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Regional controls of hydrothermal ore localization in northern Thailand

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Abstract: The stratigraphical, lithological and structural controls of hydrothermal Sb, Ba, Cu, F, Pb-Zn and Sn-W deposits of northern Thailand (viz. north of lat. 17°30' N) are statistically determined and evaluated. Most deposits appear to be strata-bound. Strata-binding mineralization of various ore deposits occurred notably in the Ordovician Hod Limestone, Silurian–Devonian Don Chai Formation, Permo-Triassic Volcanic Group and Triassic Hong Hoi Formation. The Jurassic red beds of Khorat Group are limited to copper mineralization in particular. Similarly, hydrothermal tin-tungsten deposits are invariably related to granitic rocks of Triassic and younger ages. The result of investigation has also showed that within any square grid area equivalent to the 1:50,000 topographic map sheet, the ore deposits, by large, exhibit spatial relationship to the set of lineaments whose total length is the longest.

INTRODUCTION

The hydrothermal ore deposits of northern Thailand (viz. north of lat. 17° 30′ N) consist of antimony, barite, copper, fluorite, lead-zinc and tin-tungsten deposits (Fig. 1). It is of academic as well as economic interest to investigate whether localization of such deposits are related to any regional geologic controls. In this study only three parameters which may have influence upon ore localization have been determined. They are stratigraphical, lithological and structural controls. In order to evaluate the significances of these parameters, data on mineral occurrences, stratigraphy and lithology of host rocks and lineaments' distribution have been compiled. Three series of translucent maps of scale 1:500,000 were produced to show distribution of mineral occurrences, geologic boundaries, and lineaments. Consequently, the relationship of mineral occurrences to certain rock units or any set of lineaments within a given area could easily be determined by the over lay method.

THE STRATIGRAPHICAL CONTROL

The distribution of various hydrothermal ore deposits in host rocks of different stratigraphic ages as shown in Table 1, suggest a strata-bound nature for some, if not all, of these deposits. To-date, it is still uncertain as to whether the sedimentary host rocks play an important role during the processes of ore genesis or that they merely display a spatial relationship without any genetic control.

However, stratigraphic significances of hydrothermal mineralization for each type of ores could be evaluated from the data obtained and from pre-existing literature as outlined below.

Antimony: According to Chancharoonpong (1978, 1983) the deposits are found both in Palaeozoic and Mesozoic rocks and appear to be related to two major granites:

