Chapter 5
Mineralization Related to the Nan-Uttaradit Suture Zone and Its Evaluation

The NUS zone is characterized by Paleozoic-Early Mesozoic igneous and sedimentary sequences. This zone consists of ophiolitic mafic to ultramafic and sedimentary rocks produced by pre-Permian sea-floor spreading and back-arc or inter-arc setting (Barr and Macdonald, 1987). These sequences were destroyed by continental-continental collision that completed during the Late Triassic (i.e. Bunopas and Vella, 1983, Panjasawatwong, 1991). Mineralizations associated with the NUS zone can be divided into two stages, pre-collision and post-collision. The pre-collision mineralization is composed of minerals related to oceanic crust and metamorphosed products during the collision. While the post-collision mineralization is composed of mineral deposits formed by late metamorphism, igneous activities and weathering associated with uplifting and erosion activities.

5.1 Pre-collision mineralization

5.1.1 Chromite

Rocks of mafic and ultramafic composition are the major sources of the chromite. Traditionally, the chromite ores are divided into two types, stratiform and podiform. Stratiform ores are mafic and ultramafic layered intrusions. Podiform ores, highly irregular geometry, are consistently associated with ophiolites. So, the most valuable guide to exploration, which seems to have global applicability, is the association of podiform chromite with the ultramafic zone of ophiolite complexes. However, the distribution of economic concentrations of chromite within ophiolite complexes is highly variable. For example, the Alpine belt which extends through Yugoslavia and Albania to Greece is notably rich in chromite, whereas the New Zealand ophiolites have no important concentrations of chromite (Evans, 1987).

Podiform chromite deposits are formed initially within the oceanic lithosphere, and are sometimes transported tectonically to shallower structural levels during orogenesis. Therefore, chromite with very limited geographical distribution of resources is an important strategic mineral. More than 80 % of the USA imported chromite ore in 2000 is from South Africa and the rest are from Canada, the Philippines and Croatia (Mineral Industry Survey, 2000). As a consequence of its industrial importance and limited geographical distribution, chromite is classed as a strategic mineral. It is therefore necessary to improve the geological concepts and exploration techniques that will lead to the discovery of future reserves.

In the past it appeared that there is little alternative to detailed geological mapping within ophiolite complexes, with closely spaced percussive drilling in areas with favourable geological characteristics. However, a paucity of consistent exploration guides, and a lack of appropriate indirect methods hinder the search for new podiform chromite deposits in this environment. At present, magnetic survey with a specific survey layout is proved to be an appropriate technique to delineate chromite, mentioned earlier in Chapter 4, from host rocks of serpentinite and peridotite.

In this study area, ophiolites which host podiform chromite deposits commonly form discontinuous curvilinear features and extend for a hundred of kilometres. Jeenawut (1996) summarized chromite potential areas and classified them into three different restricted places: Mae Charim, Rae Nan mining, and Tha Pla areas. These chromite ores occur as massive pods enveloped by serpentinite and peridotite blocks, disseminated chromite and accessory chromite in serpentinite and peridotite blocks as shown in Figure 4.1. In order to apply geophysical survey for chromite evaluation, a known chromite deposit with various occurrence types is selected for ground check. Chromite deposit at the locality northeast of Ban Huai Phai, consisting of massive, nodular, and accessory chromite in serpentinite, is selected for geophysical surveys (Figure 5.1). The chromite occurrences in this area are associated with negative inphase HEM anomalies located east of an elongated conductive zone.

Magnetic and electromagnetic surveys were applied in order to verify these anomalies and to correlate them with chromite occurrences. Ground magnetic survey result (Figure 4.13) indicates that chromite is a magnetic body with higher magnetic susceptibility than serpentinized dunite host rock and form as massive lenses and as small pods in the host rocks. Pintawong (1998) reported chemical analysis results of the ore with chromium to iron ratio between 1.3 to 3.0 and iron content from 11% to 13%. The conductors indicated by HEM survey were confirmed by the ground electromagnetic survey where the contacts between serpentinite and phyllitic shale formations were outlined. These assumptions can be used to outline potential areas of chromite within this selected area as shown in Figure 5.2.

The chromite ore bodies, interpreted from magnetic data, trend approximately in a north-south direction with steep dipping. In conclusion, the most promising approach indicated by this study is a combination of magnetic and electromagnetic techniques, although neither technique produced anomalies of dramatic dimensions, i.e. a limited area for drilling can be identified.

In general, chromite is the only chromium-bearing ore mineral, and in podiform deposits, it is normally associated with olivine. By-product

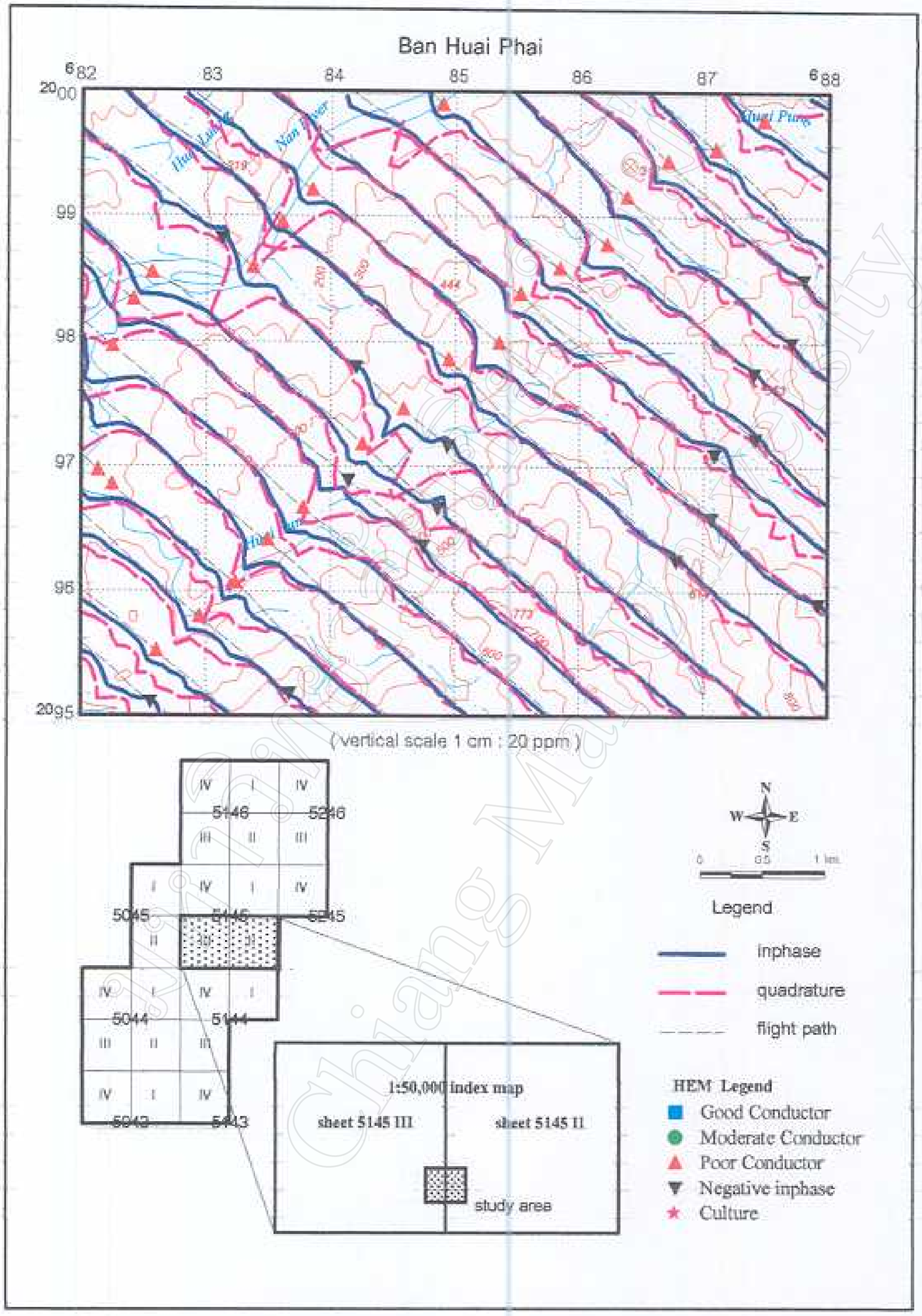


Figure 5.1 Selected area in Ban Huai Phai for chromite evaluation using geophysical survey.

