CHAPTER I

INTRODUCTION

Carbonate rocks constitute approximately 10 to 15 per cent by volume of the sedimentary rocks of the crust as contributing to some important igneous and metamorphic rock types (Fairbridge,et al., 1967). Besides, carbonate rocks are raw materials indispensable to industrial development. In addition to their direct and indirect applications in many industrial processes, limestones and dolomite are reservoir rocks for more than one-half of the known petroleum reserves of the world and act as host rock for numerous important metalliferous ore deposits. Equally impressive is the fact that in many areas, the major source of water is from limestone aquifers.

Although the economic value of carbonate rocks is emphasized, it is their physical, chemical, mineralogical, and other properties of carbonate rocks which influence their economic potential. Therefore, field and laboratory investigations of carbonate rocks must be extended beyond their economic realm into scientific aspect so that the nature, characteristics and origin of these rocks can be fully understood to solve the economic problems related to this type of rocks for future successful exploitation.

Lead and zinc are found in two distinct associations in sedimentary rocks: carbonate-hosted and shale-hosted. The carbonate-hosted ores are generally agreed to be epigenetic, deposited from low temperature hydrothermal fluids, whereas shale-hosted deposits are more controversial, but most appear to be at least partly syngenetic. Shale-hosted ore bodies can be exceptionally large, and are perhaps the most popular exploration targets among sedimentary ores at the present time. A transitional form between these two, one that is accordingly given considerable attention, is syngenetic ore in carbonate rocks. For sedimentary ores, what come to mind of many geologists are the lead-zinc ores so common in carbonate rocks. Traditionally, most American workers have regarded these deposits as epigenetic, precipitated from relatively low-temperature hydrothermal solutions. Many European workers,on the other hand, persuaded by textural evidence, have maintained that they must be syngenetic (Maynard, 1983).

In this study, an attempt has been made to study the detailed characteristics of carbonate rocks of Ordovician Period in the western part of Thailand and their relationships to associated lead-zinc ores. Despite the fact that economic lead-zinc ores in this area have been exploited for some times, the in-depth geological aspects of the carbonate-host rock have not been studied, and the mechanism of the mineralization has not been fully understood.

1.1 The study area.

The study area, covering approximately 2.5 square kilometres between the Khwae Yai and Khwae Noi rivers, is in the northwestern part of Kanchanaburi about 160 kilometres (Figure 1.1a). The precise boundary of the study area is defined in the terms of grid reference as follows:

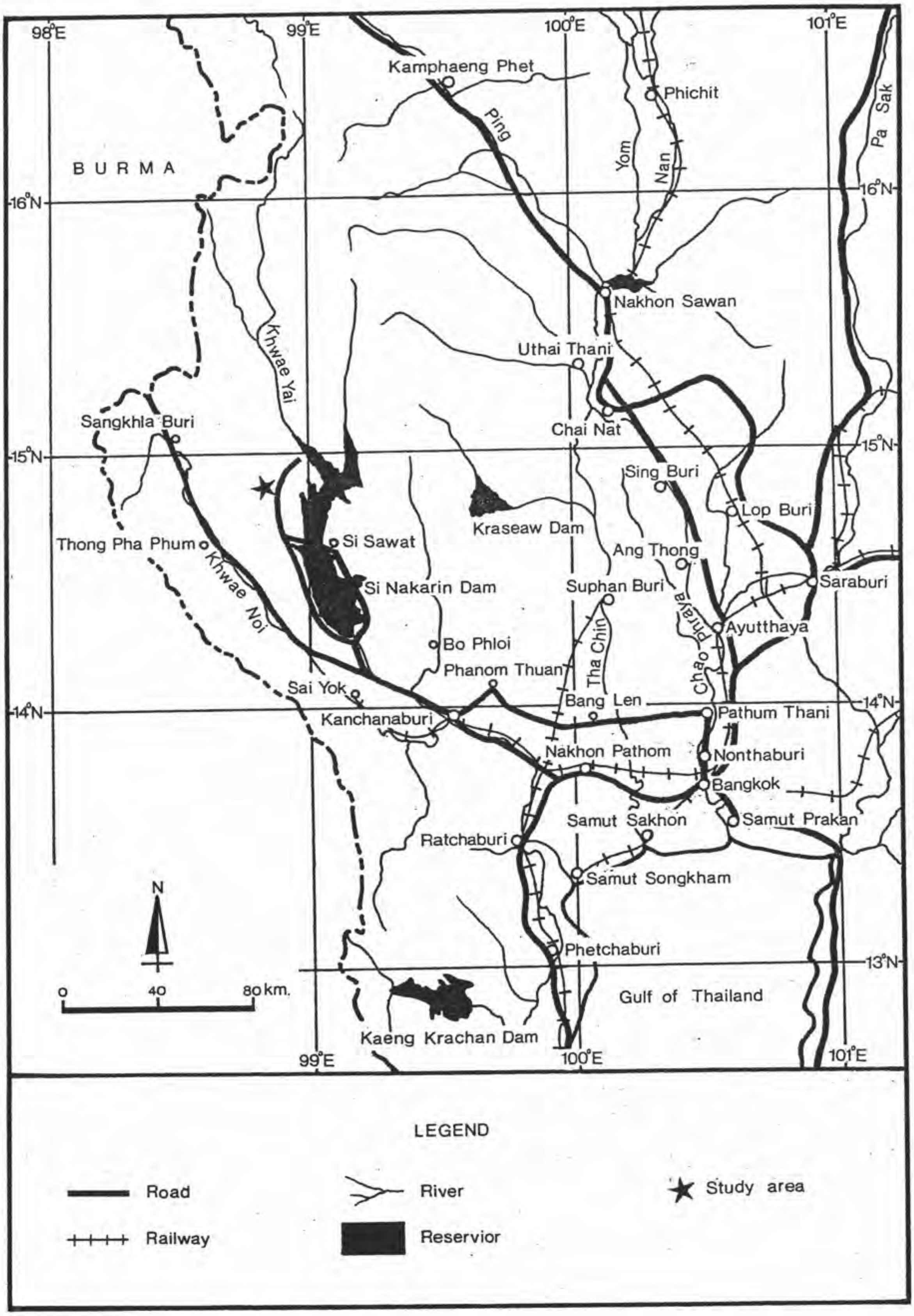

Figure 1.1a Location of the study area.

- Horizontal grid from 1639873 mN. to 1642302 mN.
- Vertical grid from 478080 mE. to 479228 mE.

The reference topographic maps employed in this study are ND 47-6, series 1501S with scale of 1:250,000; and topographic map of Khao Bo Ngam, sheet No.4738I,series L7017 with scale of 1:50,000 for regional consideration. For the field mapping purposes, topographic map and underground map of the Song Toh Mine (Geology and Survey Department of the Song Toh Mine,1983) with scale of 1:2,000 and 1:500, are employed, respectively . The aerial photographs of World Wide Survey Series (1954) with scale of approximately 1:50,000 are also used for regional geological consideration.

The study area in the vicinity of Song Toh Mine can be accessed from Kanchanaburi in two directions, namely, along the provincial highway number 3199 via Ladya, Si Nakarin Dam, Sri Sawat; along the national highways number 323 via Ban Sai Yok, Thong Pha Phum with the distances of 150 and 180 kilometres, respectively. The first route can be used all year round, whereas the second route is accessible during hot and cold seasons only.

The climate in the western part of Thailand is mainly hot and humid with little variation. The cold season lasting from November till February is pleasantly warm (17.7^{o} to 34.9^{o}C) and free of rain. The following hot season (23^{o} to 37.9^{o}C) has little rainfall starting in April, whereas the monsoon period from July until October brings a rainfall of approximately 1,115 mm. annually (Meteorological Department, 1983).

