Chapter 1

Introduction

1.1 General background

Evaluation of economic mineral potential in the Nan-Uttaradit mafic-ultramafic belt has long been a topic of interest among many geoscientists working in northern Thailand. It is believed that this belt has a high potential for many types of mineral deposit is commonly found within similar belts in the other regions of the world. The belt, on the basis of current evidence, represents a suture between the Shan-Thai (west) and Indochina (east) cratons. In this study, the name of Nan-Uttaradit suture zone or NUS zone will be used. The NUS zone is an extensive melange zone made up of variably sized blocks of different rock types enclosed in a serpentinite matrix (Panjasawatwong, 1991). Its extension in a NE-SW direction, although discontinuous, can be mapped for over 150 km covering the eastern part of Nan and Uttaradit provinces of northern Thailand. Different tectonic models regarding time and geometry of suturing, remain controversial (e.g. Thanasuthipitak, 1978; Bunopas, 1981; Helmcke, 1986; Panjasawatwong, 1991 and Singharajwarapan, 1994). The different opinions reflect not only the complicated tectonic evolution but also the scarcity of rock exposures in this suture zone.

During 1988-1989, the Department of Mineral Resources (DMR) launched nationwide airborne geophysical surveys, including magnetic, radiometric and electromagnetic (VLF-EM). On a follow-up scale, helicopter-borne survey, electromagnetic and magnetic, were made over five promising areas including Loei, Phetchabun, Kabin Buri, Lampang-Phrae and Uttaradit-Nan (KESIL, 1989). It was found that there are many mineral occurrences associated with the airborne geophysical anomalies (Kuttikul and others, 1988). Many ground follow-up surveys using geological mapping, and geochemical and geophysical techniques were made over recommended areas thereafter (e.g. Surinkum and Siripongsatian, 1992 and Surinkum and others, 1995).

Explorers use the tools of geology, geochemistry, geophysics and other fields to help identifying mineral deposits both in the regional and detailed scales. Detailed geological and geochemical surveys could provide a good basis for mineral potential evaluation of the NUS area. However, the techniques require a long period of field works and may not be cost-effective. The information obtained from such surveys will generally represent only near surface expression.

Up to now, there is no systematic study over the entire zone regarding the economic mineral potential, or criteria useful for mineral exploration in a comparable specific tectonic zone in Thailand. Besides, many land-use conflicts exist in the NUS area related to mineral resources exploitation and environment conservation. The definite answers of how and who should have the right to exploit the mineral deposits must be considered in every development plan. In order to alleviate these problems, the existing digital geophysical survey data should be integrated with other types of information to appropriately outline the status of any particular interesting area.

1.2 Purpose and scope of the study

After the decline of mineral export value of Thailand in 1985 because of the slump of global tin price (Japakasetr and Jarnyaharn, 1992), exploration programs for other types of mineral deposits were given more attention by the DMR. The NUS zone is one of the promising areas where many oversea exploration parties have shown interests, but the zone's complexity preventing them from making conclusive decisions. Moreover, the most serious issue in this particular area is the impact of development because part of the area covers watershed of Nan River where irrigation dam and flooding prevention are strongly spelled out. Most inhabitant and local non-government organization (NGO) groups are strongly against any conventional mining development program. However, it is essential to make an economic geology study of this area in order to provide a basis for further decision-making, not only for geological point of view but also for socio-economic consideration.

The three major purposes of this study are:

1. to identify mineral deposit potential area(s) within the NUS zone using geophysical data,
2. to delineate optimum procedure for exploration of various types of mineralization in the study area, and
3. to produce regional and detailed economic mineral deposit potential maps of the area.

Tectonic and geologic evolution of the NUS zone can also be explained on the basis of geophysical characteristics. These characters could be used to indicate how the NUS zone relates to Sa Kaeo suture zone to the south (Bunopas, 1981) and Lanchangjiang suture to the north (Yang and others, 1994). Moreover, the result of this study would be useful for future mining developments with optimum exploitation within the area.

Interpretation of geophysical data with emphasis on the structural geology and economic geology using appropriate approach and specific enhancement techniques was carried out. Ground checks for the interpretation results were summarized in order to verify the applicability of each technique.

Geographic information system, GIS, was also applied in this study. GIS is a collective term used to denote a combination of technology, processes, applications and products, which enable queries and reports to be carried out on data that have some form of geographic description and where the positioning description has been tied to a mapping area (Bonham-Carter, 1995). The final product of this study, in a GIS format, will be easy to use by non-geoscientist and allows operation and manipulation that previously not feasible in the present geological reports. Its application includes analytical testing and modelling against a range of criteria, e.g. economic, environmental and social.

1.3 The study area

The NUS zone is an elongated zone covering most of the eastern part of Nan and Uttaradit provinces, approximately from 100°15′E and 17°45′N to 101°15′E and 18°45′N. In order to study the entire area of this NUS zone and its adjacent area on a regional scale, the data covering twenty-three 1:50,000 topographic map sheets were selected for processing (Figure 1.1). The data was transferred to a PCs database type and divided into three different sets covering the northern part, central part and southern part of the area. Each part contains 3X3 map sheets, with two overlapping sheets between adjacent parts (Figure 1.1). Topographic map sheets and their index names used as a key connection in a GIS application are listed in Table 1.1.

Table 1.1 List of the 23 topographic map sheets

Map sheet	Index	Map sheet	Index
5044 IV	Amphoe Den Chai	5144 IV	Khuan Sirikit
5044 III	Changwat Uttaradit	5144 III	Amphoe Nam Pat
5043 IV	Amphoe Pichai	5143 IV	Amphoe Chat Trakarn
5045 I	Amphoe Rong Kwang	5146 I	Changwat Nan
5045 II	Ban Wiang Nua	5146 II	Amphoe Sa
5044 I	Amphoe Tha Pla	5145 I	Ban Nam Muap
5044 II	Ban Hat Ngiu	5145 II	Ban Na Num
5043 IV	Ban Saen Khan	5144 I	Amphoe Fak Tha
5146 IV	Ban Khuan Kaeo	5246 IV	Ban Huai Pu
5146 III	Ban Pang Chumphu	5246 III	Amphoe Mae Charim
5145 IV	Amphoe Na Noi	5245 IV	Ban Bo Bia
5145 III	Amphoe Na Mun		