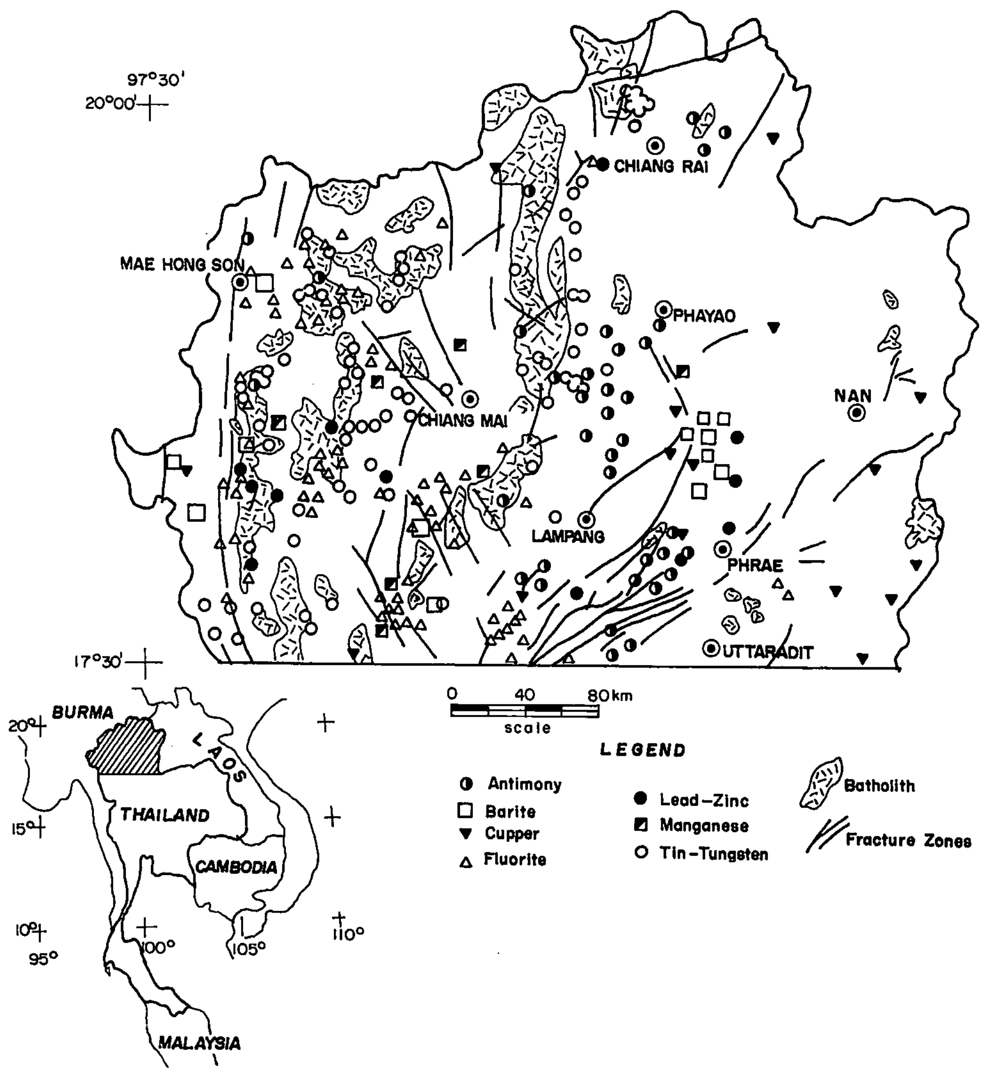

Fig. 1. Simplified map showing major ore occurrences of Northern Thailand.

the Triassic hornblende-biotite granite and the Cretaceous-Tertiary biotite-muscovite granite. The apparently young deposits (late Cenozoic ?) in some regions seem to be related to hot springs and to major faulted zones. The main antimony ore fields are restricted to the three adjoining provinces of Lamphun, Lampang and Phrae where the most extensive rock units are the Silurian–Devonian Don Chai Formation and the Triassic Hong Hoi Formation. Hence Asnachinda (1981), suggested that synsedimentary exhalative processes could contribute ore metals to the rock units. Ore deposition by lateral secretion probably occurred subsequently with the aid of regional

TABLE 1

FREQUENCY OF ORE OCCURRENCES IN HOST ROCKS OF DIFFERENT STRATIGRAPHIC AGES (AFTER ASNACHINDA AND CHANTARAMEE, 1983)

Ores / Rock Units	Sb	Ba	Cu	F	Pb–Zn	Sn–W	Total
Ordovician	—	30	—	90	5	n.d.	125
Silurian–Devonian	35	—	3	89	—	n.d.	127
Carboniferous	6	—	—	19	—	n.d.	25
Permian	2	7	—	—	11	n.d.	20
Permo-Triassic	—	52	10	—	17	n.d.	79
Triassic	77	—	—	57	18	n.d.	152
Jurassic	—	—	19	—	—	n.d.	19
Total	120	89	32	255	51	n.d.	547

n.d. = not determined

metamorphism or geothermal activity. Strata-bound antimony deposits are quite common in Burma where the geologic environment is believed to be similar to that in Thailand (Gossens, 1978).

Barite: Barite deposits of northern Thailand are clustered in three provinces: Mae Hong Son, Lamphun and Phrae. Each province has a different rock unit as far as wall-rock of the ore body is concerned. These barite deposits exhibit strata-bound features. At Mae Hong Son barite veins have been found discordantly localized in the Permian clastic rocks. Conversely, barite deposits of Lamphun and Phrae are commonly stratiform and are bounded to the Ordovician Hod Limestone and to the Permo-Triassic Volcanic Group respectively. The largest deposit of northern Thailand is the stratiform barite deposit in Ordovician Hod Limestone at Phu Mai Tong, about 80 km. south of the city of Lamphun. It should be noted that barite deposits in Southern Shan State of Burma are generally stratiform or, at least, strata-bound and confined within Ordovician limestones (Gossens, 1978).

Copper: Tantisukrit (1978) stated that, in northern Thailand, copper deposits were found in Triassic sandstones and shales of the Lampang Group in Lampang province and in Jurassic sandstones and shales of the Khorat Group at several localities in Uttaradit and Nan provinces. This has been confirmed by Asnachinda and Chantaramee (1983) (Table 1) although a number of other deposits are also found within Permo-Triassic Volcanic Group and Silurian–Devonian Don Chai Formation. Many lines of evidence suggested two major types of copper mineralization in northern Thailand. These are the volcanogenic copper mineralization associated with calc-alkaline volcanics of Permo-Triassic and younger ages and the infiltration deposits of secondary copper minerals in non-marine clastic sedimentary rocks of Mesozoic age.