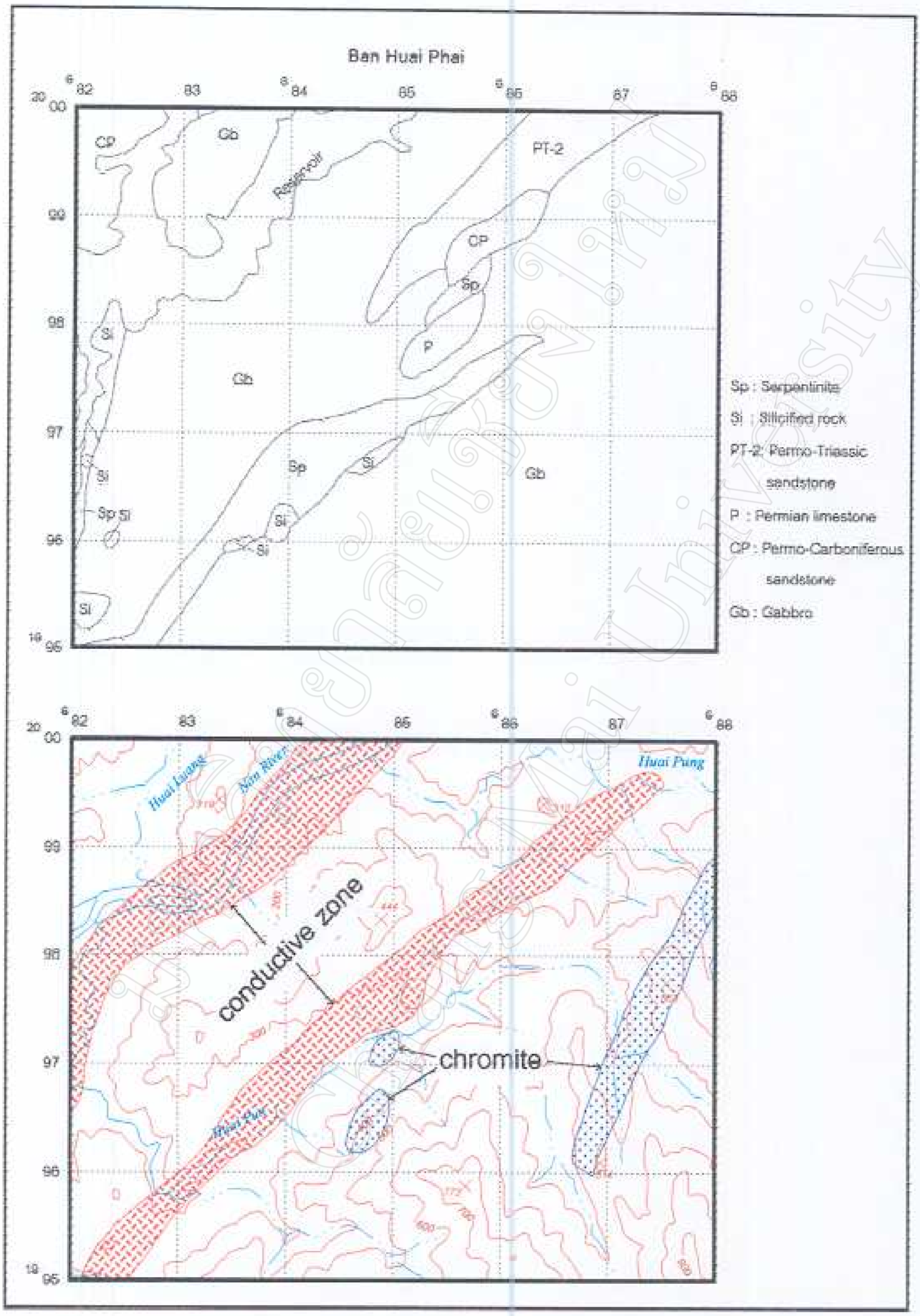


Figure 5.2 Potential area of chromite in the selected area.

(geology : after Chaturongkawanich and Leevongchroen , 1987) minerals are not characteristic of this style of mineralization. Platinum group elements are detectable in podiform chromite but not in sufficient concentration to merit their extraction (Duke, 1983). The ophiolite complexes, which host podiform chromite, may, however, also be a source of copper and are sometimes mined for magnesite, chrysotile asbestos and talc.

5.1.2 Chrysotile asbestos

Chrysotile, a fibrous variety of serpentine, is a product of low-grade metamorphic alteration from ultramafic rocks in an environment rich in water. Asbestos is a commercial term applied to natural fibrous silicates that are amenable to mechanical separation into fine filaments of considerable tensile strength and flexibility. These fibres have, by virtue of unique combinations of physical and chemical properties, a great variety of industrial uses. During the twentieth century it has become one of the principal industrial minerals used for many purposes, such as brake linings. However, their industrial uses were declined when hydrocarbon materials replaced them at the end of the twentieth century through twenty-first century. The asbestos productions in Canada were declined from 531 tonnes in 1994 down to 447 tonnes in 1997 while South Africa, a major producer, normally produces 50,000 tonnes a year started to close down some operations following a fall in world demand for blue asbestos (Lawson, 1998).

Asbestos is a group of minerals that separates readily into fibres. The minerals differ in chemical composition and in the strength, flexibility and usefulness of their fibres. Broadly, they fall into two groups; serpentine and amphibole; the latter include anthophyllite, crocidolite, amosite, tremolite and actinolite. Chrysotile is the most valuable variety. Its fibres are fine, silky, and strong; 4,350 m of thread can be spun from a kilogram of the mineral. Some varieties withstand temperatures up to 2,750°C. Tremolite and actinolite have little commercial value. Some actinolite is ground up for insulating purposes and of interest to scientists and collectors for its crystal and colour.

These minerals are found in many places along the ultramafic units in this study area but none of them can be correlated directly to HEM anomalies. The known occurrence in the Nam Sing area of Uttaradit was selected to determine their correlation with the ground geophysical survey (Figure 5.3). It was found that asbestos, like actinolite, has no definite relation with any geophysical signals (Figure 4.21). Actinolite is a moderate conductor and has low magnetic susceptibility. It occurs in the contact zone between conglomeratic sandstone and peridotite. Its location can be defined because conglomeratic sandstone has no magnetic anomaly whereas peridotite has non-systematic magnetic anomaly patterns. Ground geophysical data indicate that asbestos is a poor conductor and not a magnetic body. Therefore, ground geophysical surveys cannot be used to evaluate any asbestos potential area (Figure 5.4). However,