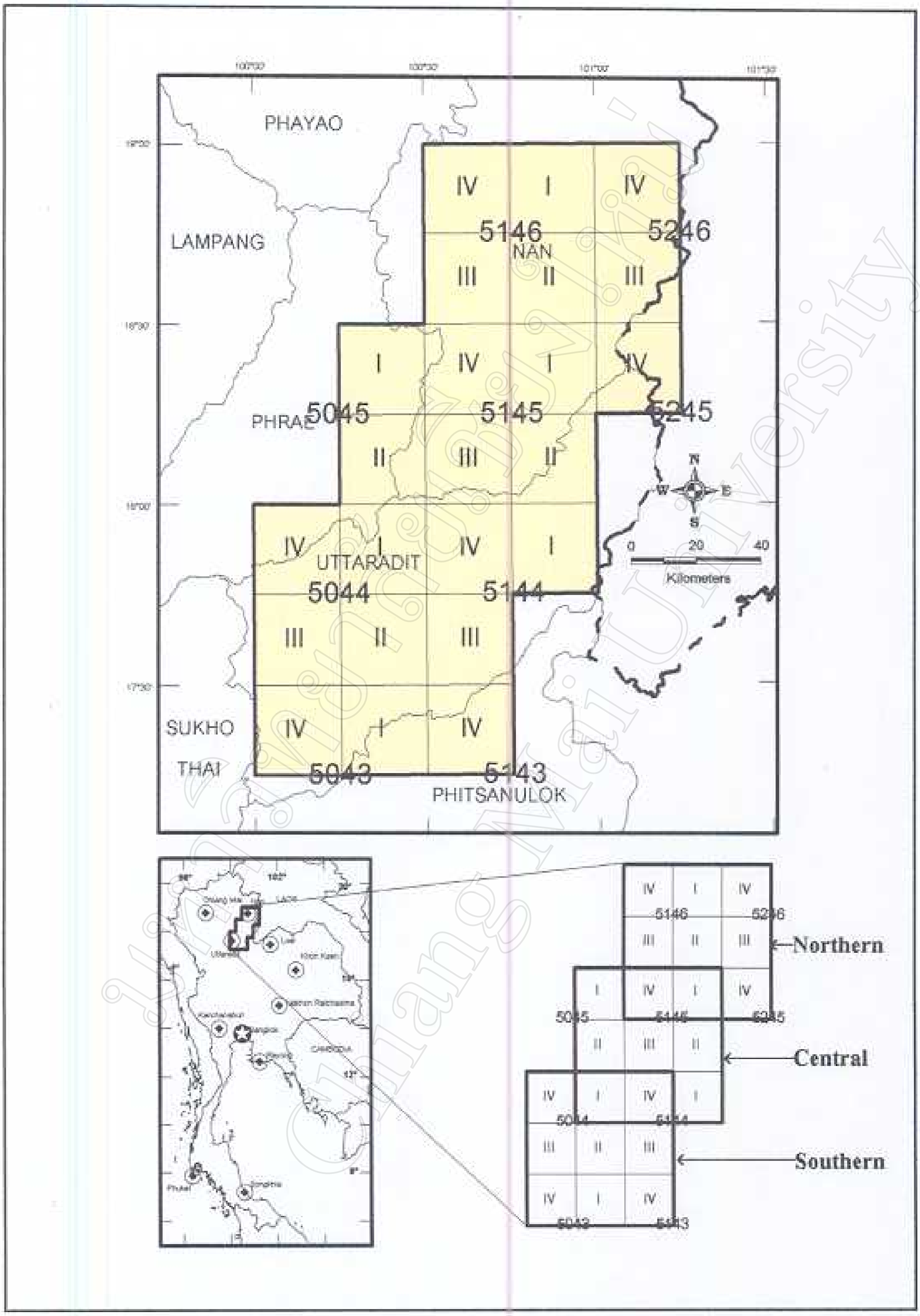

Figure 1.1 Map of the study area and its coverage.

The data from the Forestry Department (1998) on forest classification (Figure 1.2) and watershed classification (Figure 1.3), will be used as accessory factors for the final evaluation for mineral deposit potential. A total of twenty four target areas, located within thirteen map sheets, that represent all kinds of mineralization found, were initially selected for follow-up surveys. Their detailed interpretation will be used as a guideline to make the whole economic evaluation for all mineral deposits in this study area.

1.4 Previous works on the study area

1.4.1 Geophysical survey

Using an analog airborne geophysical survey data, Kuttikul and others (1988) identified helicopter-borne electromagnetic (HEM) anomalies of the Nan-Uttaradit area. Subsequent field checks revealed that a large number of the anomalies are related to geological features but not the mineralization. KESIL (1989) or Kenting Earth Science International Limited recommended several target areas for massive sulphide mineralization on the basis of electromagnetic signatures, but none proved to be economic deposits (Pintawong, 1998). Dejen (1993) made an attempt to outline geological features and mineral prospecting areas in the southern part of this NUS zone using a follow-up scale airborne geophysical data. Mappings of lineament, shear zone and fracture zones were done successfully.

Aeromagnetic, airborne radiometric and helicopter-borne electromagnetic data in the area were also studied separately, using specific enhancement technique to define true anomalies, although mineral potential of these anomalies was not attempted (Kiatiwongchai, 1995; Wisedsind, 1995; and Otarawanna and others, 1997). Neawsuparp (1997) used the Landsat TM image integrated with the aeromagnetic data to study the structure of the NUS zone and a suture major line is proposed. Tulyatid (1997) used airborne geophysical data to explain the structural control of the Chao Phraya Basin. His study reveals that the NUS zone, which can be extrapolated beneath the Phitsanuloke sub-basin, had been active through Tertiary time and controlled the oil trapping mechanism. Sukontapongpow (1997) used aeromagnetic data to define suture zones and a number of strike-slip faults nationwide. He also recommended six mineral potential areas in the NUS zone for detailed study.

There were many ground geophysical follow-up surveys to verify the anomalies indicated from each airborne geophysical data mentioned above. Some aimed to locate specific mineral deposits and some to identify type of anomalies. Siripongsatian and others (1991) selected five different HEM anomalies in Ban Hat Ngiu sheet (5044 II) for ground verification. They found that one of these anomalies is a graphite deposit (Surinkum and Siripongsatian,

