1. INTRODUCTION

1.1 General Location of Deposits.

Fluorite deposits in Thailand are distributed from north to south along the mountainous region in the western part of the country. Approximately two-thirds of the total production comes from northern Thailand, where fluorite deposits are located in Chiang Mai, Mae Hong son, Lamphun, Lampang, Chiang Rai, Tak, Kamphaeng Phet and Sukhothai Provinces.(Table A-1). In central-western Thailand, many deposits are found in Phetchaburi, Ratchaburi and Kanchanaburi Provinces. Fluorite occurrences in southern Thailand are found in Surat Thani and Krabi Provinces.

1.2 Type of Occurrence

Fluorite deposits in Thailand occur mostly as epithermal deposits, but some of them occur as pegmatite and greisen deposits. Veeraburus(1974) studied the type of fluorite deposits and presented the following classification:

1.2.1 Fissure Vein Type

This type occurs as epithermal veins in fractures and fault fissures, chiefly in granite and in the host sedimentary rocks closed to the contact with granite.

1.2.2 Pegmatite Type

Pegmatite dikes consist of fluorite and coarse grained quartz, feldspar, and muscovite.

1.2.3 Cavity Filling Type

Fluorite occurs in open fractures and cavities, mostly in limestone.

1.2.4 Replacement Type

Fluorite occurs in limestone, sandstone, conglomerate, shale, etc. Breccia zones seem to be the most important structural control. Ore textures show relic fragments and textures of the original rocks. In some stratified sandstone and shale, fluorite tends to selectively replace sandstone, particularly arkosic sandstone.

1.3 Mineral Assemblages

The associated minerals in fluorite deposits differ from one occurrence to another, according to their genesis and temperature-pressure conditions. With reference to the associated minerals, the fluorite deposits can be classified into ;

1.3.1 Fluorite - (quartz).

This type is very common in epithermal deposits. Quartz is the most common gangue and occurs in crystalline form or as cryptocrystalline varieties such as chalcedony. The mineral crystallized either simultaneously with fluorite or at a different stage. Where quartz formed before fluorite, it could have served as a nucleus for crystallization of the later fluorite. The ratio of the volumes of the fluorite and quartz is different in different deposits.

1.3.2 Fluorite - Stibnite - (Quartz)

Stibnite usually forms prismatic crystal aggregates closely

associated with grey or colorless fluorite. The stibnite-fluorite association can be seen throughout the deposit. Quartz and other sulfides are minor gangues.

1.3.3 Fluorite - Tin-Tungsten Minerals - (Quartz)

This type of occurrence seems to have formed at a rather higher temperature than the other types. In northern Thailand, fluorite is commonly found with cassiterite, wolframite, scheelite, and sulfides in pegmatite and greisens. Fluorite, cassiterite and wolframite crystallized at nearly the same time in greisen and pegmatite. Late fluorite-quartz veins without tin-tungsten minerals occur in some areas. This indicates that fluorite can crystallize either at the same time or after the Sn-W mineralization.

1.3.4. Fluorite - Stibnite - Tungsten Minerals - (Quartz)

Examples are found at Doi Ngom, Amphoe Long, Phrae Province, and Khao Sun, Amphoe Chawang, Nakhon Si Thammarat Province in southern Thailand. Fluorite and stibnite may occur in the upper parts of vein systems associated with ferberite ($FeWO_4$) in some parts. Associated sulfides are chalcopyrite, pyrite, etc. Ferberite occurs as fine grained crystalline aggregates.

1.3.5 Fluorite - Calcite.

A typical fluorite - calcite association occurs at SP. Mine, Amphoe Mae La Noi, Mae Hong Son Province. Here, calcite is formed later than fluorite and occurs as coarse grained interstitial fillings. The volume of calcite is about 3-4 times that of fluorite, and in some

places it also shows gradation of colours.

1.4 Topography and Climate of Northern Thailand

Northern Thailand is mostly mountainous. The average height of the mountain is about 1600 m. O.D., the highest peak being Doi Intanon , 2595 m. O.D., 56 km SW of Chiang Mai town. The mountain chains are oriented N-S, with many narrow or wide elongate basins between the mountain chains, such as the Chiang Mai, Lampang, and Chiang Rai basins. In these basins there are many south- flowing rivers including the Ping, Wang, Yom and Nan, which are branches of Chao Phra Ya River.