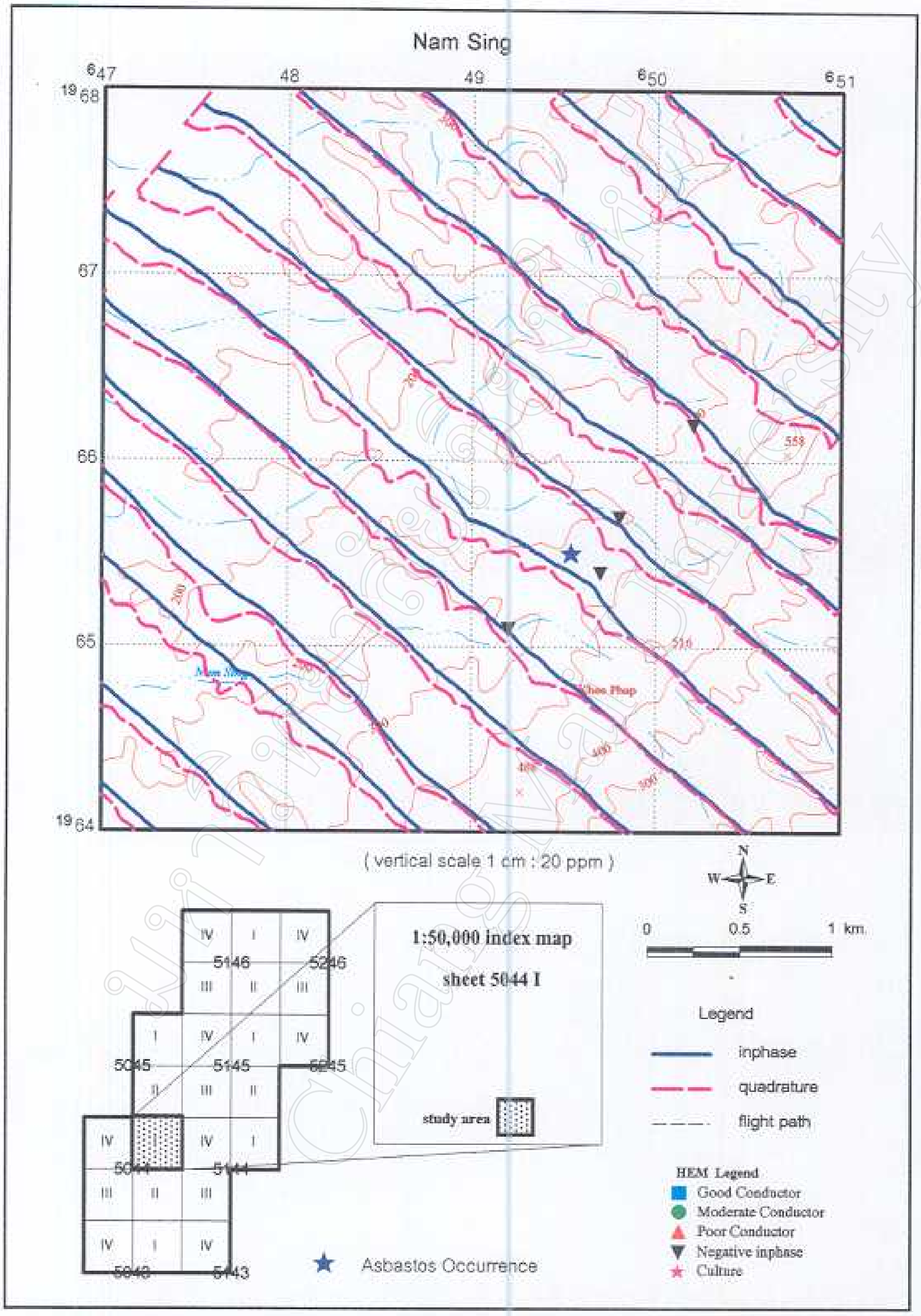


Figure 5.3 Selected area in Nam Sing for asbastos evaluation using geophysical survey.

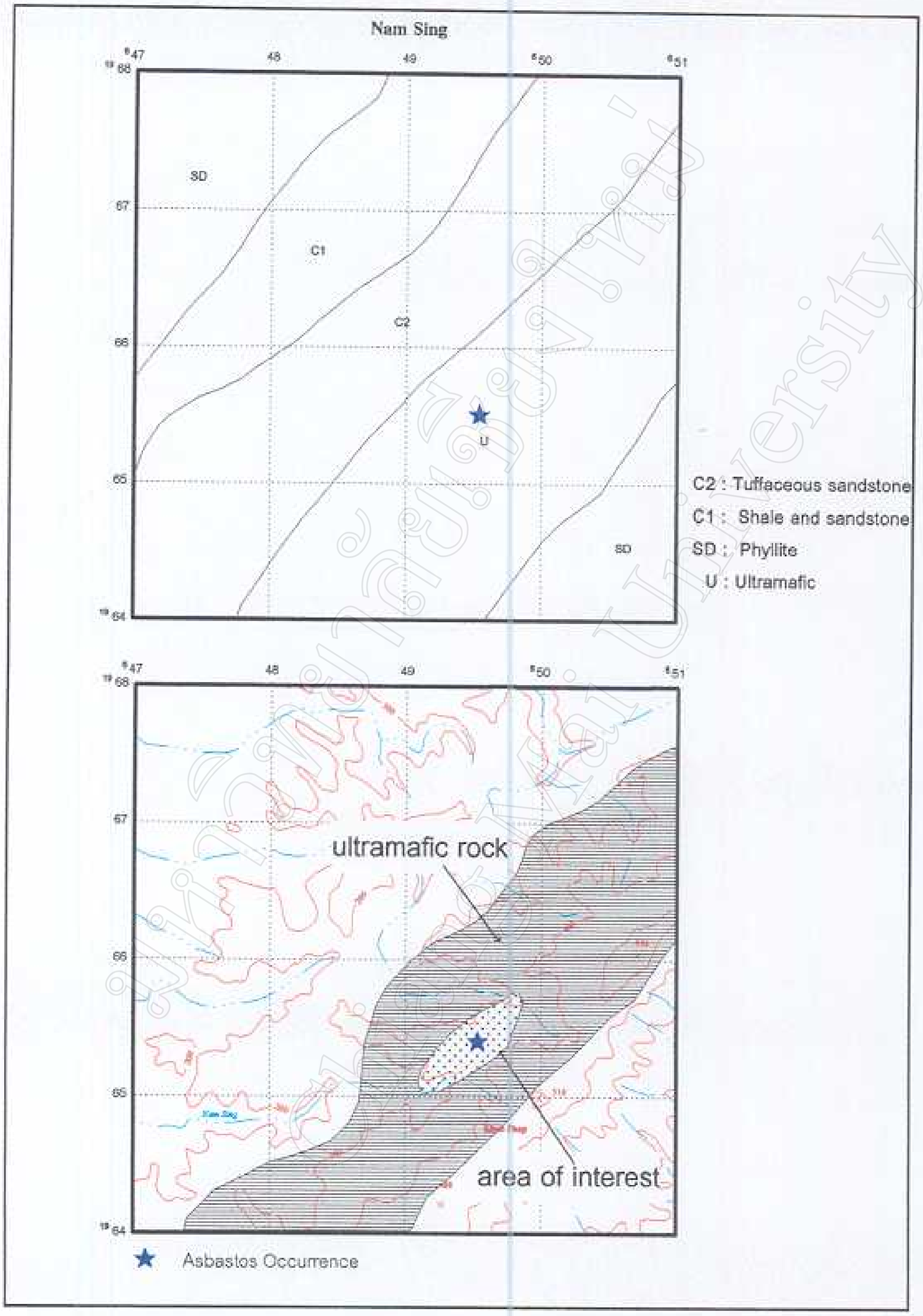


Figure 5.4 Potential area of asbestos in the selected area.

(geology : after Lumjaun and Sinpool-anant , 1987) information from HEM can be use as a guide to find where the ultramafics is and where asbestos may be located.

5.1.3 Talc

Talc is the softest of all minerals, known to everyone because of the talcum powder. It is an alteration product of magnesium silicates in ultramafic rocks, and commonly subjected to regional metamorphism. The original rocks, pyroxenite and peridotite, were altered progressively to hornblende, actinolite, chlorite, and then to talc, by hydrothermal solutions.

The softness, flakiness, and stability of talc make it a desirable substance for many purposes. In industry, it is roughly classified into hard and soft, and fibrous and flaky, and is marketed as crude, ground, and sawed. About 90 % of the United States talc are marketed as ground talc. The fibrous variety contains tremolite.

In paint, talc serves as an extender and is the white pigment of cold-water paints. In ceramics, ground talc is used for wall tile, electrical porcelain, and dinnerware. Only the finest grades of talc are used in toilet powders, lotions, and face creams.

Talc is mined by underground and open cut methods, and soapstone is quarried in large blocks ready for sawing. The talc is dried, ground and air separated, and is carried through a fine grinding stage. Cosmetic talc is hand-sorted, screened, very finely grind, and bolted through silk cloth.