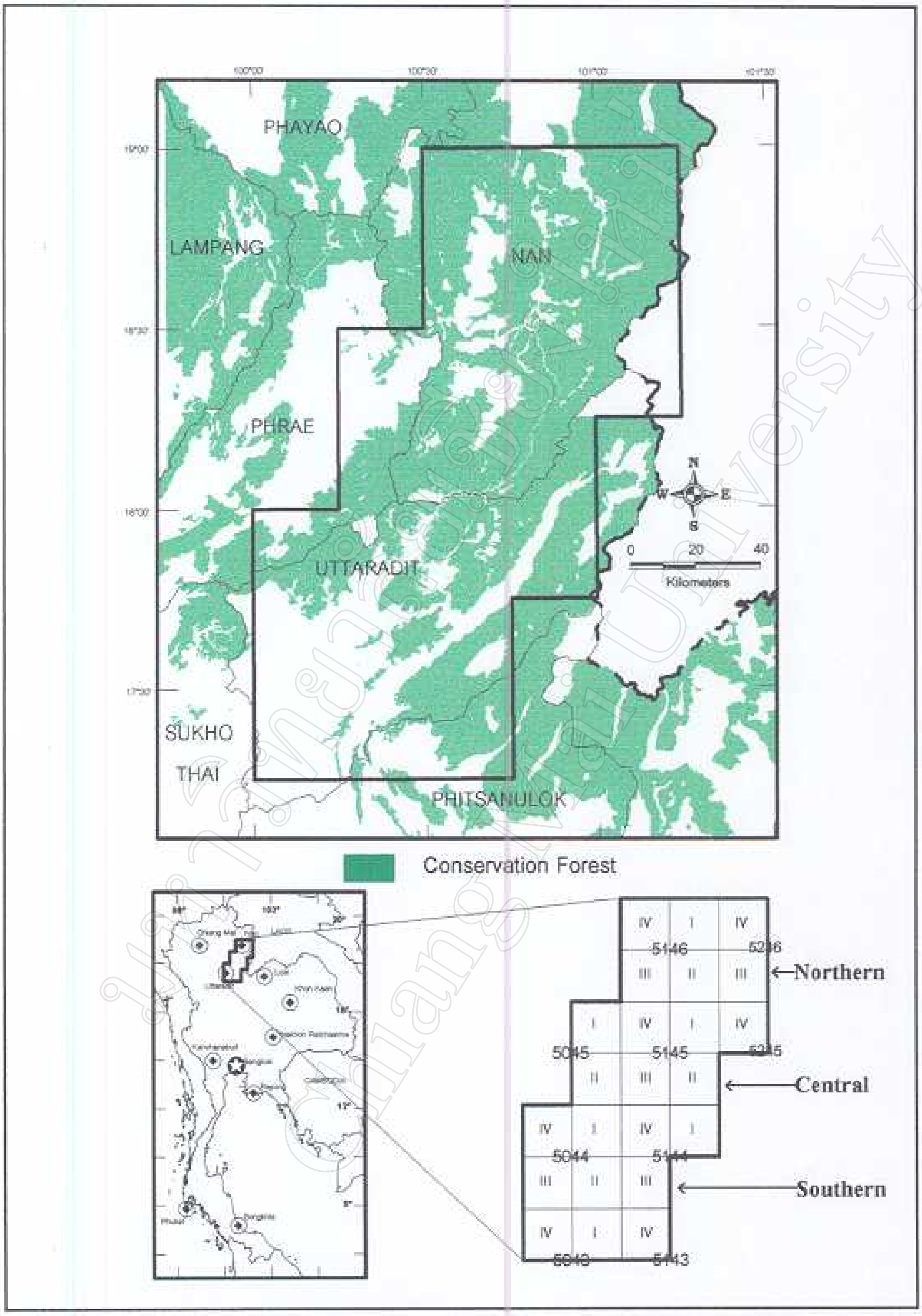

Figure 1.2 Map showing conservation forest in the study area.
(after Forestry Department , 1998)

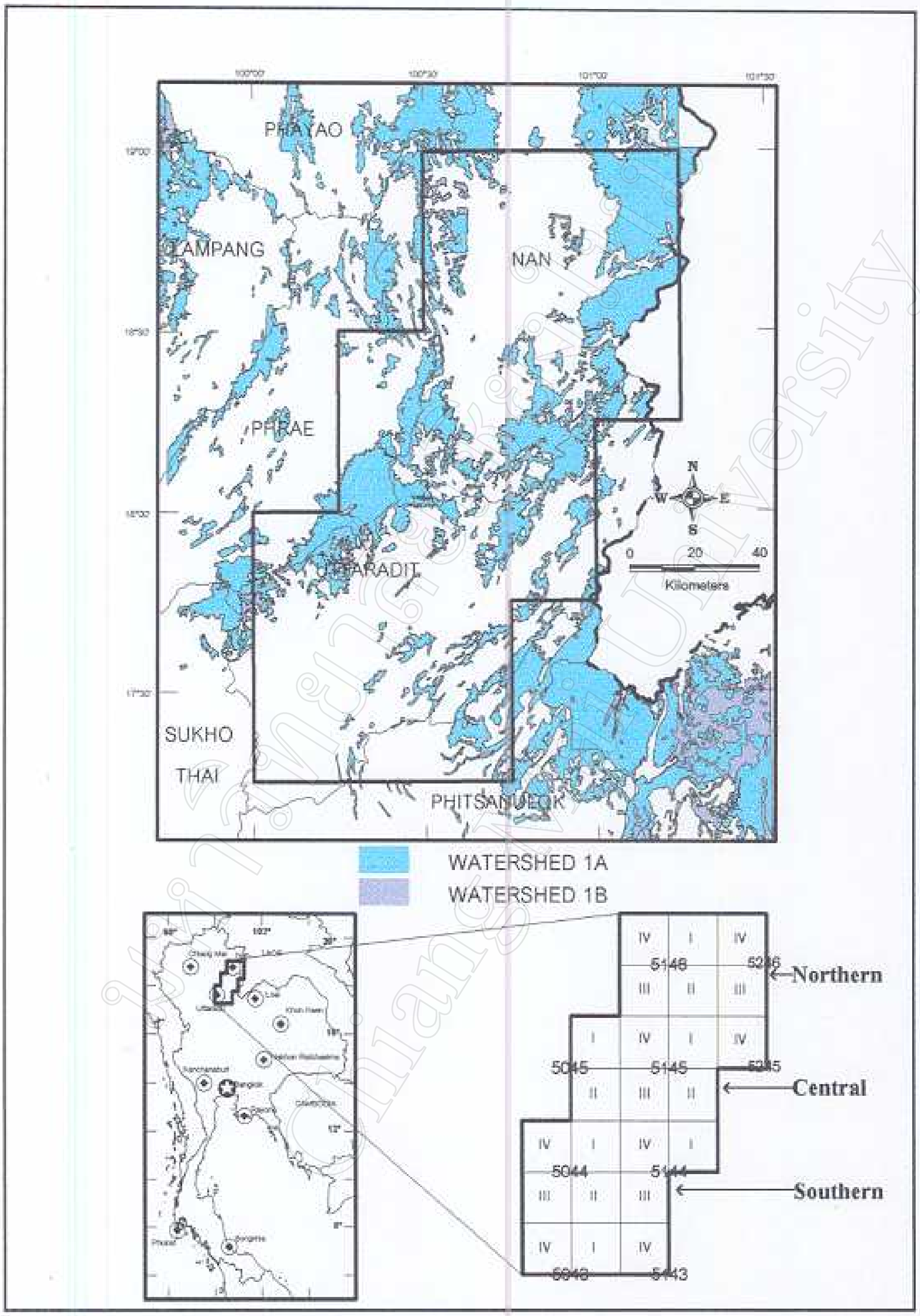

Figure 1.3 Map showing watershed classification in the study area.
(after Forestry Department , 1998)

1992). The results of their study over characters of HEM anomaly were then used as a standard for ground follow-up surveys in many areas. However, it was found later that one of their anomalies is an iron pipe used for water supply buried less than 3m deep from the surface (Paiyarom and Surinkum, 1997). This evidence indicates that a small target can definitely be located if an appropriate procedure is made.

Munyue and others (1991) correlated HEM anomalies with mineral occurrences north of the Sirikit Dam. They made some pitting and concluded that only chromite potential is worth considering. Techawan and others (1992) used the same survey system as Siripongsatian and others (1991) for the HEM anomalies in Khuan Sirikit sheet (5144 IV). They found that many negative inphase HEM anomalies are associated with chromite occurrences. In such case, magnetic survey plays an important role in locating a center of each chromite deposit because chromite is a magnetic body (Surinkum, 1989) while electromagnetic survey needs more specific interpretation diagram to make a right model (Neawsuparp, 1996). Seesamrurng (1996) used an induced polarization method to study the model of a graphite deposit and found that the result does not give a definite answer on the ore potential.

