper contents of underground samples were plotted and contoured on the cross section of the Theingon Mine (Figs. 15 to 18). Contouring on Figure 18 reveals that significant concentrations of all three metals occur within broad, but distinct overlapping vertical zones. Copper is commonly concentrated in the lower parts of the Theingon orebody, mainly below the 420 level. Overlapping and extending above these areas of copper mineralization are zones of zinc and lead mineralization.

GENESIS OF THE THEINGON OREBODY

With respect to host rock stratigraphy, structural setting of the orebody, and mineralogy, there are similarities between the principal Mississippi Valley-type deposits of Heyl *et al.*, (1974) and the Theingon deposit (Table 2). Data presented by Heyl *et al.*, (1966), Hall and Heyl (1968) suggest that weakly developed lateral zoning

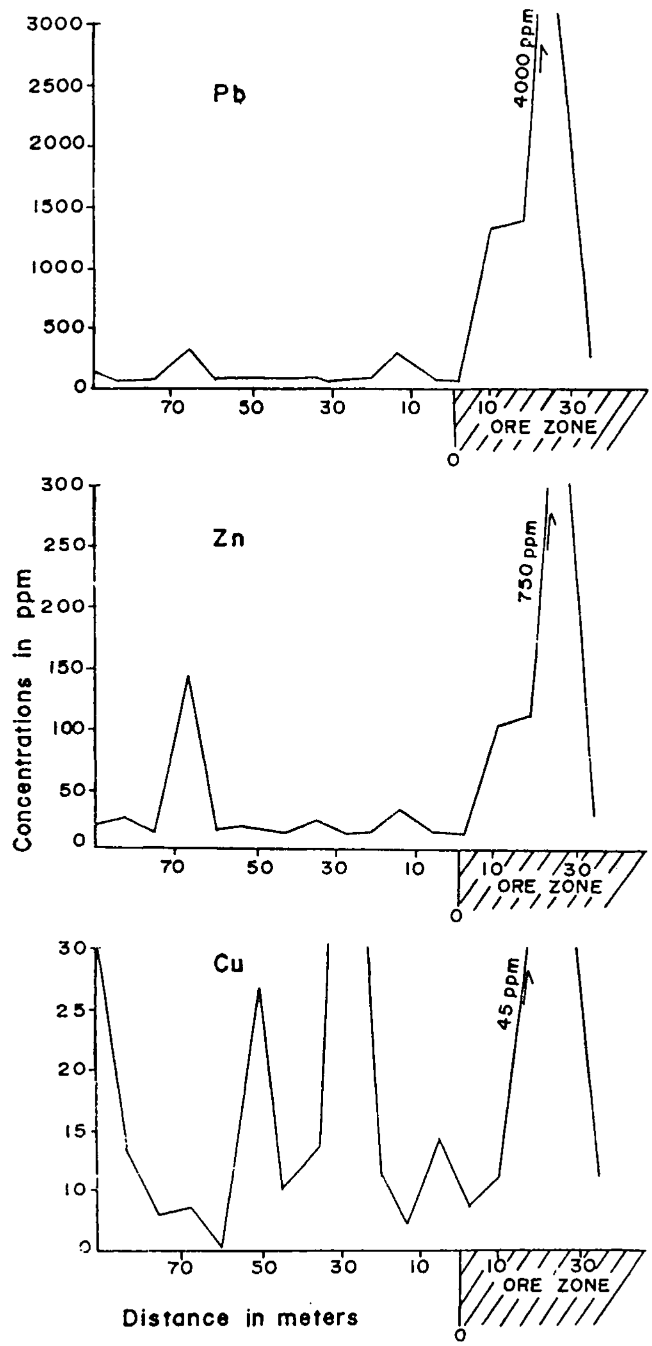

Fig. 12. Graphs showing distribution of Pb, Zn and Cu with distance from the ore zone on the 200 level, Theingon Mine.