HEM anomalies in Pak Huai Chalong area of Uttaradit was selected for economic evaluation of talc deposit using geophysical survey (Figure 5.5). KESIL (1989) outlined this zone as U-13 and pointed out that this zone consists of negative inphase responses that arise because of the very active magnetic body in the region. They also stated that host rock must be either serpentinite or andesite based on magnetic responses in the other areas. This talc pit is a lens trapped in phyllitic part of a complex folded structure (Tulathammagul, 1993).

It appears that one HEM anomaly is located over the talc pit (Figure 4.7b) and the other on the riverbank where there is a talc occurrence. Talc is directly related to both electromagnetic and magnetic anomalies. Talc veins show high conductivity, compared with the adjacent areas. They are detected as moderate to good conductors. The important characteristic is that non-magnetic part is in the magnetic anomalous zone (Figure 5.6). This is because peridotite or serpentinite is serpentinized to hydrated ultramafic by a hydrothermal process and is metamorphosed to be talc after magnesium and calcium exchanged with iron and lost its magnetism (Surinkum and others, 1995). The talc mineralization zone is now within a magnetic low intensities, indicating a relative lack of magnetite, presumably due to iron-replaced magnesium. This may not be the only source of flat magnetic relief as any non-magnetic rock

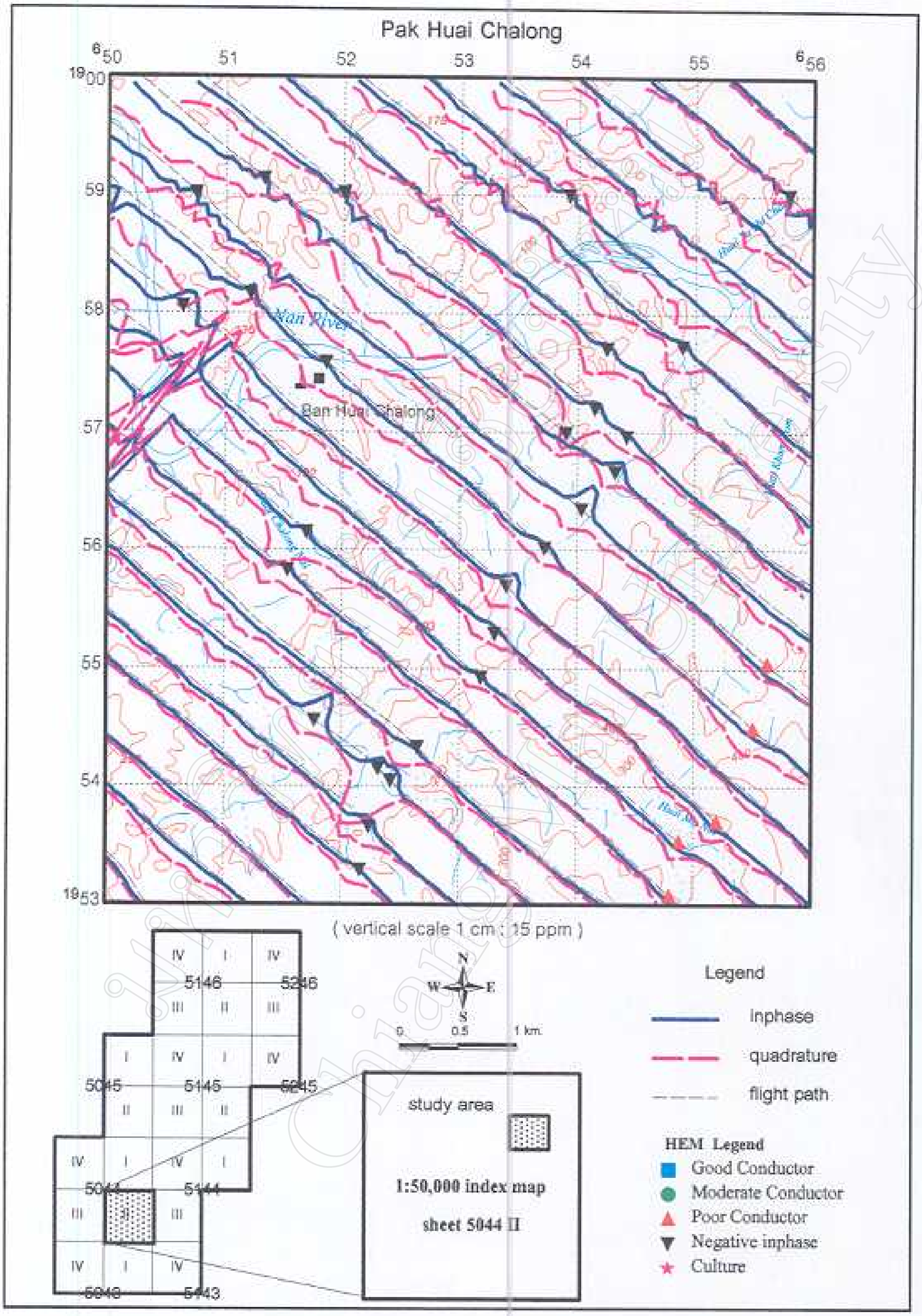


Figure 5.5 Selected area in Pak Huai Chalong for talc evaluation using geophysical survey.

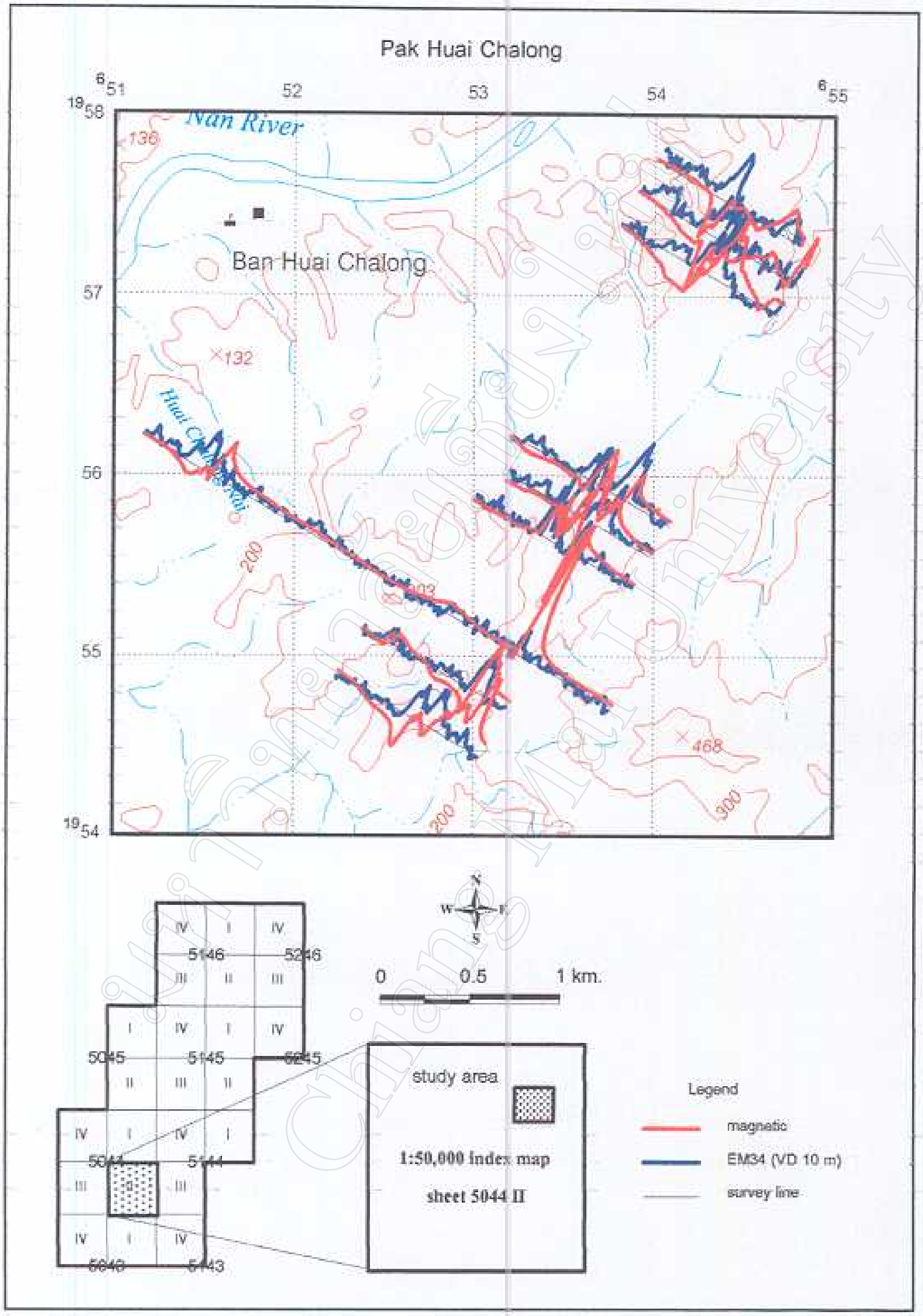


Figure 5.6 Ground magnetic and electromagnetic survey over talc selected area.
(after Surinkum and others , 1995)