1.4.2 Geology

Hinthong and others (1999) reconstructed geology of the Nan area and its vicinities using new evidence along a new road cut. The geologic maps of both 1:250,000 scale (Figures 1.4-1.7 and Table 1.2), and 1:50,000 scale, published during 1975-1977 and 1984-1989 respectively, were used as base maps. Previous works on geology, such as Macdonald and Barr (1984), and Barr and Macdonald (1987), were also considered. Although their study covers only the northern part it can be correlated with the entire NUS zone. They interpreted that the Nan area was subjected to some degree of deformation and tectonism. Faulting effects can be observed from Permo-Carboniferous through Quaternary (Fenton and others, 1997). The major fault lies between Permo-Triassic ophiolite complexes and Cretaceous continental redbeds. This fault had been active as a left-lateral wrench fault through Tertiary time (Tulyatid, 1997). Two major cleavage directions: northeast-southwest and north-south, typically developed in the Permo-Carborniferous through Jurassic sequences along with overturned anticlinal structures of angular, tight, and isoclinal fold. Folding in the Cretaceous sequences are open fold.

Shallow marine depositional environments prevailed in the Carboniferous through Permian periods (Sukvattananunt and Assavapatchara, 1987). Subsequently, the sedimentary basins became deeper during Permian to Triassic periods. Pre-Permian oceanic arc setting produced mafic and ultramafic rocks (Barr and Macdonald, 1987). During

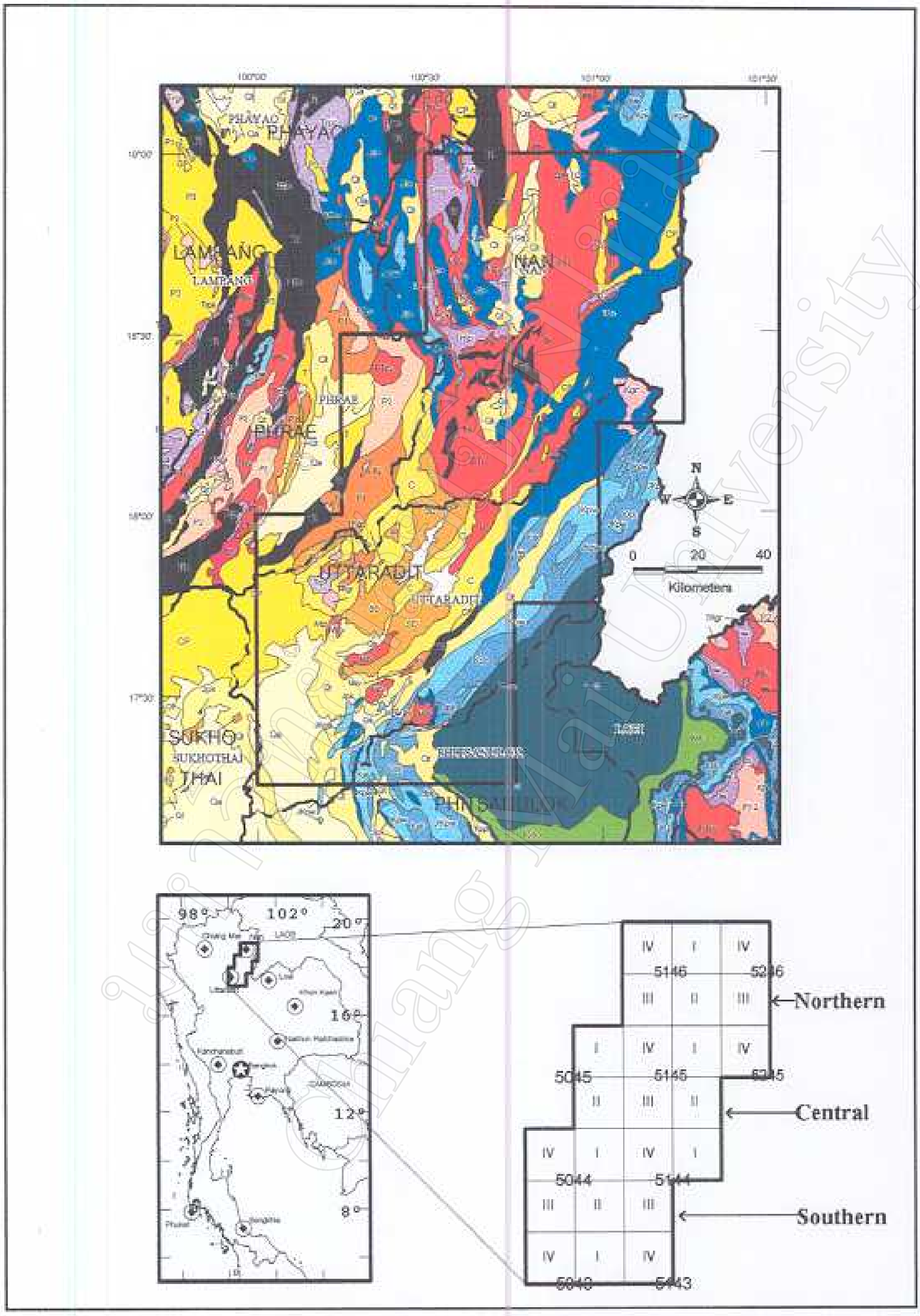

Figure 1.4 Geological map of the study area.
(after ESCAP, 2002)