The shape of the study area is a rectangular of approximately 1.1x2.3 square kilometres (Figure 1.1b). The central part of the study area, where the lead-zinc ores are found and active mining operation is undertaken, is elongated in the valley with north-south trend. The elevation of the ground surface within the valley varies between 610 to 670 metres above the mean sea level. The eastern side of the valley is bounded by limestones and shale mountain ranges with the maximum elevation of 720 to 800 metres above the mean sea level. The western side of the valley is bounded by isolated hills and mountains of various heights ranging from 670 to 873.5 metres above the mean sea level. The overall topographic expression of the valley is undulating sloping northwardly (Figure 1.1c).

1.2 Objectives and scope.

The primary objective of the study aims at defining the lithostratigraphy, microfacies as well as the geochemical facies of Ordovician carbonate rocks in the vicinity of the Song Toh Mine. Additional attempt will be focussing upon the associated lead-zinc ores and the possible relationships between the carbonate-host rock and the mineralization.

In order to fulfill the objectives of the study earlier stated, the scope of the study programme has been accordingly defined as follows:

1.2.1 Background geology.: The background geological conditions have been focussing upon two different levels, notably, regional geological condition of western Thailand and Burma, and

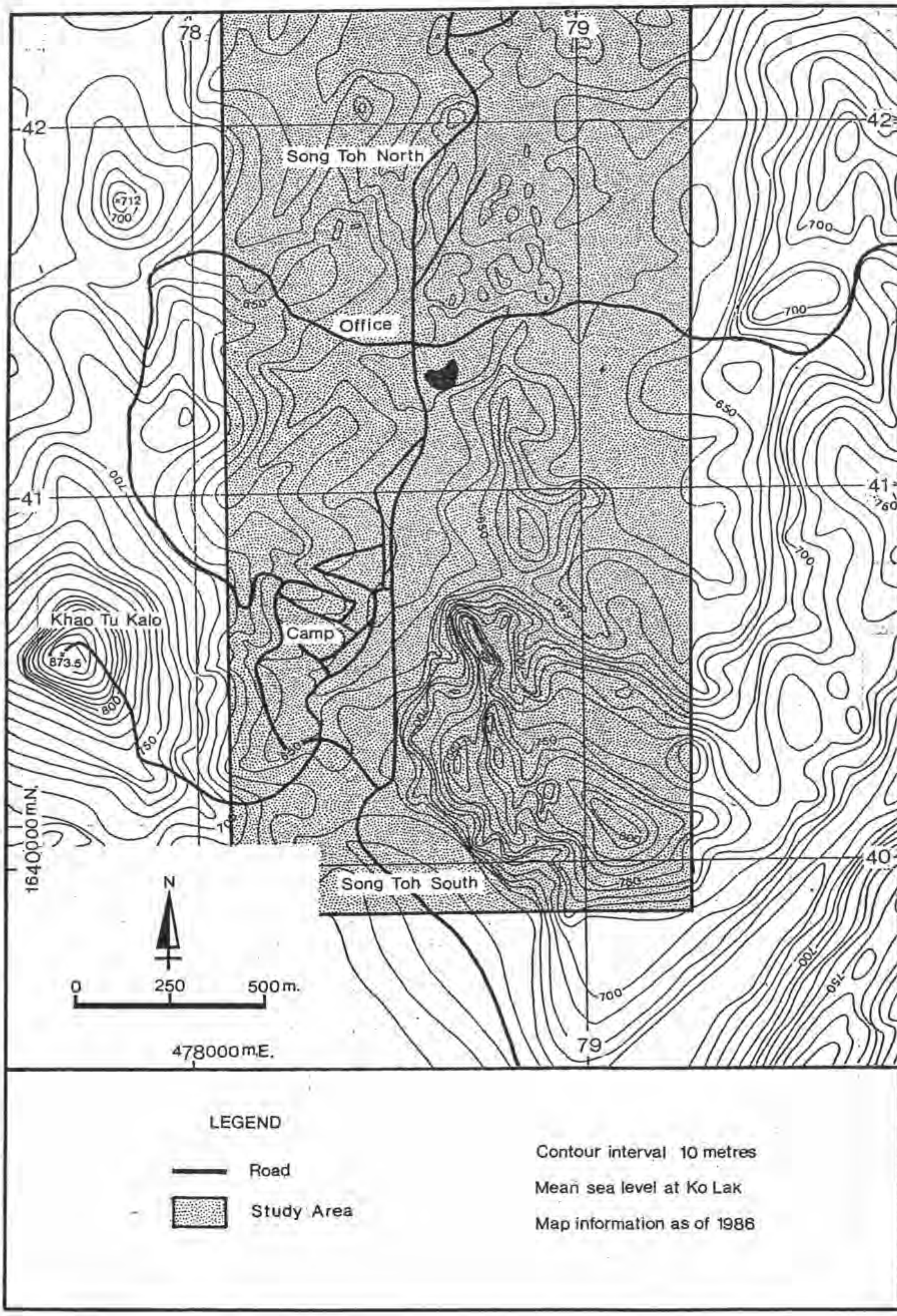

Figure 1.1b Topographic map of the Song Toh Mine area (Modified after Geology and Survey Department of the Song Toh Mine, 1983).

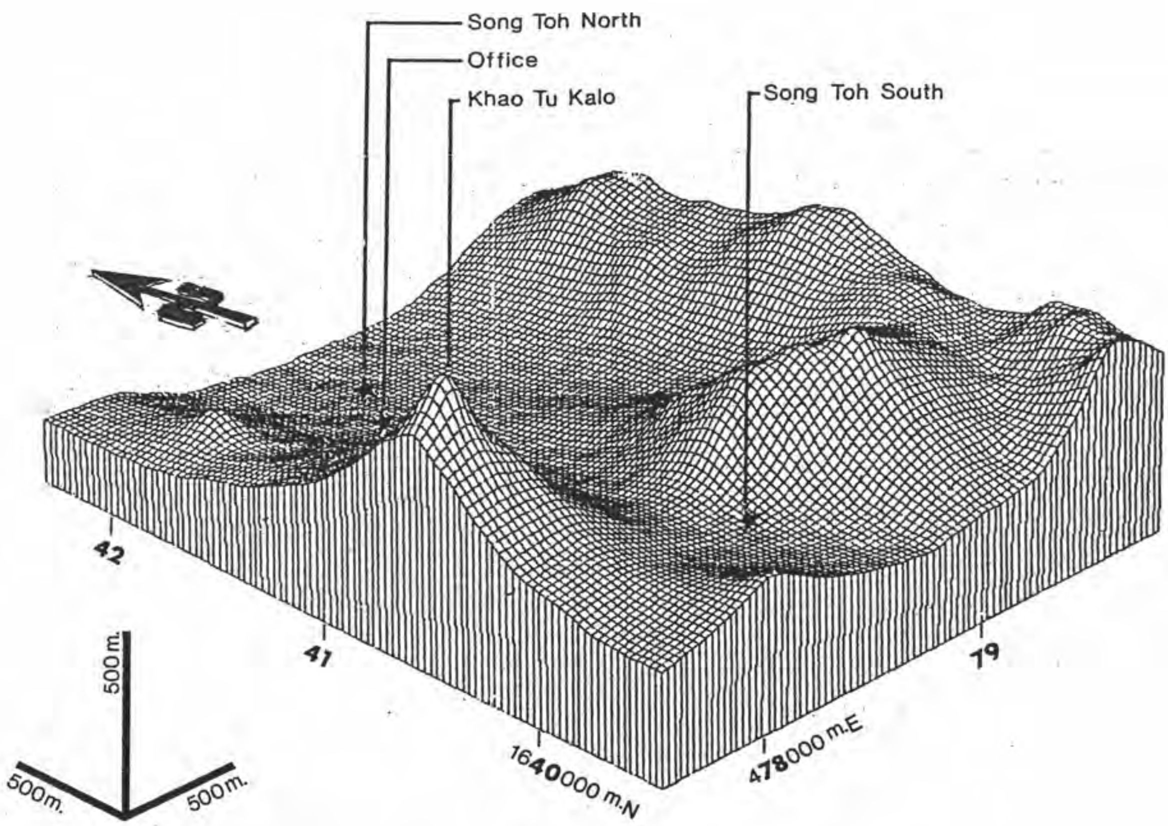

Figure 1.1c 3-dimension surface of the Song Toh Mine area.

detailed geological condition within the 2.5-square kilometre area under the present investigation.