will produce similar anomalies, but it can be discriminated on the basis of shape and geological setting of this area.

High conductivity may be resulted from moisture content in talc that is higher than in peridotite or in serpentinite as found in this area. Integrated data of both HEM and ground geophysical surveys, electromagnetic and magnetic, are quite useful for evaluation of talc potential area (Figure 5.7). Pitting and hand auger drilling made later indicated that non-magnetic part within a conductive zone of serpentinite is a talc lens. Therefore, a simple magnetic survey across the metamorphosed ultramafic units is a recommended procedure to find talc lenses in this NUS zone.

5.2 Post-collision mineralization

It is interpreted that the NUS zone was subjected to some degrees of deformation and tectonism. Overturned anticlinal structures are found in the Permian, Triassic through Jurassic sequences, whereas that of Cretaceous shows only open fold style. The presence of intercalation of shallow intrusive and volcanic rocks in the Triassic-Jurassic sequences in the west indicates that this area was activated after the final collision in Late Triassic (Hinthong and others, 1999). Post-collision intrusions occurred inasmuch as uplifting and pre-Jurassic sequences are available sites for mineral deposition. Weathering process is also a major factor for many residual concentrations, both in high land and low land areas. Intercalated red beds in the east indicate a transitional environment from marine facies up to continental facies toward Jurassic where mineral deposits associated with evaporite are expected. Therefore, various mineral deposits were subjected to post-collision activities.

5.2.1 Gold

Gold associated with ultramafic rocks is statistically of only slight interest because of its low production. Therefore, only gold associated with hydrothermal activities of post-Permian intrusions in both Shan-Thai and Indochina paleo-continents are being discussed. In general, gold deposits in Thailand can be geologically classified into two types: primary and secondary.

Primary deposit type is related to igneous, sedimentary and metamorphic rocks. Geological processes of the deposit are hydrothermal, metasomatic and silicification. Gold normally occurs as invisible grains disseminated in the rocks and veins. Economic concentration of gold is at least 3 grams per metric tons of rock. The examples of these deposits are Toh Moh deposit in Narathiwat, Ban Bo Thong deposit in Prachin Buri, Khao Mo deposit in Phichit-Phetchabun and Pha Hee deposit in Chiang Rai (Potisat, 1996).

Secondary deposit, sometimes called placer deposit, occurs close to the primary one. Gold found in this deposit type is in grain, nugget or flake derived from weathered gold bearing rocks. The gold is transported away

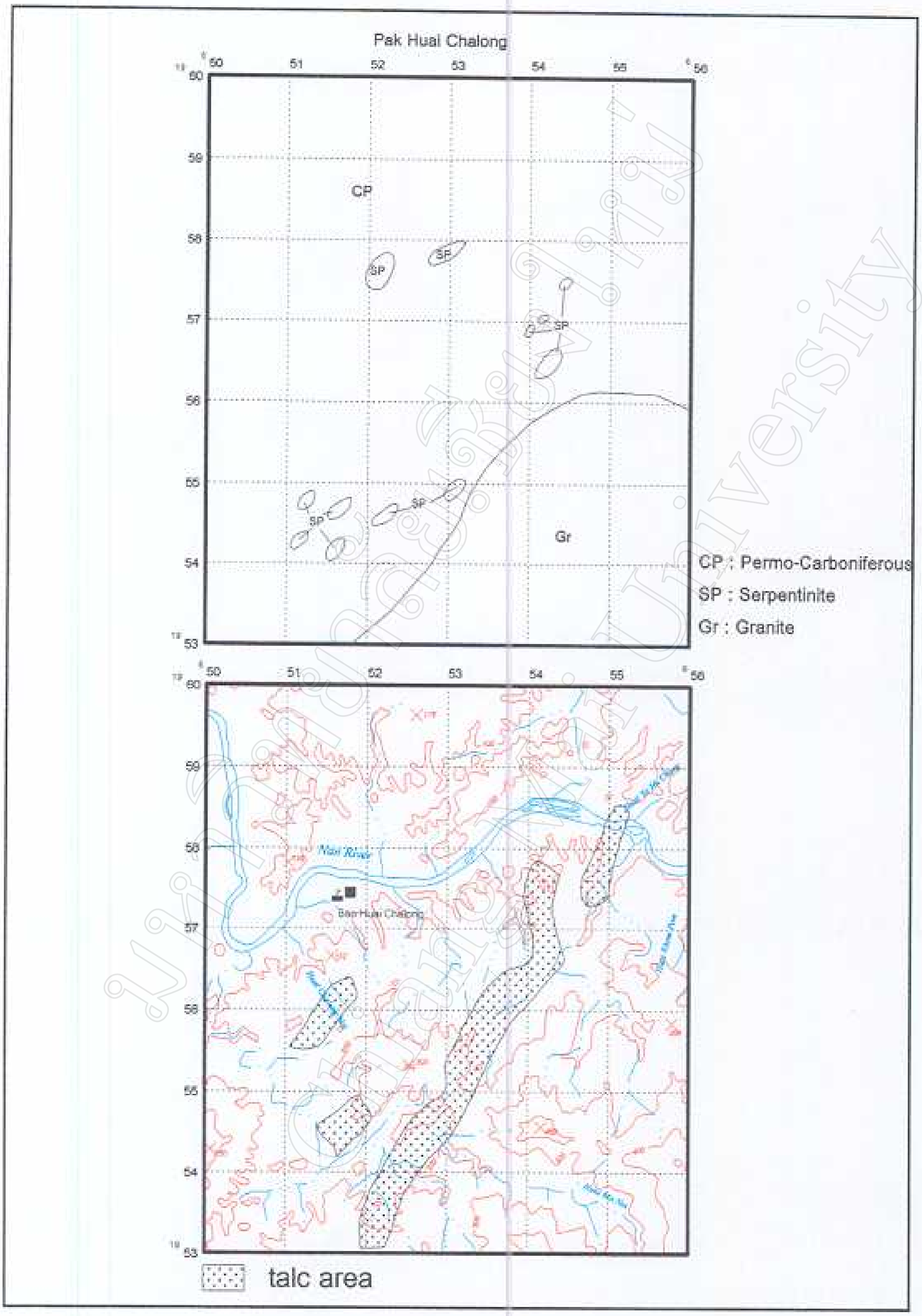


Figure 5.7 Potential area of talc in the selected area.
(geology : after Sukvattananunt and Prasittikarnkul , 1985)

from its source and is re-deposited along a hill slope a stream bed or a gravelly sand placer. Some examples are Ban Paron deposit in Prachuap Khiri Khan and Ban Na Lom deposit in Prachin Buri (Kumanchan, 1989).