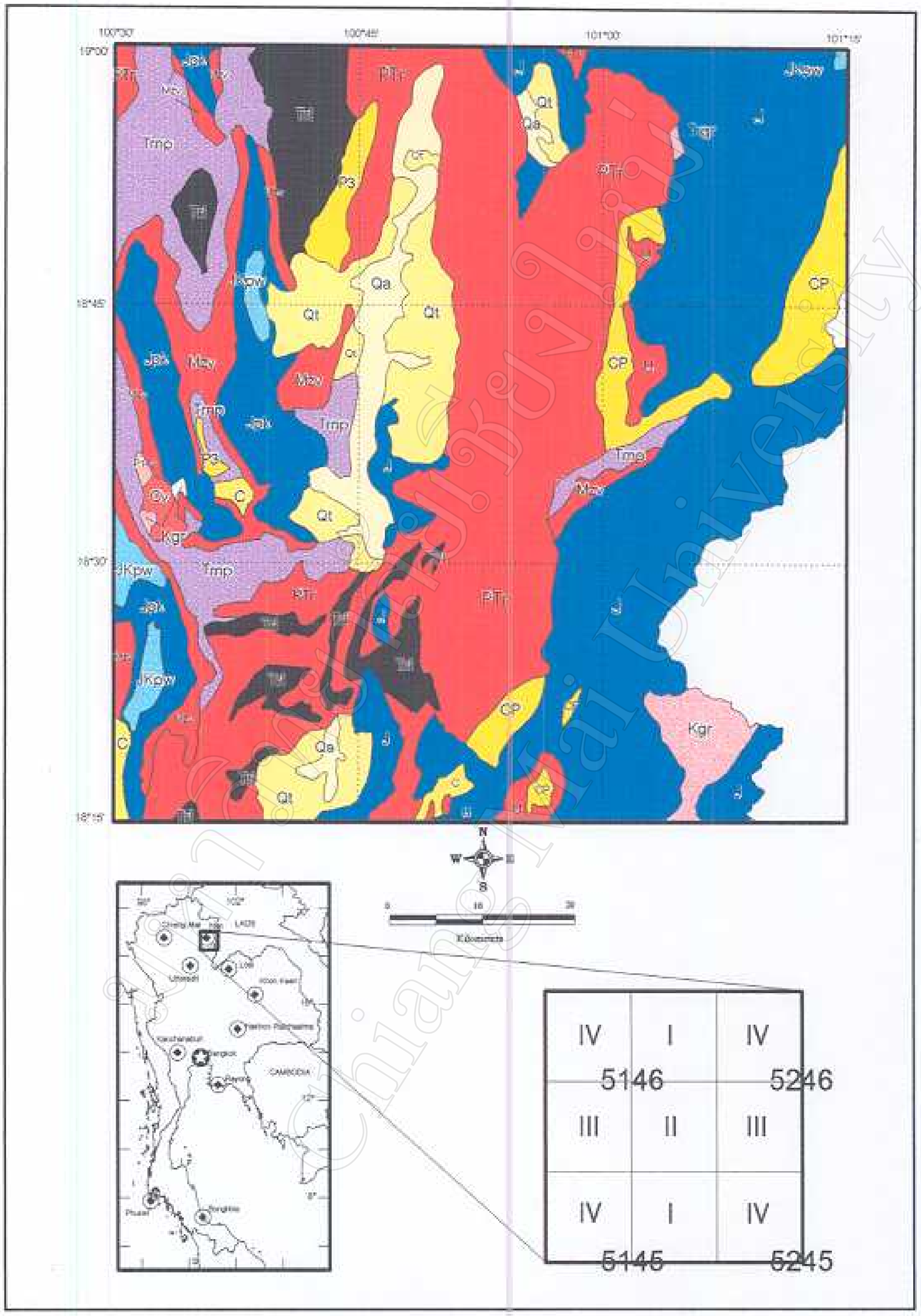

Figure 1.5 Geological map of the northern part of the study area.
(after ESCAP, 2002)

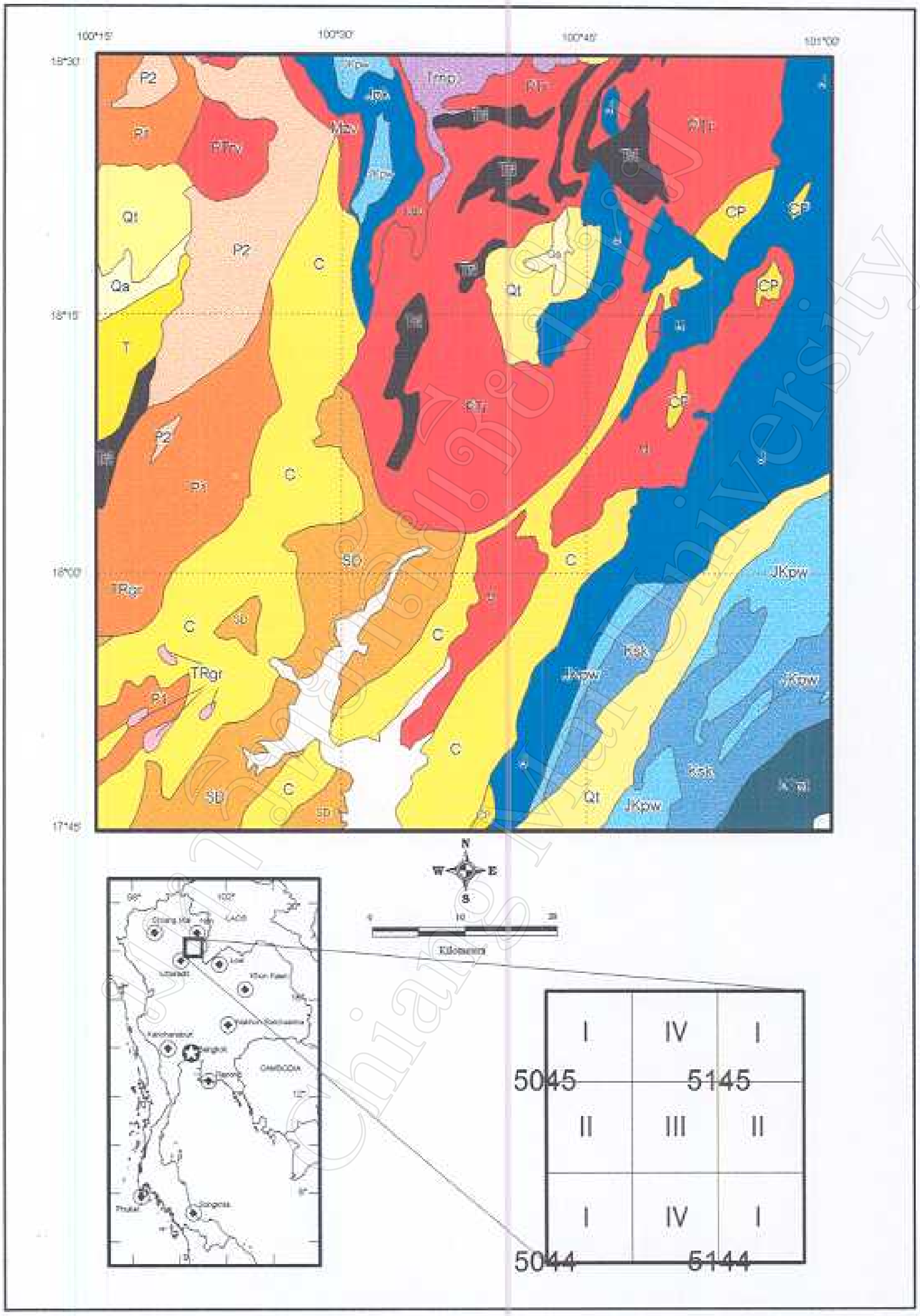

Figure 1.6 Geological map of the central part of the study area.
(after ESCAP, 2002)