1.2.2 <u>Measured lithostratigraphic sections.</u>: The subsurface lithostratigraphic sections along the Dewatering Drift, the underground tunnel, and the drill-holes have been measured. In addition, surface lithostratigraphic sections have been supplementary measured whenever necessary. An intensive rock sampling programme has also been conducted simultaneously with the measuring sections.

1.2.3 <u>Microfacies analysis.</u>: Totally about 540 standard thin-sections of carbonate rock samples are prepared for all the measured sections of approximately 2,000 metres in length including the surface sampling for microfacies analysis. These thin-sections cover both non-mineralized and mineralized zones.

1.2.4 <u>Geochemical and mineralogical profiles.</u>: Geochemical profiles for important major, minor, and trace elements, as well as mineralogical profiles of carbonate and non-carbonate minerals are prepared along side with the microfacies profiles.

1.2.5 <u>Ore petrography.</u>:For the mineralized zone, petrographic examination of ore and gangue minerals association are conducted.

1.2.6 <u>Evaluation.</u>: Relationships among microfacies, geochemical and mineralogical characteristics as well as mineralization will be established on the bases of existing data and information of the Song Toh Mine.

1.3 Methodology.

Prior to the design and formulation of the study methodology of the present investigation, literature studies regarding the geology as well as mineralization of the study area, and state of the art on carbonate-hosted lead-zinc mineralization have been conducted to serve as a background of the project. Following these backgrounds and objectives earlier outlined, the study methodology has been accordingly developed as a mean towards the ultimate goal of the study programme.

Basically, the methodology can be categorized into three parts, namely, fieldwork, laboratory work, and office work. Detailed description of the methods employed under the present investigation are as follows:

1.3.1 Background literature research.: Upon the selection of probable study area of lead-zinc deposits, preliminary assessment on literatures and maps regarding the geology, mineral deposit, and development status of the deposit has been carried out. Concurrently with the geological of the study area, an extensive review on theories as well as case studies on important carbonate-hosted lead-zinc deposits has been undertaken to fully understand state of the art of the theoretical aspect of the deposit.

This background study is a prerequisite for subsequent stages of field and laboratory investigations. Besides, an attempt has also been made to communicate with the owner of the deposit for the permission to access the area as well as the existing information.

1.3.2 Fieldwork.: It is realized that prerequisites for microfacies analysis are geological field studies and profiles, with special consideration of facies criteria. Therefore, the geological field investigation of the lead-zinc deposit at the Song Toh Mine and adjacent area has been carried out. Detailed measurements of lithostratigraphic sections of three important zones, notably, from the 545-metre level underground tunnel along the Dewatering Drift to Huai Chanee of approximately 1,500 metres long, the drill-hole number 68, and the drill-hole number 67 with the collar elevation of 575.714 metres above the mean sea level have been conducted. Besides, both ore and rock samples have been taken from the 545-metre level underground tunnel.

Extensive rock and ore sampling programmes have been carried out during the general surface-geology investigation and the measuring of the lithostratigraphic sections. In facies analyses, sampling units have been selected for which approximately similar or analogous sedimentation conditions can be assumed. The sampling method being employed is the stratified sampling.

In addition to the previously described geological investigation of the study area and the measuring lithostratigraphic sections, direct field observation on the mineralized zone as well as the ore sampling programme including the direct observation on the mining operation have been made. These direct field observation and sampling on the ore deposits and mining activities are considered to be important in finding the relationships between the lithostratigraphy and the mineralization on the megascopic scale.