Fluorite: Fluorite deposits occur mostly in the western part of northern Thailand. A large number of deposits have been found in the Ordovician Limestones and the Silurian–Devonian clastic formations which are the most common country rocks of the widely distributed Triassic granites. Premgamone (1980) proposed a hot-spring model of ore genesis, since most deposits are associated with hot springs and occur in strong tectonic or faulted zones at the margin of Cenozoic basins. The age of mineralization was said to be young, probably from Late Tertiary to Recent (?)

However, as one can see from Table 1, quite a number of deposits occur in the Triassic Lampang Group (Hong Hoi Formation in particular) in Lampang and Phrae provinces where hot springs and granites are scarce. Brown *et al.*, (1951) also noted the occurrences of fluorite in epithermal barite-lead-copper veins in Ban Pin area, Phrae province. It is quite probable that some fluorite occurrences are relatively old and genetically related to base metal sulphide mineralization in some rock units such as Triassic Hong Hoi Formation or even Ordovician Hod Limestone.

Lead-Zinc: Lead-zinc and barite mineralizations apparently occurred in the same geologic environments. Then the stratigraphical control of barite occurrences could be well applied for the lead-zinc too. For instance, Kumanchan (1978) suggested that lead-zinc massive sulphide deposits should be found in shale beds laterally away from the stratiform barite ore body at Phu Mai Tong. However, only five lead-zinc occurrences in Ordovician host rocks are known in Mae Hong Son and Chiang Mai provinces. In Southern Shan State of Burma however many lead-zinc and barite deposits are essentially restricted to the Ordovician Wumbye Formation (Gossens, 1978).

According to Yaemniyom and Yaemniyom (1976), the apparently stratiform lead-zinc deposits associated with barite, gypsum and traces of copper ores have been found in many places at Ban Pin area, Phrae province. Asnachinda and Chantaramee (1983) indicated that a number of lead-zinc deposits at Phrae and nearby provinces occurred mainly in Permian, Permo-Triassic and Triassic rock units. These units are notably volcanogenic or, at least, volcaniclastic in parts. Therefore, it seems plausible that those associated ore deposits are related to volcanogenic massive sulphide of perhaps the Kuroko Type (?).

Tin-Tungsten: The stratigraphic position of wall-rocks where tin-tungsten mineralization occurs has not been determined. However, Vichit (1983) has noted that hydrothermal quartz veins are commonly found cutting granites and metasedimentary rocks especially those of Silurian–Devonian age. To his knowledge, the primary tin deposits that are confined to Mesozoic strata have never been recorded in northern Thailand.

THE LITHOLOGICAL CONTROL

The relationship of the hydrothermal ore deposition to lithology of host rocks as investigated by Asnachinda and Chantaramee (1983) is shown on Table 2.

Granitic rocks: In general the granites are one of the most important ore-bearing rocks of northern Thailand. Deposits of tin-tungsten, lead-zinc, fluorite, and antimony are commonly located within the peripheral zone of a granitic batholith either as

TABLE 2

FREQUENCY OF ORE OCCURRENCES IN HOST ROCKS OF DIFFERENT LITHOLOGY AND FACIES (AFTER ASNACHINDA AND CHANTARAMEE, 1983)

Lithology and Facies \ Ores	Sb	Ba	Cu	F	Pb–Zn	Sn–W	Total
All granitic rocks	49	—	2	126	13	239	429
Calc-alkaline volcanics	—	52	10	—	17	n.d.	79
Eugeosynclinal clastic rocks	119	7	3	145	18	n.d.	292
Shallow marine shale/ limestone	1	30	—	90	16	n.d.	137
Non-marine shale/ sandstone	—	—	19	—	—	n.d.	19
Total	169	89	34	361	64	239	956

n.d. = not determined

hydrothermal veins or as pyrometasomatic ore bodies. However, not all granitic rocks are related to ore deposits. Asnachinda (1978) reviewed the relationship of specialized granitoids to tin mineralization of Thailand.

According to the German Geological Mission (1972), the Carboniferous granites did not yield any mentionable mineralizations. All of the known tin-tungsten, fluorite and antimony deposits are said to be genetically associated with Mesozoic granites. The relationship between the Mesozoic granite and a minor lead-zinc mineralization is also obvious. The Ban Muang Kut pyrometasomatic lead-zinc-silver deposit of Amphoe Mae Taeng, Chiang Mai province is supposed to represent this category. The youngest "Neogene" granites were considered to be responsible for mineralization of fluorite.