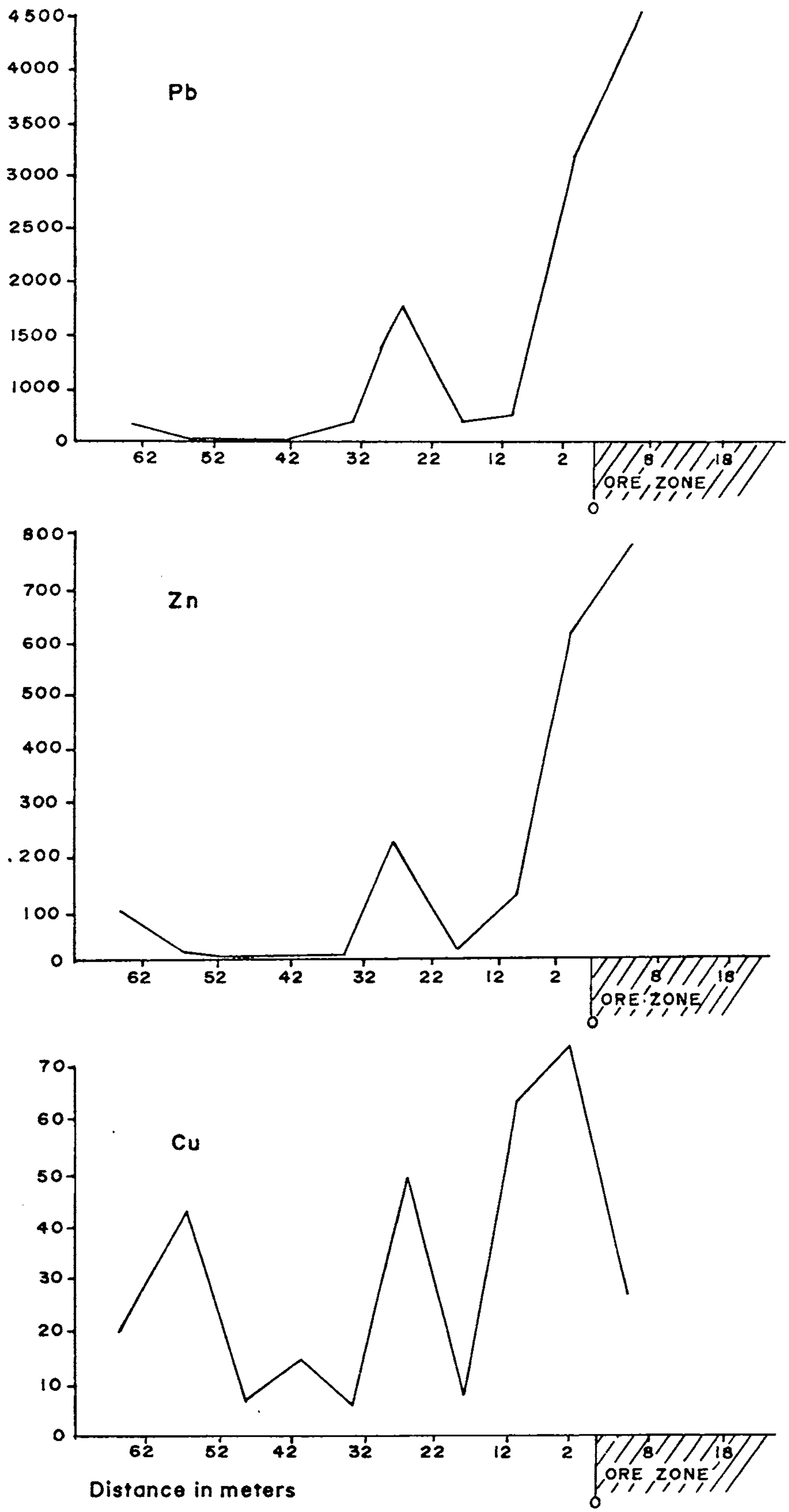

Fig. 13. Graph showing distribution of Pb, Zn and Cu with distance from the ore zone on the 300 level, Theingon Mine.