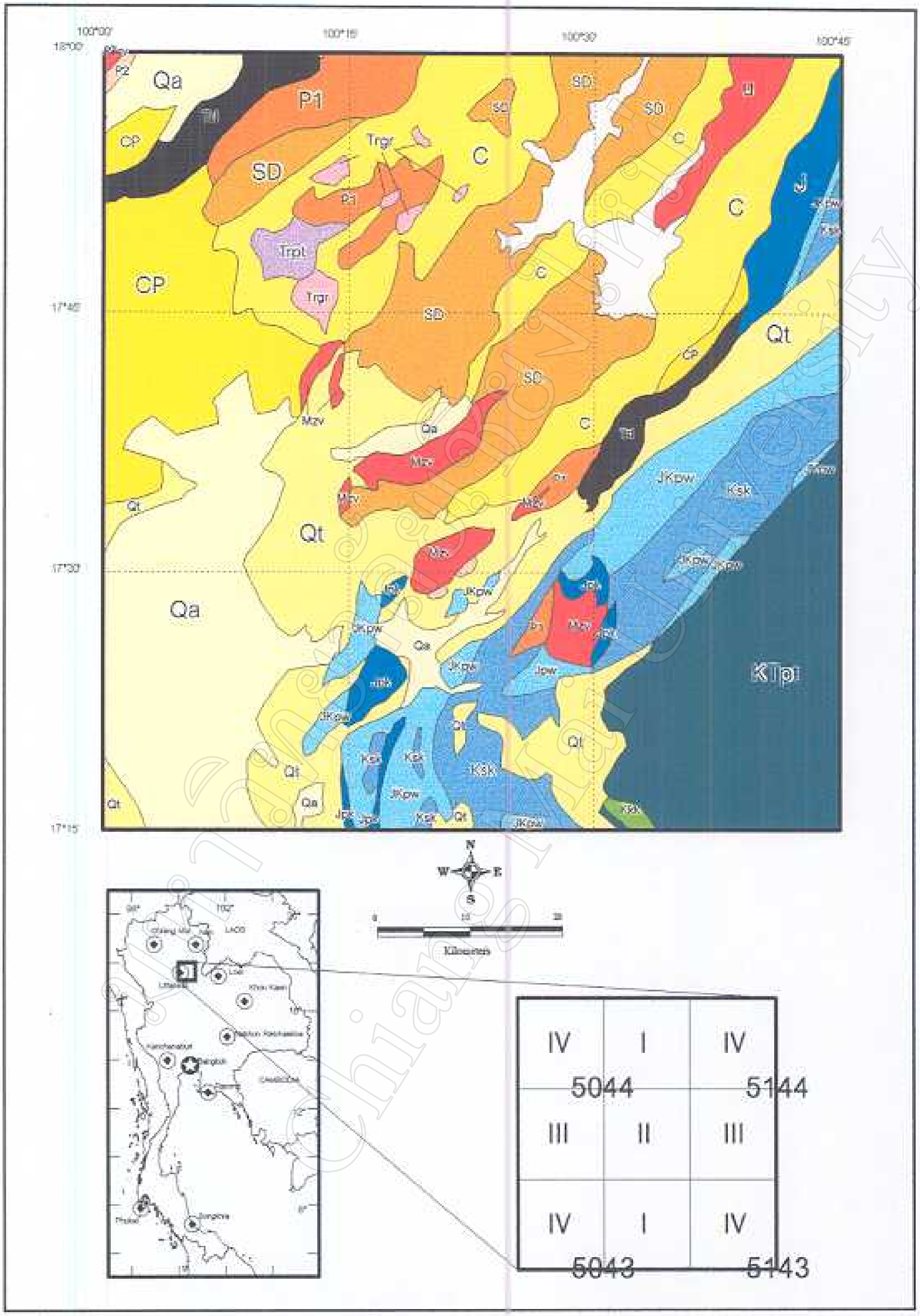

Figure 1.7 Geological map of the southern part of the study area.
(after ESCAP, 2002)

AGE	SEDIMENTARY AND METAMORPHIC ROCKS		IGNEOUS ROCKS
QUATERNARY	Qa: Alluvial deposit:river	Qt: Terrace and colluvial deposits	bs: Basalt
TERTIARY	T: Sandstone, shale, oil shale, lignite, limestone, and locally rare conglomerate	Kpt: Brownish-red, fine-medium grained, well sorted sandstone	
CRETACEOUS		Kkk: Brown, reddish-brown micaceous sandstone Kpp: White to yellowish brown, pebble sandstone Ksk: Reddish brown siltstone, mudstone, sandstone, and shale	Kgr: Granite, granodiorite, and diorite
JURASSIC	J: Limestone, argillaceous limestone, shale and siltstone	JKpw: White to light brown quartz sandstone; siltstone, and shale Jpk: Purplish-red siltstone and sandstone	Mzv: Rhyolite, andesite, and tuff
TRIASSIC	TRk: Marine: sandstone, tuffaceous sandstone, limestone, and greenish grey shale Trpk: Grey; massive and banded with shale and sandstone Trpt: Basal conglomerate; sandstone, agglomerate and tuff	Trnp: Brown to red sandstone, shale, and conglomerate Trhl: Interbedded shale, mudstone, siltstone, greywacke with volcanic rocks and plutonic rocks	Trgr: Pophyritic biotite granites, granodiorite hornblende-adamellite and fine-grained muscovite-tourmaline granite u: Basic and ultrabasic plutonic rock
PERMIAN	PTr: Marine:sandstone, shale, and limestone P3: Shale, calcareous/carbonaceous shale; with chert bed P2: Bedded to massive limestone, shale, tuffaceous sandstone, tuff and chert P1: Tuffaceous shale and sandstone	P1-2: Limestone	PTrv: Andesite, rhyolite, tuff, and agglomerate
CARBONIFEROUS	CP: Sandstone, shale, and chert C: Conglomerate, sandstone, shale, chert beds, and limestone		Cv: Mainly andesitic agglomerate, also minor tuff, breccia, and volcanic conglomerate
DEVONIAN	SD: Quartzite, phyllite, schist, sandstone, shale, and tuff		
SILURIAN			

Modified from ESCAP (2002)

Table 1.2 Legend and description of geological units.
(referred to in the geologic maps : Figures 1.4 - 1.7)

the continent-continent Shan-Thai/Indochina collision, both marine sedimentary sequences and oceanic crusts were compressed and formed an accretionary complex. It is also evident that such collision took place during Late Triassic period, leading to the culmination of the marine sedimentary basins and commencing of the continental deposit (Singharajwarapan, 1994). There was a transitional environment from marine facies in Triassic grading up to continental facies toward Jurassic (Hinthong and others, 1999).

The Triassic-Jurassic sequence comprises mostly argillaceous rocks in the lower part and arenaceous rocks in the upper part. Some are intercalated with shallow intrusive and volcanic rocks, as well as volcanic tuff. Intense-folded units of redbeds, mostly sandstone, delineate Jurassic rocks of which brackish water bivalve indicating marine incursion. The continental redbeds of the Cretaceous are characterized by brick-red mudstones and siltstones of relatively less deformed sequence, coupled with evaporites and rock salts. The Tertiary sequence consists mostly of sandstones and siltstones with lignites underlying the Quaternary sediments. Terrace deposits and unconsolidated sediments are the Quaternary sequences found within the intermontane basins in the area.

1.4.3 Mineralization

Many mineral deposits, asbestos, talc and chromite, are associated with the mafic-ultramafic plutonic rocks of this study area (Brown and others, 1951; Suwanasing, 1963; and Shawe, 1984). Sekthera and others (1978) carried out a regional geochemical survey and recommended that there is a potential for nickel and chromite south of the Sirikit dam. Pitragool and others (1986) selected chromite target area at Ban Huai Lao for economic evaluation using various methods including some geophysical surveys for detail study on magnesite and chromite mineralization in Doi Phuk Sung area, east of Na Noi District of Nan. However, the geophysical data was not quite useful and many questions about the economic evaluation must be answered. Orberger and others (1989) studied the distribution of platinum group elements (PGEs) in the whole rock unit in this mafic-ultramafic belt. They concluded that this belt is quite promising for both PGEs and other associated mineral. But only one chromite deposit near Ban Ngom Tham of Uttaradit province is drilled and considered as one of the most promising area for further development (Jeenawut, 1996). Gold and copper mineralizations have also been reported by various authors (e.g. Chaleechan, 1954 and Carrel, 1964) but their accessibility for further study is limited. Some geochemical survey thereafter did give more specific target areas for gold and copper but not a conclusion about their economic potential (Paopongsawan and others, 2000).