The climate in northern Thailand is tropical savannah type according to Koppen (Klammesri, 1973). The temperature is always above 0 °c, except on some high mountain peaks in winter, when small ice drop may form. Climatic data for northern Thailand in the year1951-1975 is given in Appendix A, Tables A-2.1,A-2.2 and A-2.3 .

Seasons in northern Thailand are classified as follows:

1.4.1 Rainy Season

This begins when the South-West monsoon passes across the country, for a period of 6 months from mid May to mid October. This rainy season may be earlier or later than this by about 2 weeks. Mean monthly rainfall in northern Thailand reaches the maximum in August with 442.5 mm.at Chiang Rai, and 408.9 at Mae Sod. The mean relative humidity also reached the maximum in August. Mean annual rainfall ranged from 1054.1mm. at Tak to 1795.1 mm. at Chiang Rai. Mean monthly temperature is relatively

constant during the rainy season. After the rainy season, very little rainfall is experienced during the six month dry period.

1.4.2 Winter

Climate is effected by the cold winter or NE monsoon from November to February. Mean monthly temperature is at a minimum in January (19.6° c at Chiang Rai, 20.0° c at Chiang Mai, and 20.6° c at Mae Hong Son). According to Clammesri (1973), the minimum temperature recorded at Chiang Mai during 1951-1965 was 14.4° c.

1.4.3 Summer

This stretches from mid February to mid May. Mean monthly temperatures in northern Thailand reach a maximum in April, 32.3° c at Bhumiphol Dam to 27.5° c at Chiang Rai. The maximum temperature recorded during 1951-1965 is 36.8° c in April.

The periods between the NE monsoon and the SW monsoon, (mid February to mid May, and late September to mid October), are characterized by uncertain wind direction.

1.5 Geologic Setting of Deposits

Most of the fluorite deposits in northern Thailand are in or near the granite mountain ranges and at the contact between granite and various sedimentary rocks (Fig.4.8). The granitic country rocks are of both Carboniferous and Triassic age, but the relationships of the granitic rocks in northern Thailand are still not clear.