Prior to this study, there is no report of gold associated with the NUS zone and its vicinities. Thongchit (1997) made an interpretation of airborne geophysical data in Nan–Xaignabouri area in a regional scale and recommended an area for ultramafic related minerals over the ultramafic unit east of Mae Charim. More specific study, over the recommended areas of Ban Nam Pun and Ban Nam Phang, was made in order to verify correlation of airborne geophysic anomalies with various rock types (Figure 5.8) and also to verify associated mineral potential. Geochemical survey, of the selected area, was done initially for chromite and nickel evaluation (Paopongsawan and others, 2000). Gold was found later, in Nam Phang area (Figure 5.9) by chemical analysis: 27-146 part per billion in stream sediments near granitic rocks (Figure 5.8c). More intensive geochemical survey and geological mapping were subsequently made and gold potential area is outlined (Yawichai and others, 2001). The gold potential area is confined along the contact of the pink granite of Triassic and meta-sandstone intercalated with meta-shale of Permian (Figure 5.10).

5.2.2 Illite

White clay mined in Thailand is from both primary and secondary deposits or from geological setting classified as sedimentation, alteration and weathering. Uttaradit white clay, illite, is a well-known clay found in this study area (Kuentag, 1995). The ore, derived from parent rocks alteration, is a part of the Mesozoic volcanic rocks that are mainly composed of rhyolite and rhyolitic tuff (Piyasin, 1975). Uttaradit white clay dominantly contains illite which is physically different from white clay in other places, for example in whiteness, grain roundness, very fine-grained nature and low refractory. Generally, clay is one of the most widespread and earliest mineral substances utilized by man. A wealth of artistic wares culminated in the eighteenth century, but today utility holds sways in the utilization of the varied clay products. The uses of clay, illite, from this area are mainly for paint industries.

It was formerly thought that the clay was composed mostly of kaolinite. It is now known that, although kaolinite contains considerable amount of illite, other clay minerals are major constituents. In general it contains approximately 60% illite, 10% kaolinite and other minerals such as montmorillonite, quartz, chlorite and feldspar. The ratio of illite to kaolinite is 85:15 (Kuentag, 1995). The clay in this deposit is formed by hydrothermal and pneumatolytic processes. The alteration activities are seen in all volcanic rocks with different degrees depending on the parent rock composition (Figure 4.8).

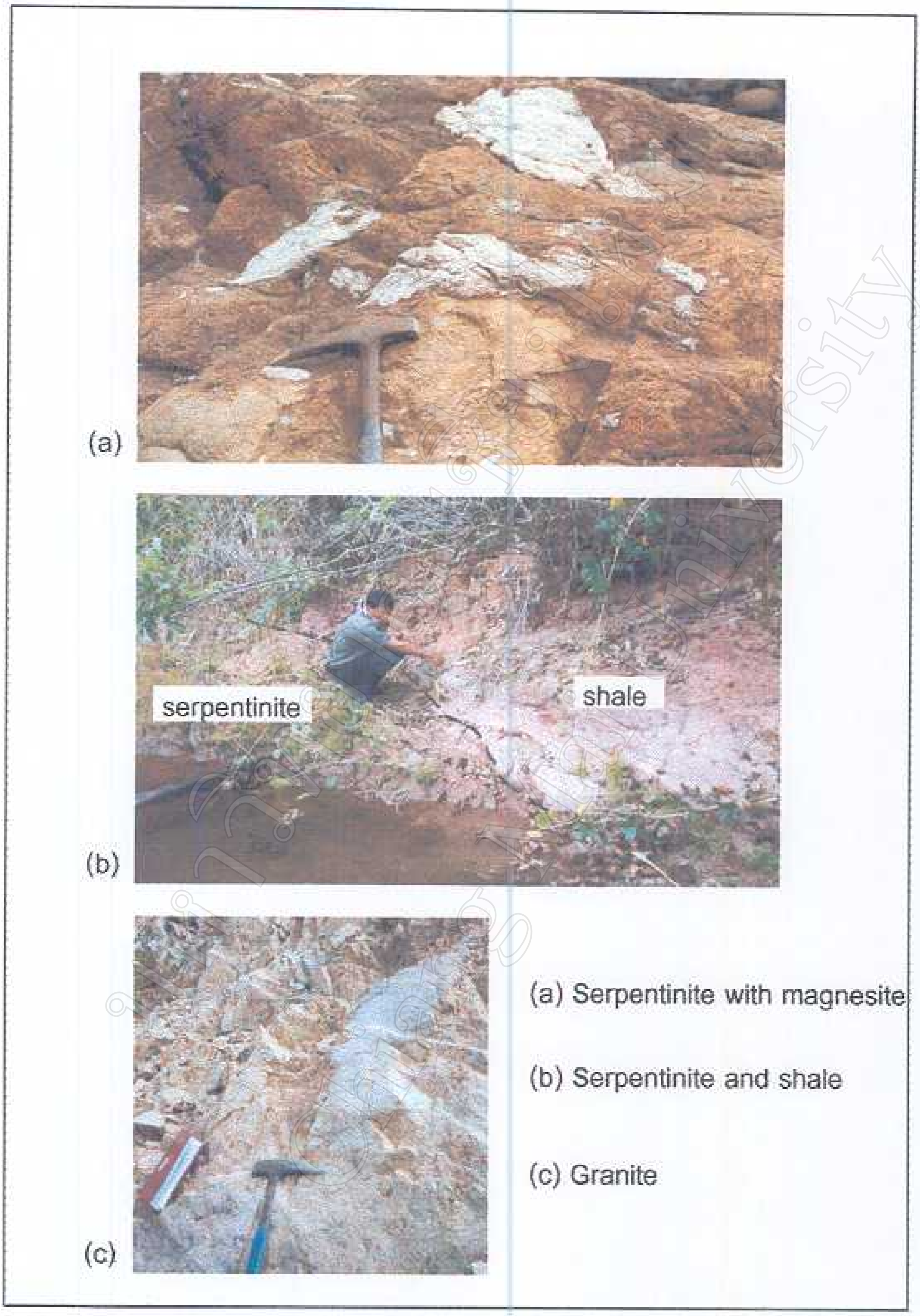


Figure 5.8 The various rock types in Ban Nam Phang area.