Ounchanum and others (1991) made a petrographic study of serpentine minerals in the NUS zone and reported that talc here was first developed by shear mechanism and then by hydration. Surinkum and Siripongsatian (1992) who were the first to report a graphite occurrence in the NUS zone, believed that the graphite is altered organic matter formerly present in the sedimentary unit located on the southernmost of this suture zone. They proved that there is an extension toward the north via the zone of HEM anomaly. Marble which is located not far from the graphite and may be formed with the same mechanism, is mined from Permian limestone. The potential of illite in the area was outlined using Landsat imageries (Leungingkasoot and Techawan, 1997). Four different zones of illite were subsequently located by ground geophysical surveys (Surinkum and others, 1997). Mineral inventory reported by these authors is summarized in the map of mineral occurrences of the NUS zone shown in Figure 1.8.

Kumanchan (1992) made the first mineral resources map of Thailand (scale 1:500,000) and indicated that the most important mineral deposit is nickel-chromium associated with an elongated ultramafic unit. This unit is 15 km wide and 124 km long as shown in Figure 1.9.

Other types of the ground follow-up surveys over the NUS zone, is a geochemical survey. Pintawong (1998) reported on the mineral potential of the NUS zone based on semi-detailed geological mapping and chemical analysis. He made mineral potential evaluation and showed that there is also a potential for nickel exploration. Stream sediment and bank-soil geochemical studies were also made, but the techniques were considered ineffective for this complex zone (Paopongsawan, 1996). In general, geochemical survey data reveal that the distributions of chromite, nickel, cobalt, copper and lead are controlled by the bedrock geology (Yensabai and Watcharachaisuraphol, 1992).

The mineral potential map, at 1:250,000 scale, covering the NUS zone indicates that there are at least eight potential areas (Yensabai, 2002). The most pronounced potential areas are nickel and chromium in the central part and gold in the northern part (Figure 1.10).

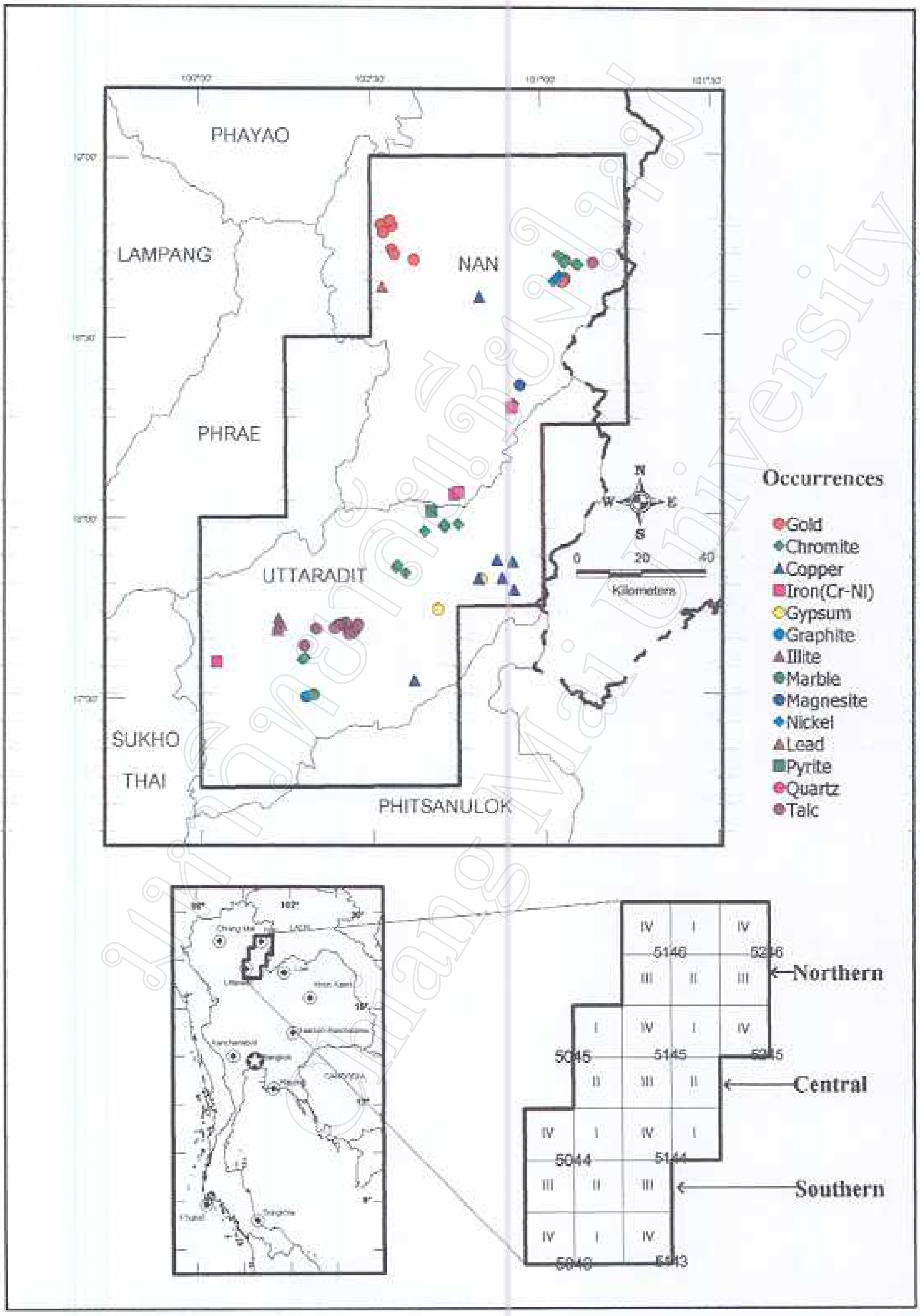

Figure 1.8 Map showing mineral occurrences in the study area.