1.3.3 Laboratory work.:

1.3.3.1 Petrographic study.: Standard thin-sections are prepared from all the rock samples collected during the geological field investigation and measuring stratigraphic sections for detailed petrographic study. Besides, acid etching and staining technique are employed whenever necessary to differentiate various carbonate minerals present. A data sheet for petrographic examination of carbonate rocks for the microfacies analysis is presented in the Appendix A. The classifications of carbonate rocks selected to be used in the present studies are proposed by Folk (1968) and outlined in the Appendix B. The technique for microfacies analysis of limestones employed in this study is modified after Flügel (1978).

The data and information obtained from the measuring of the sections and petrographic examination are finally presented as microfacies profiles.

1.3.3.2 X-ray diffractometry.: Apart from the petrographic identification of the mineralogical composition of rock samples, the X-ray diffractometry analysis has been employed to assist in the mineral identification, and the determination of calcite/dolomite ratio (Hutchison, 1974). For clay identification the procedure used is after Carroll (1970).

1.3.3.3 Geochemical facies analysis.: Generally, the interpretation of microfacies can be useful if it is supplemented by geochemical study. Carbonate sediments and rocks consist of two groups of elements: a) elements bound to a carbonate phase i.e., Ca, Mg, Sr, Mn, sometimes Ba and b) elements bound in minerals of acid non-carbonate residue i.e., Si, Al, Fe, B (Siegel, 1967).

In this study, an attempt has been made to determine the elemental composition of carbonate rocks, and the amount of elements present. These elements, however, can be classified into three classes, notably, major, minor, and trace. The major elements include calcium, magnesium; while the minor elements are lead, zinc, iron, and silicon. For trace elements which occur in concentration between 10^{-2} to 10^{-3} weight per cent, or less, include strontium, mercury, manganese, chromium, cobalt, nickle, copper, and silver (Flügel, 1978).

The technique employed in the determination of elemental composition is the atomic absorption spectrophotometry. The sample solution preparation under the present investigation is after Varian Techtron (1979). The analytical procedure used is after the manual of Shimadzu Atomic Absorption and Flame Emission Spectrophotometer Model AA-650, and the measuring conditions and absorption sensitivities for various elements are presented in Table D-1 (Appendix D). The analytical results are presented as geochemical profile together with microfacies profile.

1.3.3.4 <u>Ore microscopy.</u>: For the lead-zinc mineralized zone, ore samples are microscopically examined for the mineralogy, textures, ore paragenesis, and relationships among ore and gangue minerals, the carbonates and some shale-host rocks. The factual information obtained from the microscopic study will be served in establishing of paragenesis. The ore samples are prepared as doubly polished thin-sections to be examined under a petrographic transmitted and reflected light microscope.

1.3.4 Data evaluation.:

The data and information obtained from the petrographic study particularly regarding to the allochemical and orthochemical components, and mineralogical composition have been evaluated and compared with the carbonate facies models for facies determination and reconstruction of depositional environments.

The carbonate facies models employed in the present investigation are after Reeckmann and Friedman (1982), and Flügel (1978; Appendix E).

For geochemical data evaluation, an attempt will be made to correlate the relationships among Ca/Mg ratio with the acid insoluble residue, relationships between Ca/Mg ratio and other trace elements, relationships among trace elements, contents of trace elements and acid insoluble residue in each rock type.

Finally, with respect to the ore microscopic work, emphases have been given to the interpretation of primary and secondary ore textures, relationships among ores, gangue minerals, host rock, and paragenesis.

1.4 Previous investigations.

The lead-zinc deposits in the mountainous area of western Thailand have been known for quite a long time, but they have been described in detail recently.

During 1968 to 1971, a regional geological mapping of Kanchanaburi area was carried out by joint operation between the Department of Mineral Resources (DMR) and German Geological Mission (GGM). Almost all of the present knowledge on regional geology under the present study is based on their reports.

Yokart (1977) has carried out a general mineragraphic and geochemical study on various lead-zinc deposits in Thailand. A limited number of specimens of lead-zinc ores from Song Toh, Bo Yai, and Bo Noi Mines of Kanchanaburi area were also collected and described.