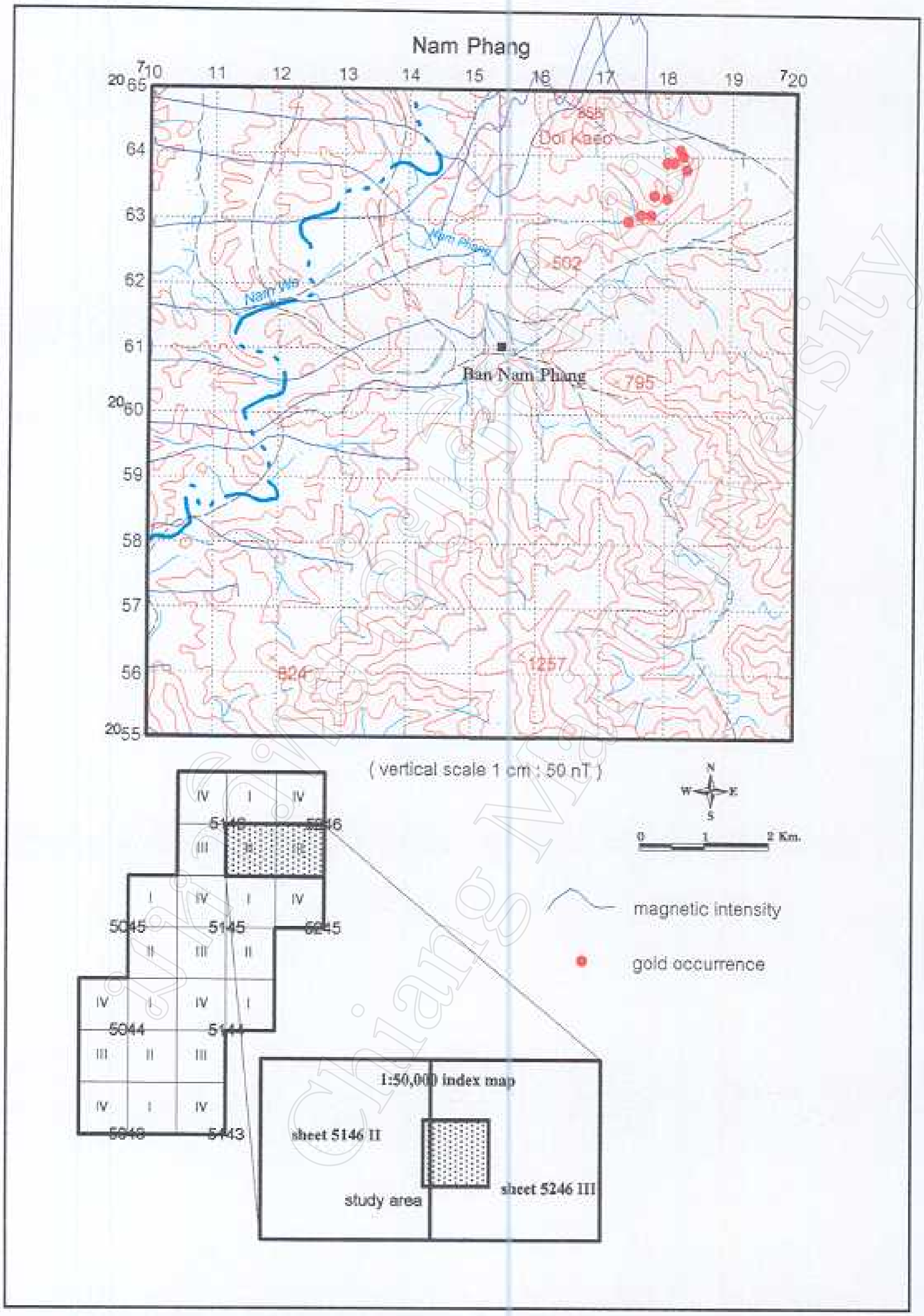


Figure 5.9 Selected area in Ban Nam Phang for gold evaluation using geophysical survey.

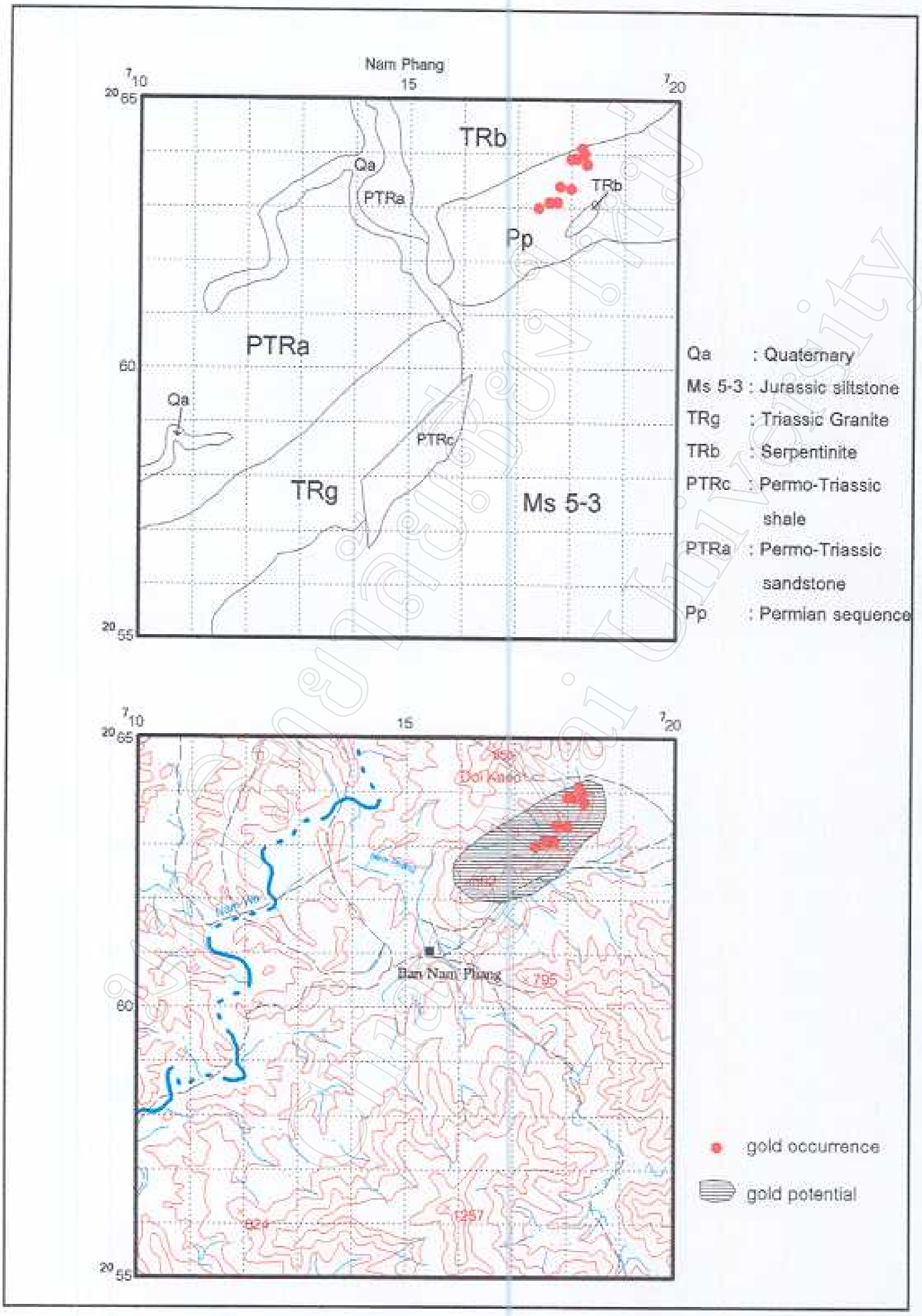


Figure 5.10 Potential area of gold in the selected area.
(geology : after Yawichai and others , 2001)

Illite is normally found along valleys although some are found at the hilltops in the mountain east of Ban Ngiu Ngam in Uttaradit (Figure 5.11). The mountain range of volcanic rocks, which has the highest altitude at Kui Mamun, is deformed by faulting and consequently altered by hydrothermal fluid flowing through N10°E faults defined from an aerial photograph. However, the ore body changes in width, length and depth from place to place depending on geological structure and flow direction of the parent rocks. This makes surface geological exploration ineffective. Drilling information from each drill hole are incoherent making correlation between holes very difficult, therefore, interpretation of ore potential is almost impossible.

Airborne geophysic anomalies show that this illite zone is associated with potassium anomaly (Figure 5.11) but the illite is not reflected by potassium anomaly. Various geophysical techniques were applied to define the illite potential, and electromagnetic survey, conductivity measurements (Figure 5.12), was proved to be most suitable (Surinkum and others, 1997). However, conclusions from geophysical ground surveys are not directly used in a final potential evaluation of this area (Figure 5.13). This is because spacing of the traverse survey lines is too far (1000 m) making data interpolation between the lines less reliable.

Aeromagnetic and airborne radiometric data both indicate a possible existence of a hydrothermal deposit at Huai Yuak, although, according to the geologic map, the potential area is underlain by Mesozoic redbeds (Figure 5.14). Subsequent ground check revealed the presence of acidic volcanic rocks, rhyolitic porphyry, with some alteration products in the target area.

5.2.3 Graphite

Graphite was once mistaken for lead, it was called "black lead", and pencils made from it are still called "lead pencils". Although chemically the same as diamond and charcoal, it is a crystalline modification of carbon. The high melting temperature of graphite (3000 °C) and its insolubility in acid create many uses for it. The oldest use is in making pencils, which still persists. The softest graphite is finely ground, mixed with clay and baked, the amount of clay and the time of baking giving the desire hardness (Jensen and Bateman, 1979).

Graphite occurs in metamorphic, igneous, and sedimentary rocks in flakes, lumps, and dust. It originates by magmatic concentration, contact metasomatism, hydrothermal deposition in veins, and metamorphism. Most of them originate through metamorphic processes (Edwards and Atkinson, 1986).