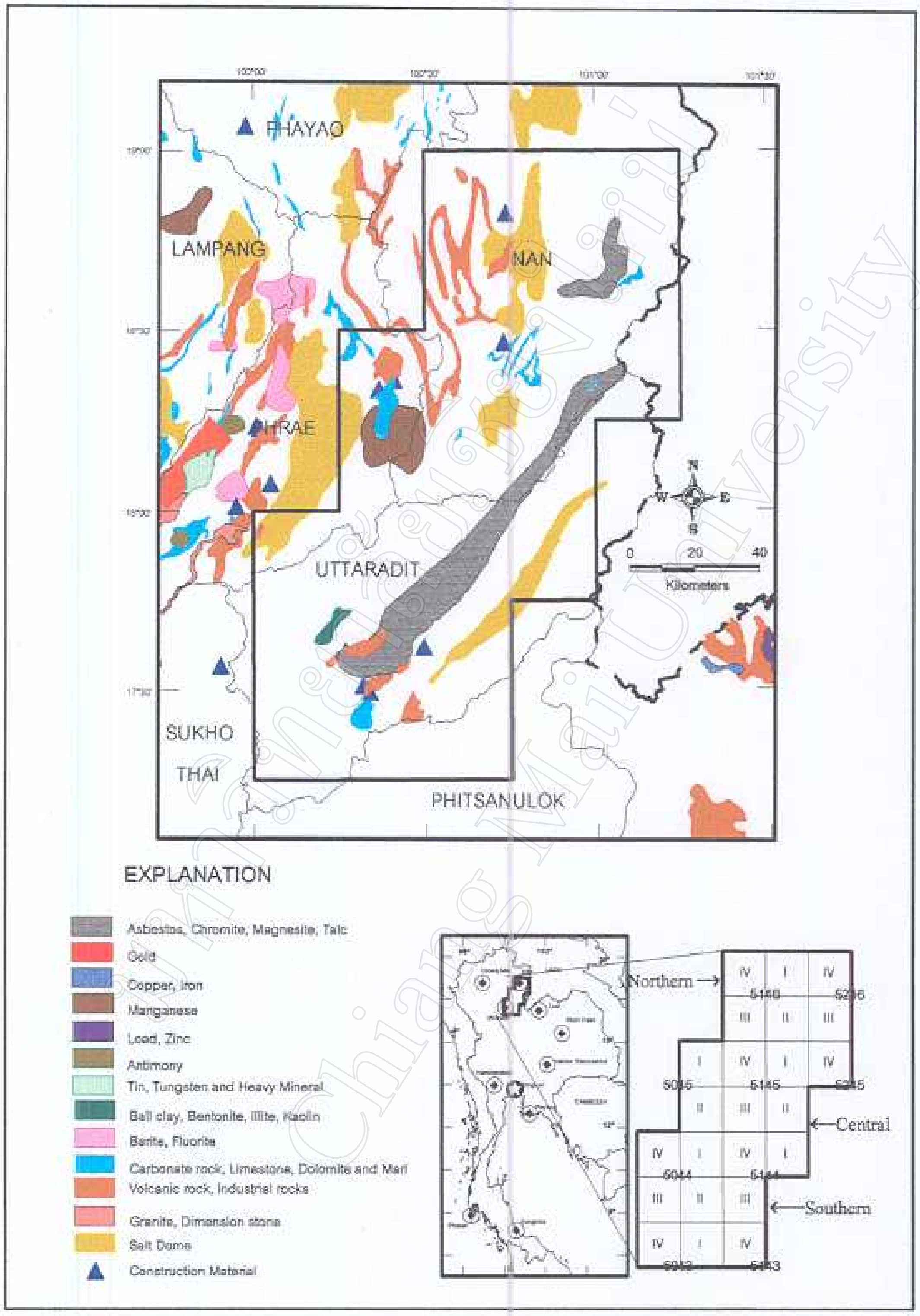

Figure 1.9 Mineral resources map of the study area.
(after Kumanchan , 1992)

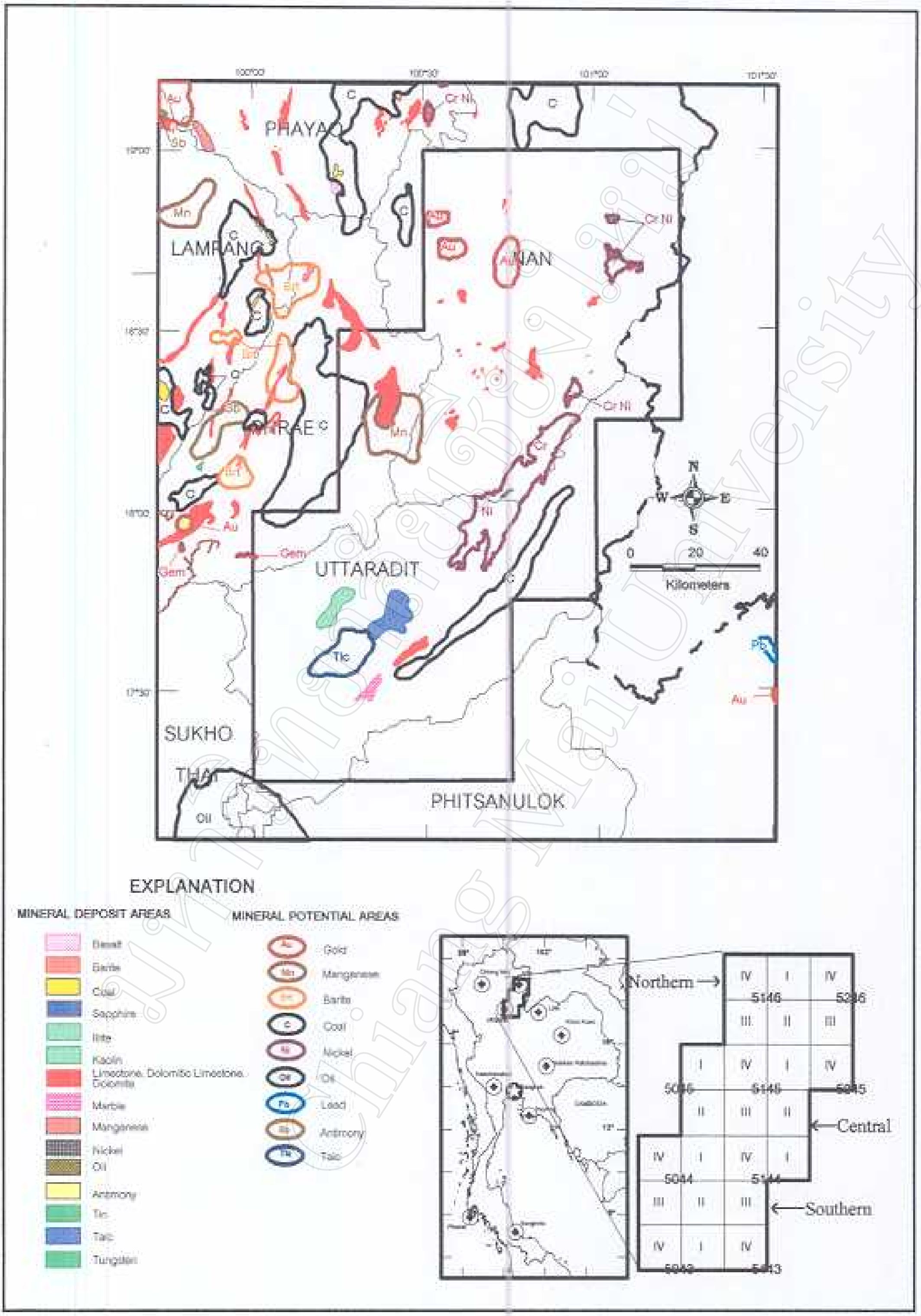

Figure 1.10 Mineral potential map of the study area.
(after Yensabai , 2002)