Calc-alkaline volcanics: The Permo-Triassic Volcanic Group (Piyasin, 1972) consists of rhyolites, andesites, tuffs and other volcaniclastic rocks. The rock unit is widely distributed in Lampang and Phrae provinces. Since the rock unit was generated under island arc setting (Bunopas and Vella, 1978), then its spatially associated barite, lead-zinc, and copper deposits may have formed during submarine volcanism.

Eugeosynclinal clastic rocks: The clastic rocks of eugeosynclinal facies include sandstones, shales and tuffs of both Silurian–Devonian (Don Chai Formation) and Triassic (Hong Hoi Formation) ages. A considerable number of fluorite, stibnite and lead-zinc deposits found in this type of rock suggests a presence of strata-binding mineralization. However, the rocks especially the Don Chai Formation were, at places, intruded by granitic batholiths which could also be responsible for the mineralization.

Shallow marine shales and limestones: In northern Thailand shales and limestones of shelf facies are principally of Ordovician and Permian age. Localization of magmatic hydrothermal fluorite, barite, and lead-zinc deposits in these rocks was probably due essentially to physical and chemical properties of the rocks themselves. But, these could also be strata-bound Pb-Zn-F-Ba (The Mississippi Valley Type) deposits.

Non-marine sandstones and shales: Non-marine red beds of the Jurassic Khorat Group in northern Thailand are particularly related to copper mineralization. According to Carrel (1964) it seems that copper deposits of this area are in fact infiltration or telethermal deposits (Smirnov, 1976; Park and MacDiarmid, 1975). They are genetically similar to the uranium mineralization found at Khon Kaen province, northeastern Thailand. Deposition of copper as well as uranium ores in Jurassic sandstones of Khorat Group are probably due mainly to lithologic controls such as permeability and organic content.

THE STRUCTURAL CONTROL

Asnachinda and Chantaramee (1983) investigated the relationship of fracture (lineament) pattern to the distribution of epigenetic ore deposits found elsewhere in northern Thailand. The lineaments which were interpreted from landsat imagery had been transferred on to a transparent map sheet of scale 1:500,000. The map also illustrates a series of square grids representing areas covered by any 1:50,000 topographic map sheets. They found that, in any square grid area equivalent to the 1:50,000 map sheet, the ore deposits in general tend to be associated with a certain set of lineaments whose total length (for 10 degrees interval) is maximum. Distribution and attitudes of such lineaments are shown on Fig. 2.

In order to review the structural relationship in detail, the ore deposits are classified into three groups according to their relative positions to a certain lineament. Deposits of group 1 occur right over a lineament, those of group 2 occur along both sides of the lineament, and those of group 3 are found close to both ends of the lineament. Distribution of these deposits is limited to a distance of less than 1.5 kilometre. Results of this investigation are summarized in Table 3.

TABLE 3

NUMBER OF OCCURRENCES OF PRESUMABLY FRACTURE-RELATED ORE DEPOSITS (AFTER ASNACHINDA AND CHANTARAMEE, 1983) SEE TEXT FOR GROUP'S DESCRIPTIONS

Ores	Number of deposits			Total
	Group 1	Group 2	Group 3	
Antimonry	70	21	2	93
Barite	33	8	2	43
Copper	—	—	—	—
Fluorite	128	26	8	162
Lead-zinc	20	2	—	22
Tin-tungsten	68	40	10	118
Tin-tungsten	68	40	10	118
Total	319	97	22	438