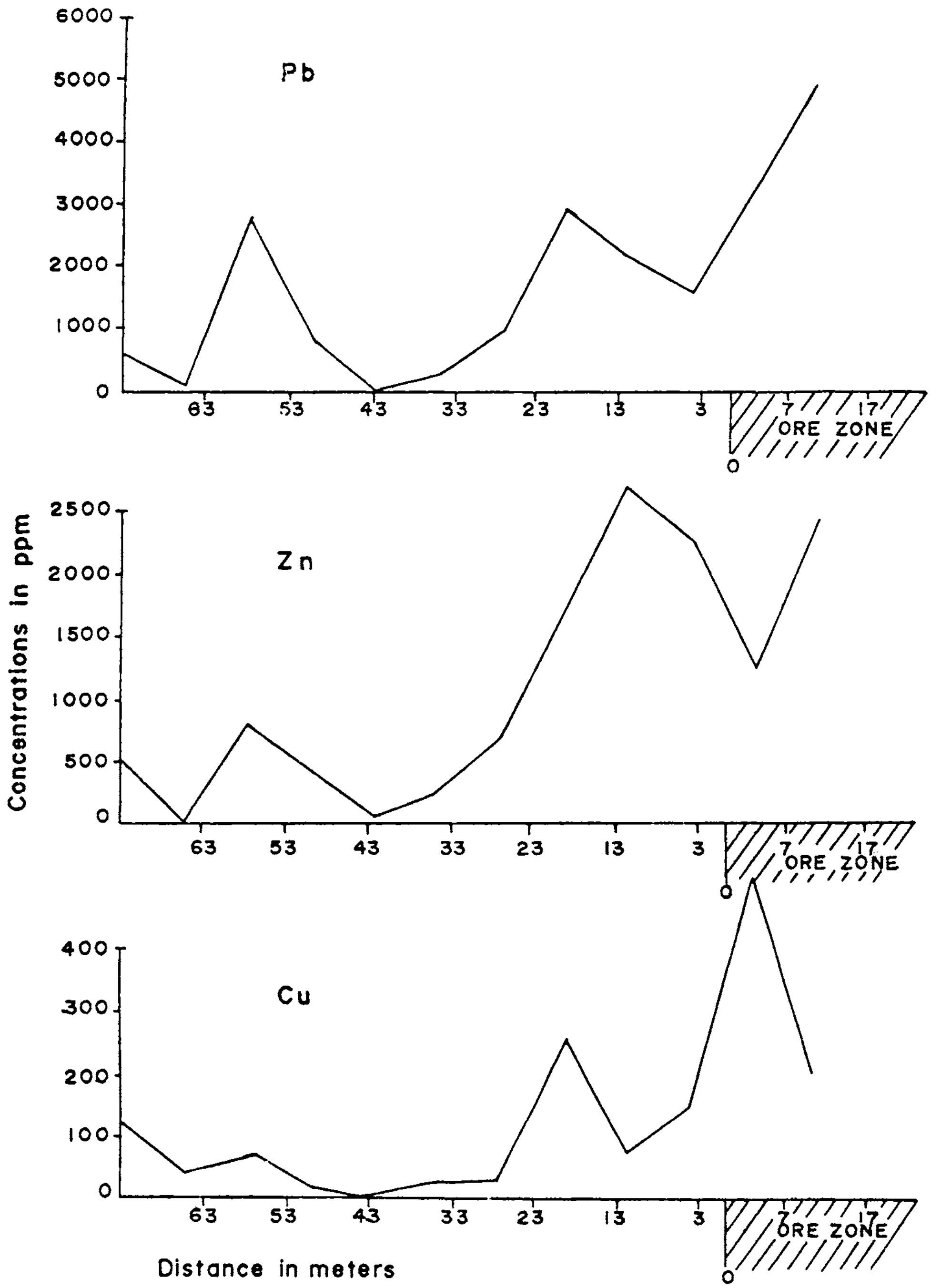

Fig. 14. Graphs showing distribution of Pb, Zn and Cu with distance from the ore zone on the 500 level, Theingon Mine.