Granites are the only igneous rock closely associated

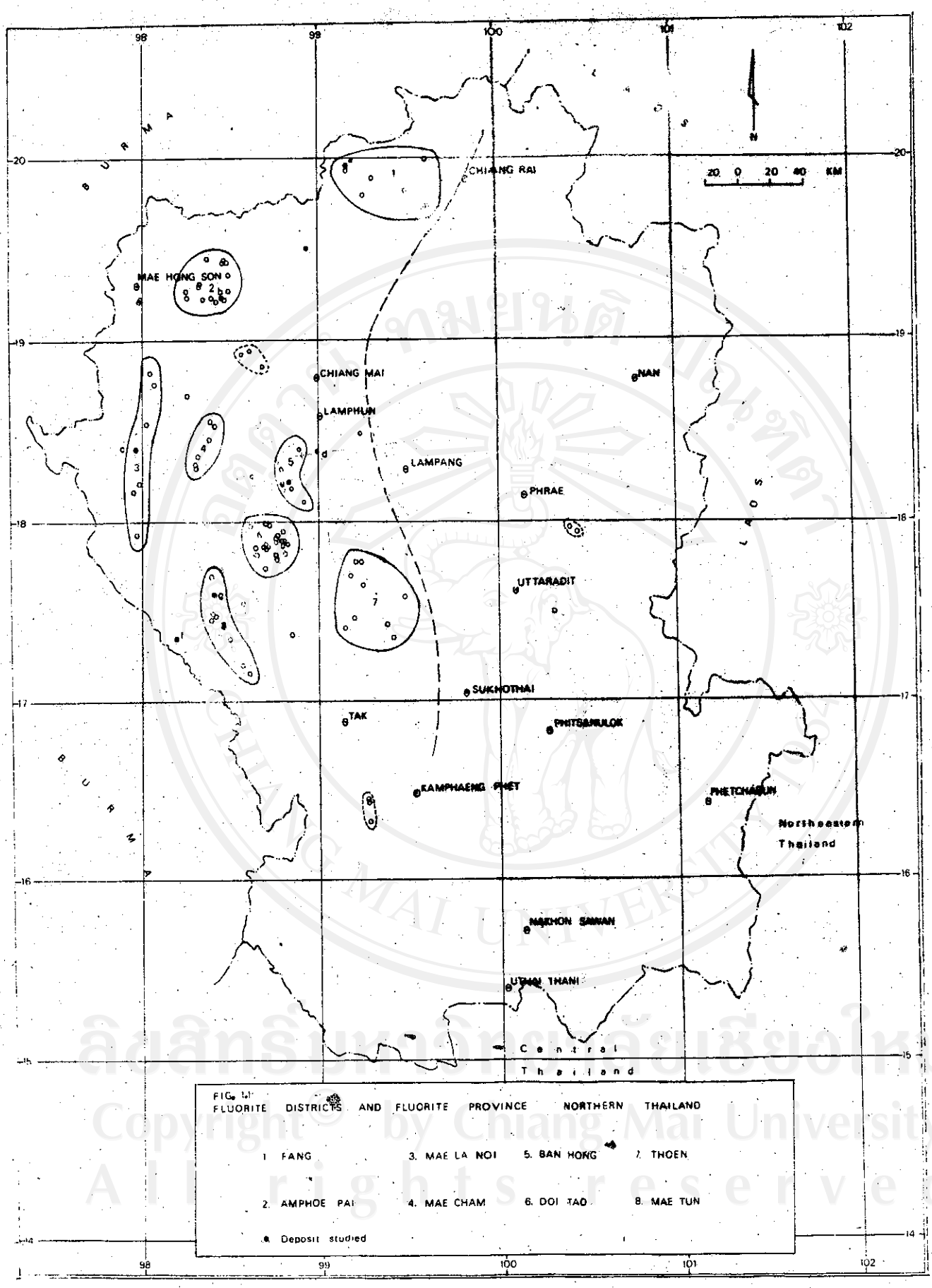

FIG. 1. FLUORITE DISTRICTS AND FLUORITE PROVINCE NORTHERN THAILAND

1. FANG
2. AMPHOE PAI
3. MAE LA NOI
4. MAE CHAM
5. BAN HONG
6. DOI TAO
7. THOEN
8. MAE TUN

● Deposit studied

with the fluorite deposits. Among the sedimentary rocks occurring near the granite plutons, limestone seem to be the most common host rock for fluorite deposits, mainly of replacement type. However, fluorite also replaces sandstones, shales, etc.

Fluorite commonly occurs as fissure vein and cavity filling types along major faults, boths in granite and sedimentary rocks. The major faults, shear zones, and fault breccias are the important as channels for mineralizing hydrothermal solutions and serve as open space for deposition.

Most of the fluorite deposits in northern Thailand occur in fault zones in the rock near the edge of Cenozoic basins. The elevation of the exposed veins is similar to that of the adjacent basins. (Table A-3).

Most of the fluorite deposits occur close to the hot springs, or there may be active hot springs within the deposits themselves.

1.6 Fluorite Districts

Regions containing fluorite deposits in northern Thailand are situated in the western part between 17° - 20° N, and longitude 97° 50' E - 99° 36' E. About 53 deposits are located in the Chiang Mai Province, 26 deposits in Mae Hong Son Province, 7 in Lamphun, 8 in Lampang, 3 in Chiang Rai, 5 in Tak, 3 in Kamphaeng Phet, and 1 in Sukhothai (Table A-1 Appendix A.). They can be divided into 8 districts (Fig.1.1), as follows:

1.6.1 Fang District

This district contains 4 known deposits. The district lies mainly in Chiang Mai Province but also includes the deposits in the western part of Chiang Rai Province. The biggest deposit is at Thepnithi Mine near the well known Fang hot springs at the edge of the Fang Basin. The district is half-circle shaped, and covers an area of about 2580 square km.

1.6.2 Pai District

This district contains more than 15 known deposits mostly along the banks of the Pai River in Mae Hong Son Province. The biggest deposit is at Mahalanna Mine. Large reserves of at least 200,000 tons are also reported at the Universal claim, 20 km west of Mahalanna Mine, along the Pai River, but the deposit is not yet in production. Many hot springs are found near these deposits. The district is circular in shape, with an area of about 1230 square km.