In 1981, Kuchelka gave a comprehensive report on the geology, mineralization, exploration, and development of the Song Toh lead-zinc deposit. In the same year Diehl and Kern discussed in detail on the geology, mineralogy, and geochemistry of the carbonate-hosted lead-zinc deposits in Kanchanaburi area. They discovered that sulphide mineralization is strata-bound and closely related to the development of reef-like algal crinoidal buildups which are incorporated in a thick Ordovician carbonate sequence. The sulphide precipitation was mainly controlled by primary porosity and permeability of the host rock. They concluded that the origin of the metal-bearing solutions is uncertain, but the chemical characteristics of the Song Toh deposit and mineralized tuff plus breccias near the deposits possibly indicate their genetic relationships to an igneous source.

In 1982, Permthong reported on the geological and mineragraphic study of strata-bound lead-zinc orebodies, Song Toh

Mine, Kanchanaburi. He concluded that sedimentary processes were responsible for the origin of the Song Toh mineralization and the orebody had been deformed penecontemporaneously with the enclosing rocks under low temperature conditions.

1.5 Exploration and mining history of the Song Toh Mine and its adjacent area.

Mining activities must have flourished for several centuries in the mountainous region between the two rivers (Khwae Yai and Khwae Noi). Numerous slag dumps furnish evidence of ancient mining aimed at producing silver. The slag contains mainly lead and silicates. The age of the first known mining activity can be dated between 1310 to 1640 A.D., before Ayutthaya Period (Kuchelka, 1981).

The ultimate aim of those early mining ventures was the extraction of silver. The remaining slag might have served for lead smelting later, e.g. production of bullets and Buddha images. Many lead ingot poured into clay moulds or bamboo canes have been found. Besides, several objects of silver and lead from the surroundings have been discovered. De la Loubère in of his voyage to Thailand in the mid-17th century reports of a well established lead mining and smelting industry (Kuchelka, 1981).

In the vicinity of Song Toh Mine a great number of twin shafts about approximately 0.4 square metres were discovered and they probably served for mining a horizontal outcrop of ores below and overburden of laterite. The name of Song Toh, which means "two pipes", is derived from these twin shafts (Kuchelka, 1981).

In 1912, the German-Austrian prospectors discovered the orebody of Bo Yai where a number of drill-hole and several adits were carried out in order to evaluate the grade and mineable ore reserve as well as the formulation of transportation plan. However, all works ceased during World War I. Between World War I and World War II some unsuccessful attempts were made by the Thai Army Signal Corps to start the ore production in solving the domestic shortage of lead.

In 1949, the joint operation between Royal Department of Mine and U.S. Geological Survey had conducted a reconnaissance survey of the Bo Yai lead-zinc deposit. The ore specimens of fine-grained galena and sphalerite containing a maximum of 1 per cent silver was reported (Brown, et al., 1953).

Subsequently, Smith and Rachadawong (1960) studied and made a report of Nong Phai and Bo Ngam lead-zinc deposits, Amphoe Sri Sawat.

The first modern type of mining in the area was carried out by Cominco (1949 to 1953). During that time over 100,000 tons of crude ores were extracted and concentrated by means of jig. In 1953, Mr. Bhol Kleabbua (shareholder of KEMCO) took over Cominco's mining rights and secured further claims in the surroundings. He started surface mining at various outcrops and since then sold more than 100,000 tons of lead concentrated including lead slag to Metallgesellschaft (Kuchelka, 1981).

As the easily accessible ores at surface had been exploited, Mr. Bhol Kleabbua and Metallgesellschaft AG in 1969 founded the joint venture company KEMCO with the aim to explore further deposits underground. German geologists carried out an exploration programme with more than 3,000 metres of diamond drilling which indicated potential reserves of 1.5 million tons of ores. Because of low metal prices and insufficient accessibility to the area, further exploration was ceased during 1971 to 1974 (Kuchelka, 1981).