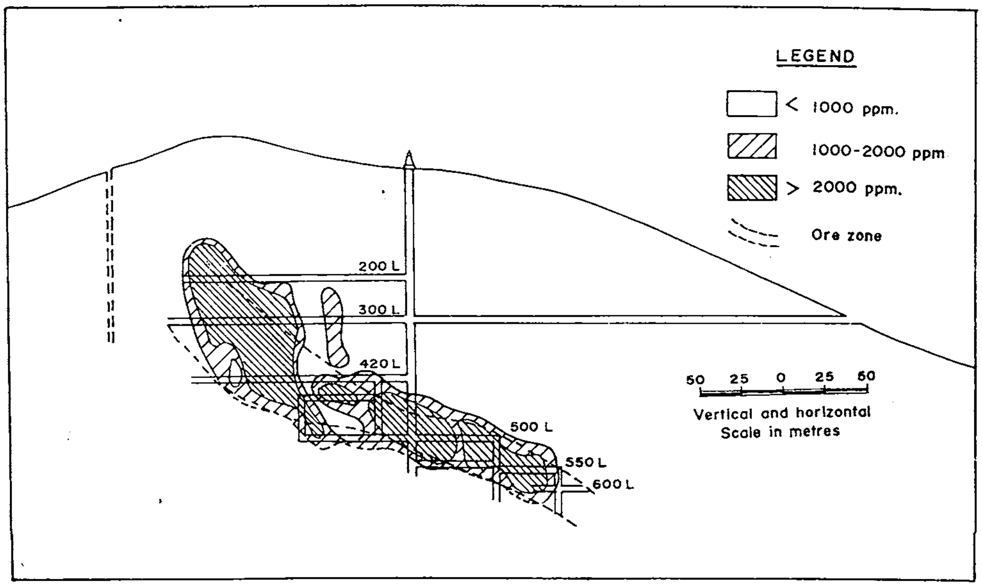

Fig. 15. Longitudinal section (looking east) showing distribution of lead in the Theingon orebody, Bawsaing, Southern Shan State, Burma.

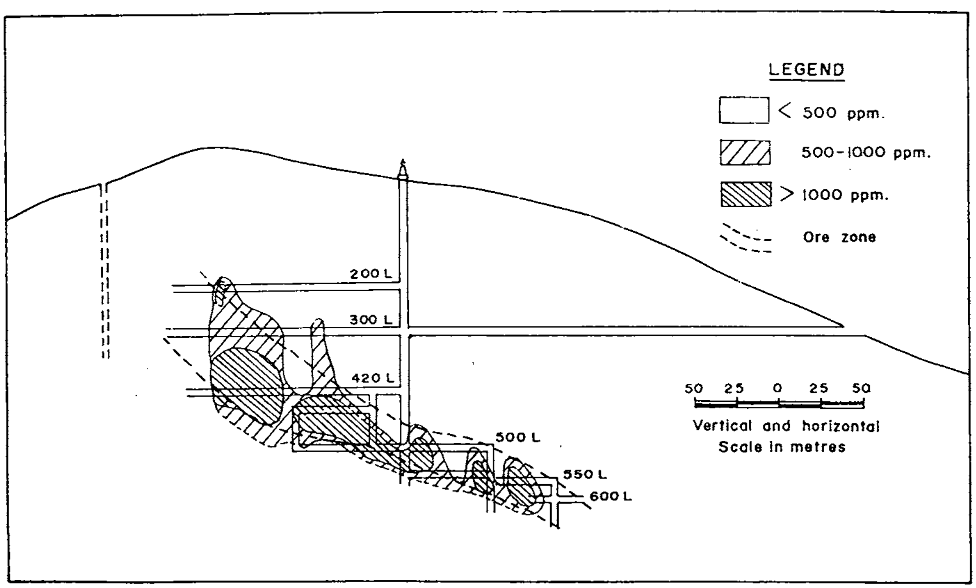

Fig. 16. Longitudinal section (looking east) showing distribution of zinc in the Theingon orebody, Bawsaing, Southern Shan State, Burma.

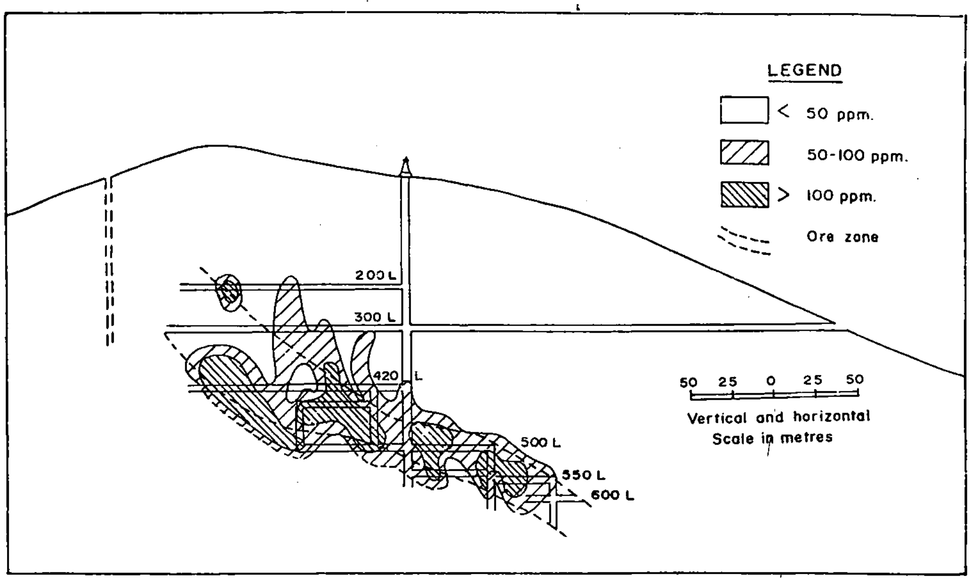

Fig. 17. Longitudional section (looking east) showing distribution of copper in the Theingon orebody, Bawsaing, Southern Shan State, Burma.