1.6.3 Mae La Noi District

This district consists of the Mae Sariang fluorite deposits (Sahachart Mine near Mae Sariang Town), the Mae La Noi fluorite deposits (S.P. Mine), and the Mae La Luang deposits (Universal Mining Co.). This district runs N-S parallel to the major fault system developed between Mae Sa Riang and Mae Hong Son. The district covers an area of about 1650 square km.

1.6.4 Mae Cham District

The deposits in Amphoe Mae Cham, Chiang Mai Province,

occur along fault zones both in the Mae Cham Basin and along the Mae Cham River. They include the Tha Wang Pha fluorite deposit. The district is oval- shaped trending N-S, and is about 600 square km.

1.6.5 Ban Hong District

This district includes all deposits in Amphoe Ban Hong, on both sides of the Paholyothin Highway at km 54 in the concessions of the Universal Mining Co., Thai Fluorspar & Minerals Co., and the deposits at Doi Tone, km 48. This district has produced most of the fluorite from Thailand in the past ten years. Most deposits are in the regions of strongly faulted sedimentary rocks, and are alined parallel to the Nam Mae Li fault. The district is mango-shaped, with an area of about 660 square km.

1.6.6 Doi Tao District

In the vicinity of Doi Tao District, Chiang Mai Province, fluorite deposits of fissure vein type occur along fault in granite and in the contact zone of granite and sedimentary rocks, and within the sedimentary rocks. Many mines are at Khao Pae Po Mug. The district is circular-shaped, and covers an area of about 1040 square km.

1.6.7 Thoen District

Thoen fluorite district in Lampang and Sukhothai Provinces is a pear-shaped area of about 2320 square km. The deposits are concentrated in the north-western end of the district, but some are situated in the south-eastern part of the district. Most of the deposits in this

district are located at the same elevation as the present basin or stream not on high mountains. The district also includes the Mae Phu deposit near Amphoe Thung Saliam, Sukhothai Province.

1.6.8 Mae Tun District

The fluorite deposits are found in the fault zones in granite and nearby sedimentary rocks along the Tun River in Chiang Mai and Tak Provinces. The most important deposit is the Doi Chang deposit near Ban Huai Nam Khao, which is mined out by Sun Mui Co. This district also includes Ban Sop Lan fluorite deposit, 30 km north of Tumbol Tun, and Pa La Door and Huai Nok Nuek fluorite deposit on both banks of Tun River in Amphoe Mae Ramat, Tak Province. The area is 1030 square km.

1.6.9 Other Deposits

Some deposits which are also of economic importance, occur outside these districts. The Mae Tha fluorite deposit in Ban Mae Kha-nad, Tumbol Tha Kad, Amphoe Mae Tha, Lamphun Province which belong partly to Universal Mining Co., and Thepnithi Co., has been one of the most productive fluorite deposits of northern Thailand during the past ten years. The deposits are in strongly faulted sedimentary rocks near the margin of the Mae Tha Basin. Other important deposits include the Samoeng fluorite deposits in Amphoe Samoeng, Chiang Mai Province, Muang Ngai deposit in Tumbol Muang Ngai, Amphoe Chiang Dao, Chiang Mai Province, and Tha Song Yang fluorite - stibnite deposit in Tak Province.

1.7 Previous Work

Brown and others, 1951, noted the occurrence of fluorite associated with epithermal barite - lead - copper veins in Ban Pin area, Phrae Province, and fluorite veins in a porphyritic granite in Amphoe Pai, Mae Hong Son Province. None of this narrow vein deposits was considered economically. Gardner and Smith, 1965, estimated the reserves 500,000 tons of fluorite at Doi Tao, Chiang Mai Province, and 3,600,000 tons at Ban Hong, Lamphun Province. They concluded that most of the fluorite occurs in epithermal veins in fault zone in granite and in metasedimentary rocks are similar in mode of occurrence and indicated a contemporary genesis in Tertiary Time. Takimoto(1968) studied fluorite deposits at Doi Tao, Chiang Mai Province, and concluded that all the fluorite deposits of Thailand belong to the same metallogenic province which is related to the post - igneous activities of granite magmas. During 1965 - 1971, the German Geological Mission (a joint operation of the Geological Survey of the Federal Republic of Germany and the Thai Government) surveyed the Kanchanaburi region and parts of northern Thailand. In the 1972 final report, they described various fluorite deposits, some of which were interpreted to be young in age as evidenced by fluorite deposits in Pleistocene terrace gravel at Ban Hong (Universal Mine), and other places.