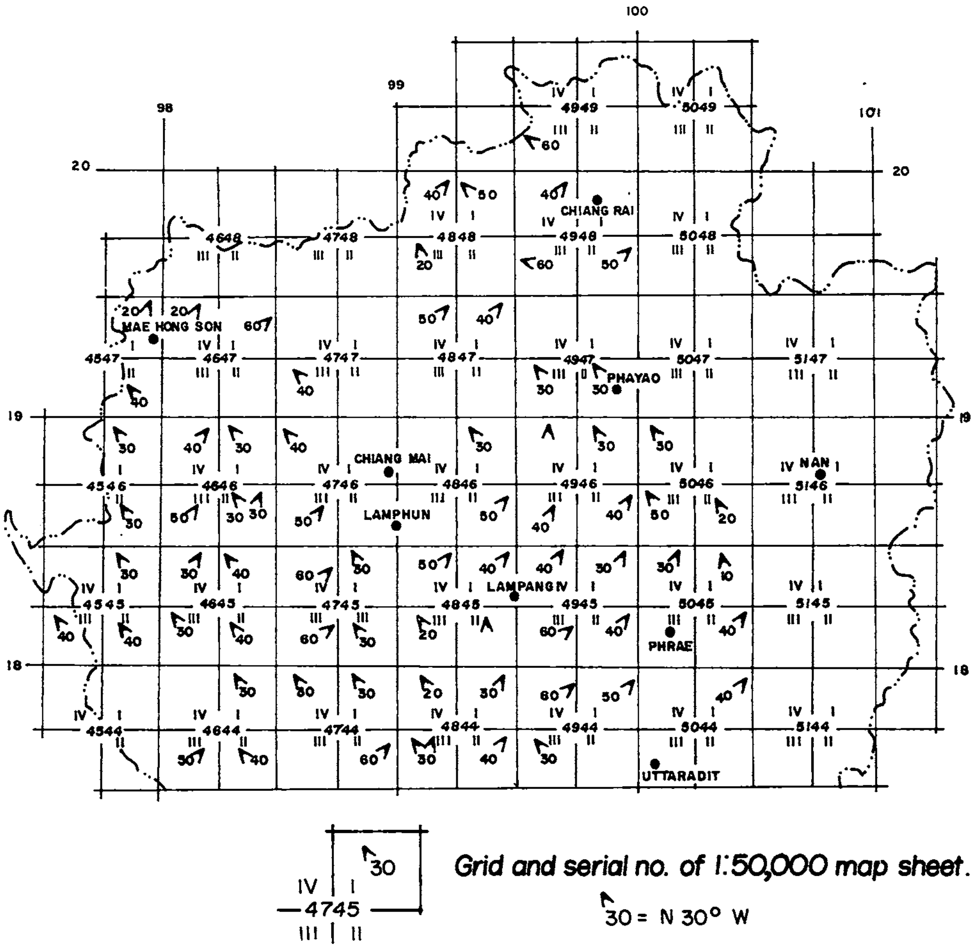

Fig. 2. Map showing distribution and attitude of the lineaments whose total length is maximum for a grid area of 1:50,000 map sheet (After Asnachinda and Chantaramee, 1983).

It is evident that for a given area of 1:50,000 map sheet most of the fracture-related deposits are localized to the set of lineaments whose total length is maximum.

CONCLUSION

With the above account of stratigraphical, lithological, and structural controls of hydrothermal ore localization the following conclusions could be made:

1. Antimony deposits are mostly strata-bound being confined within eugeosynclinal clastic rocks of essentially Silurian–Devonian and Triassic ages.

2. Deposits of barite are definitely strata-bound to host rocks that are Permian clastic rocks, Ordovician shale and limestone and Permo-Triassic volcanics for ore fields at Mae Hong Son, Lamphun and Phrae provinces respectively.

3. There are two major types of copper mineralization in northern Thailand. They are volcanogenic sulphide deposits genetically associated with calc-alkaline volcanics of Permo-Triassic and younger ages, and the infiltration or telethermal deposits of secondary copper minerals in Jurassic red beds of the Khorat Group. Structural control of ore localization is apparently lacking.

4. Localization of fluorite deposits are essentially controlled by availabilities of granitic source rock, geothermal system, fractured and and faulted zone, and chemically reactive wall-rock such as limestones. However, association of fluorite with Pb-Zn-Ba ores found in the Hong Hoi Formation or even the Hod limestone at places indicates strata-binding mineralization of fluorite along with base metal sulphides.

5. Apart from a few occurrences of pyrometasomatic deposits which are related to limestone-granites interaction, most lead-zinc deposits are strata-bound or perhaps stratiform in places. It is probable that the Mississippi Valley Type deposits occur in Ordovician Hod Limestone at Mae Hong Son and Chiang Mai provinces. Similarly, the volcanogenic Kuroko Type deposits could also be present in Permian, Permo-Triassic, and Triassic rock units at Phrae and nearby provinces.

6. Tin-tungsten deposits are invariably related to granitic rocks of Triassic and younger ages. However, it has been noted that rocks of Silurian-Devonian age or, at least, older than Mesozoic are normally present as the wall-rocks.

7. Within a given area of 1:50,000 map sheet, ore deposits are generally localized over a set of lineaments whose total length is madimum.

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