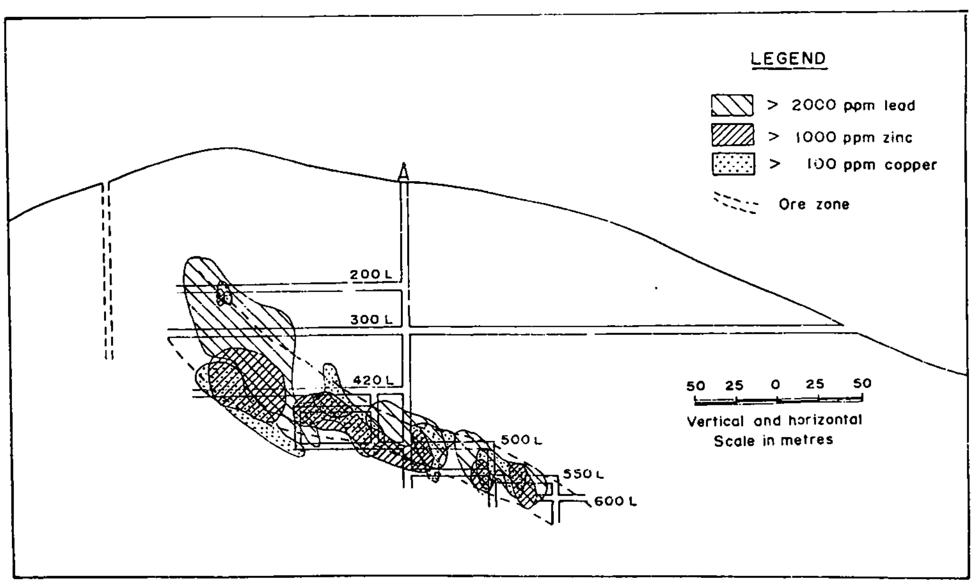

Fig. 18. Longitudional section (looking east) showing distribution of lead, zinc, and copper in the Theingon orebody, Bawsaing, Southern Shan State, Burma.

TABLE 2

SOME COMPARISONS BETWEEN THE THEINGON DEPOSIT AND MISSISSIPPI VALLEY-TYPE DEPOSIT

	MISSISSIPPI	THEINGON
Type of host rock	Mostly in carbonate rocks (commonly dolomitic)	Carbonate rocks (oolitic and dolomitic).
Age of host rock	Paleozoic (Cambrian to Pennsylvanian).	Paleozoic (Lower to Middle Ordovician).
Structural setting	Most deposits are epigenetic, structurally controlled open-space fillings, which in places, occur in the crests or lobes of fractured major domes or gentle anticlinal uplifts.	Epigenetic, structurally controlled open-space fillings localised in limb of east-dipping small overturned anticline.
Ore mineralogy	Principally galena, sphalerite, barite, and fluorite.	Mostly galena and sphalerite with minor tetrahedrite-tennantite, covellite, chalcopyrite, digenite, and argentite.
Gangue mineralogy	Mainly calcite, dolomite and cryptocrystalline quartz.	Mainly calcite and quartz.
Zonation of ore	Mineralization is distinctive and districtwide; vertical mineral zonation is present in places but much less widespread.	Overlapping, vertical ore metal zoning, mainly within the orebody.

patterns are exhibited by silver in galena and by $206_{pb}/204_{pb}$ ratios in galena from the Illinois-Kentucky and Upper Mississippi Valley districts. However, vertical, metal-zoning patterns such as those found in the Theingon orebody are not well developed or widespread in Mississippi Valley districts, but are a classic characteristic of magmatic-hydrothermal ore deposits. Geologists working in the Theingon Mine area previously hypothesized that the sulfide ore minerals were deposited by magmatic-hydrothermal solutions, which passed upward along fissures and hence into the solution channel that ultimately localized ore deposition. Characteristics listed in Table 2, particularly the complex nature of the ores and the presence of tetrahedrite-tennantite and agrentite, make this a permissable genetic interpretation. Lack of a prominent wall rock alteration halo around the mineralized zone and the absence of outcrop of intrusive rocks within several kilometers of the mine are not substantial objections to such an interpretation. Morris and Lovering (1979) have observed in the East Tintic district of the western United States that major magmatic-hydrothermal lead-zinc-silver orebodies in carbonate rocks can occur without pronounced wallrock alteration, and are present as far as 2 km from the nearest outcropping igneous stock. Moreover, the extensive alluvial and colluvial cover around the Theingon Mine could easily hide large bedrock exposures of intrusive rock.