Previous detail studies on each fluorite deposits have been done mostly by the D.M.R. geologists, especially those from the Economic Geology Division. But most of the work has concentrated on exploration and development of the deposits. However, complete estimation of

fluorite reserves of Thailand is not possible because data on deposits which have been extensively drilled by private operators is not available. Some exploration by diamond drilling has been done by the D.M.R. The last compilation was made in July 1973 (Veeraburus, 1974). The estimated potential reserves of metallurgical grade fluorite in Thailand may exceed 11,500,000 metric tons.

Geophysical exploration was carried out by the D.M.R. in in the area 40 km south of the town of Lamphun (Veeraburus, 1974). Gravimetric and magnetic methods were applied for detecting geological structures suitable for fluorite deposits. Faults of high potential for fluorite deposits were located. However, several thousand feet of diamond drilling revealed only the fault structures and traces of fluorite. They concluded that geophysical methods are useful only in a broad way for outlining the structures. Further study and more experiments with geophysical methods are required.

The regional geology and mineral resources in Amphoe Pai region, Mae Hong Son Province were surveyed by the E.G.D. of D.M.R., (Vichit and others, 1971). 17 fluorite deposits in this region were discussed and the location of hot springs noted, numerous along the Pai River. At least 2 stages of mineralization of fluorite were observed at the Thai Resources Development Mine from field evidence.

Charoensri (1972 a,b,and c) reported on the geology and estimated reserves of fluorite deposits at Doi Chang, Muang Ngai, and Ban Hong. Diamond drilling at Muarg Ngai indicated 35,000 tons proved reserves and more than 5,000 tons potential reserves. At Ban Hong drilling

indicated 16,000 tons of proved reserves in Thai Flourspar Mine.

Japakasetr and others, (1973) reported on the geology and mineral deposits in the Nam Mae Li Region, Lamphun Province, especially the Ban Hong fluorite deposits, Mae Tha deposits, and Doi Tao deposits.

Dr. M. Shouls (1974), Colombo Plan Instructor in the Department of Geological Sciences, Chiang Mai University studied the possible relationship between hot springs and fluorite mineralization in northern Thailand. He also reported on the chemical analysis of selected hot spring waters for SiO_2 by a student at the Department of Chemistry, Chiang Mai University in 1974.

In 1977, Sandra Barr Mcdonald, CUSO instructor in the Department of Geological Sciences, Chiang Mai University, and others, studied the chemical geothermometer of hot springs in northern Thailand, and also the geothermal gradient in the Fang Basin to determine the likely depth at which the hot springs reservoirs occur. This bears indirectly on the relationship between hot springs and fluorite deposits.

1.8 Problems of Fluorite Genesis

Even though there are many economic fluorite deposits in Thailand, the genesis of fluorite deposits is still not well understood. Problems include:

1.8.1 Age of the Fluorite Mineralization

Fluorite deposits in or near the granitic rocks can be dated only by geologic relations. The age relations of the same type and different types of deposit are complex.

1.8.2 The Relationship between Fluorite Deposits and Hot Springs

Shouls (1974) concluded that fluorite can be deposited from the hot spring water even at the present day. Veeraburus (1974) stated that there is no definite evidence that fluorite was deposited by solution from hot springs, but he did not research this.

1.8.3 The Pressure - Temperature Conditions of Formation

For the Mae La Ma District, Panupaisal (1977), from a study of phase assemblages, reported that the late fluorite crystallized at about 475-390 °c. Veeraburus (1974) noted that some pegmatite fluorite is related to hydrothermal solution and that pressures and temperatures during formation were high. He also stated that fluorite with colloform banding and crustified textures seem to form under very low temperature and pressure conditions. Fluid inclusion studies are an important means of understanding the genesis of fluorite. The temperature of homogenization of fluid inclusions is a guide to the formation temperature. The composition of inclusion fluids is also very important. These aspects are the aim of the present study.