Consequenlty, presently recognized geologic, mineralogic, and geochemical characteristics are consistent with an interpretation whereby the epigenetic Theingon ore deposit is the result of some combination of magmatic-and meteoric-(White, 1974) hydrothemal circulation. The distinct fissure-filling character of the ore zone precludes a sedimentary syngenetic origin for the Theingon ore deposit.

The source of the ore metals in the Theingon deposit is conjectural. The orebody occupies a solution channel, which appears to represent one of the type B subsurface erosional features of Callahan (1967, 1974), who postulates that associated mineralization is probably epigenetic rather than syngenetic. Concentration of ore metals in the carbonate wallrocks generally increases with increasing proximity to the ore zone (Figs. 12 to 14). This trace element halo presumably resulted from leakage of small amounts of ore fluids into surrounding wallrocks during ore deposition, or, alternatively, from leaching of Pb, Zn and Cu from subjacent host rock by percolating ground waters, which then migrated into the solution channel depositing these metals there and in immediately adjacent wallrocks. These ground waters could have been heated by deep circulation into the sedimentary basin or by interaction with a subsurface igneous heat source.

Goossens (1978) believes that disseminated grains of galena in oolitic dolomitic limestones in the Theingon Mine area represent subeconomic, low grade, primary (?) mineralization. If so, this galena constitutes an additional source of metal subject to leaching by percolating meteoric waters and by circulating hydrothermal fluids. The wide geographic distribution of Pb-Zn occurrences in the Southern Shan State region (Myint Lwin Thein *et al.*, 1972; Myint Lwin Thein, 1979) is consistent with such an interpretation. Furthermore, a characteristic feature of the ore zone is the occurrence of ore minerals (galena and sphalerite) as blocks and fragments varying from 1m long to pea size, which are always embedded in yellow clay. The ore zone appears to be a clay-filled channel, implying that meteoric water was responsible for the formation of the channel and was therefore a potential component of the ore fluids.

Fluid inclusion studies of ore and gangue minerals from Theingon Mine were conducted in an attempt to estimate the temperature range of ore deposition. Unfortunately, no useable primary inclusion were found. Secondary inclusions in late, drusy calcite crystals gave filling temperatures of less than 50° C. However, the relationship of the fluids in the secondary inclusions to the ore-bearing fluids is unknown.

In closing, it should be pointed out that the present studies do not rule out deposition of the Theingon deposit by mixing of two brines (basinal fluid and the host rock formational fluids) as proposed by Beales (1975) and Anderson (1973, 1975). Isotopic and additional geochemical studies on representative ore and gangue minerals are required to ascertain the source or sources of the Theingon ore fluids.

Guidelines for Pb-Zn exploration:

Present investigation suggests a new mode of genesis of the Theingon ore deposit and the following features should be utilized as guides in further Pb-Zn exploration modeling in the Bawsaing area: 1). The Theingon deposit is, as other mineral showings in the area, stratigraphically confined to the Wunbye Formation (Lower to Middle Ordovician) of Pindaya Group. 2). The Theingon deposist and other Pb-Zn occurrences in the Bawsaing area are in a north-south trending zone and related to anticlinal crests, or anticlinal flanks. 3). The galena has been deformed tectonically suggesting that its deposition predated a tectonic epsiode.

The Bawsaing area is potentially a major Pb-Zn district, and further geological exploration in the area is warranted and should focus on the stratigraphic succession and the lithologic character and facies of the Wunbye Formation.

Continued detailed geological mapping of the distribution of the stratigraphic sequence and structures and galena occurrences will aid designing a drilling programme for orebody targets. Further works may show that localisation of the ore in the Bawsaing area may be largely, if not all, related to the paleophysiographic setting. Paleokarst surfaces, reef complexes, facies boundaries and other paleophysiographic features which prevailed are sites of ore deposition.

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