During the ground follow-up of HEM anomalies in Uttaradit area, it was found that one of the most prominent HEM anomalies is located at Khao Khee

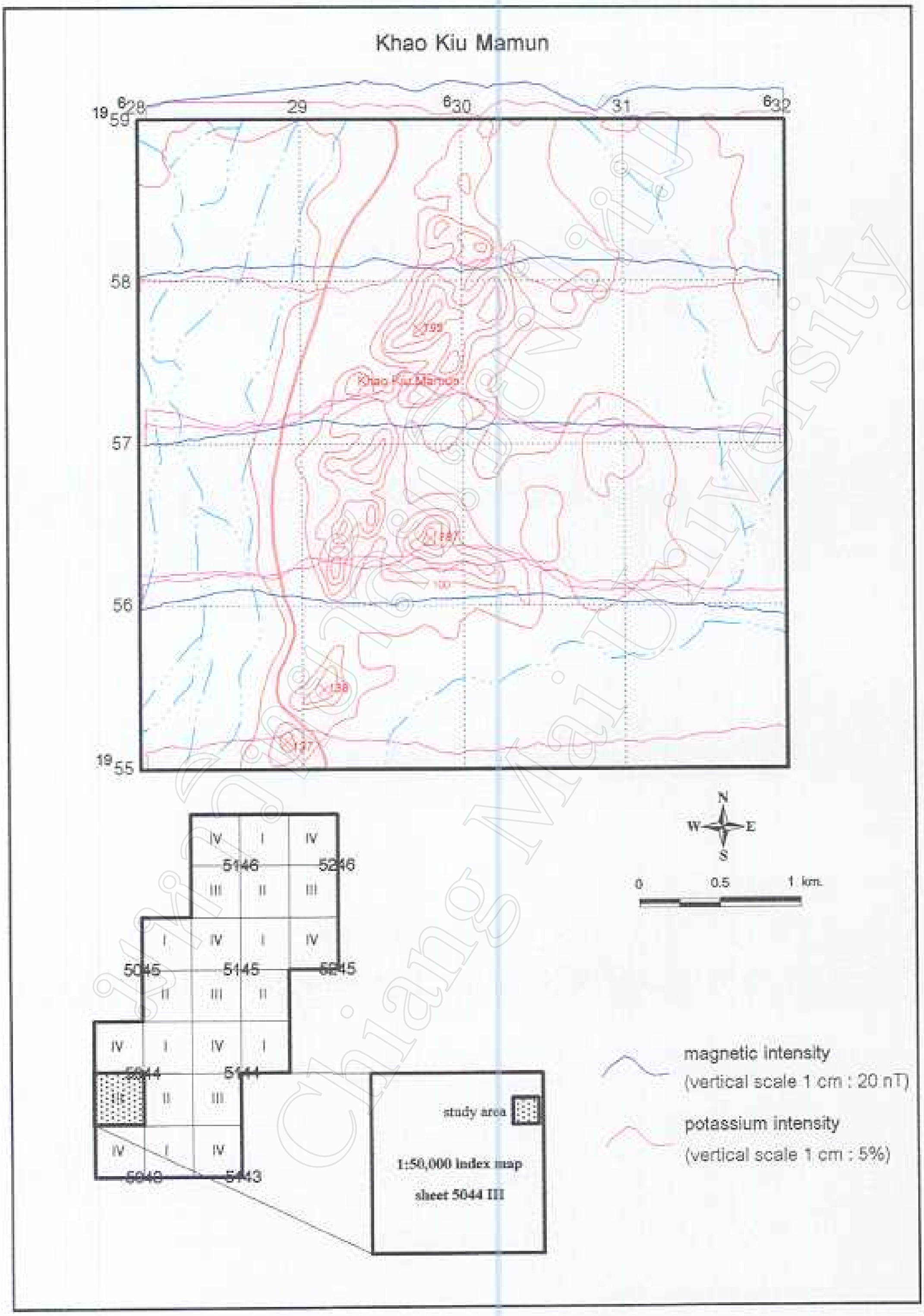


Figure 5.11 Selected area for illite evaluation using geophysical survey.

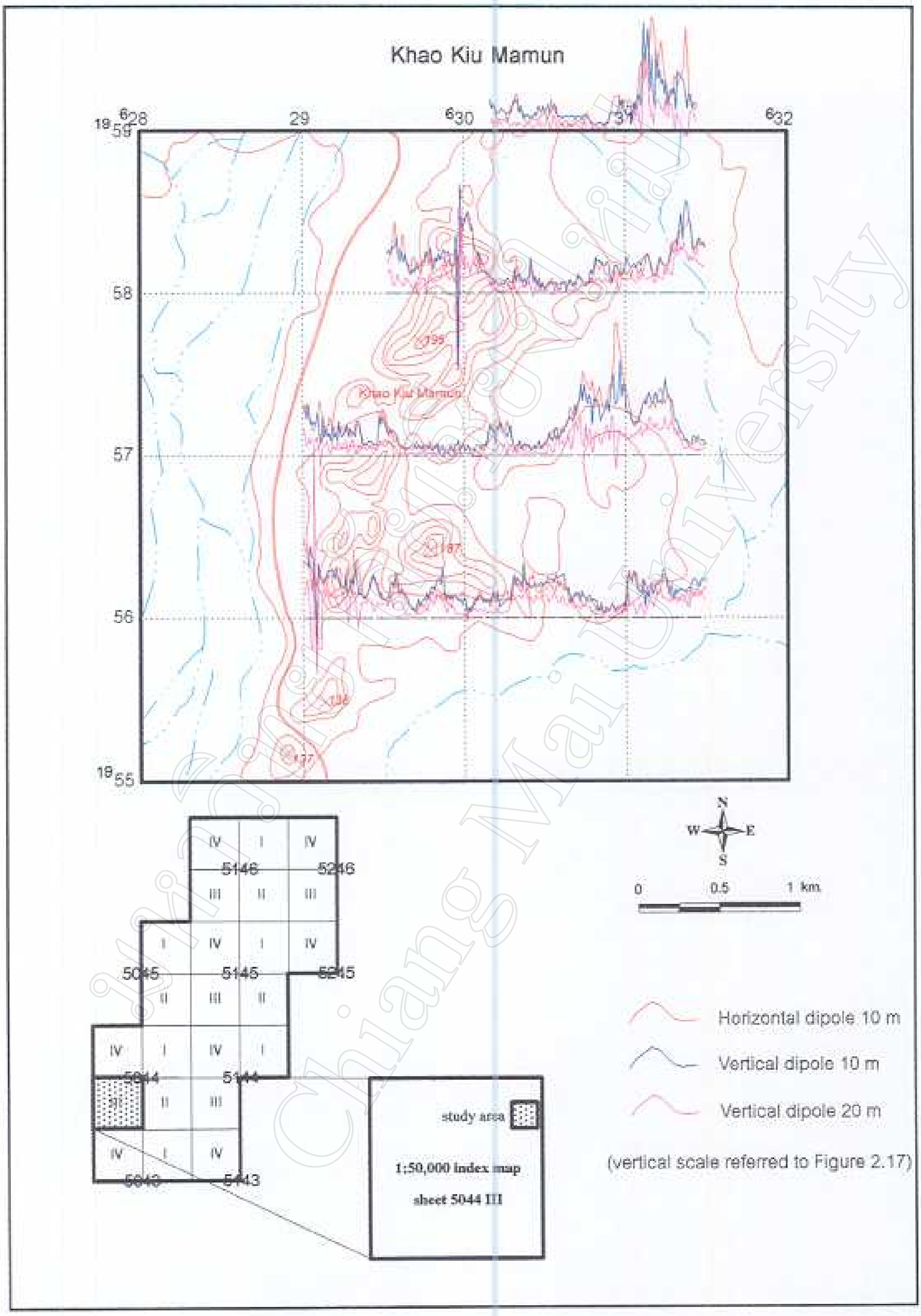


Figure 5.12 Ground electromagnetic survey over illite selected area.
(illite zone referred to Figure 4.16)

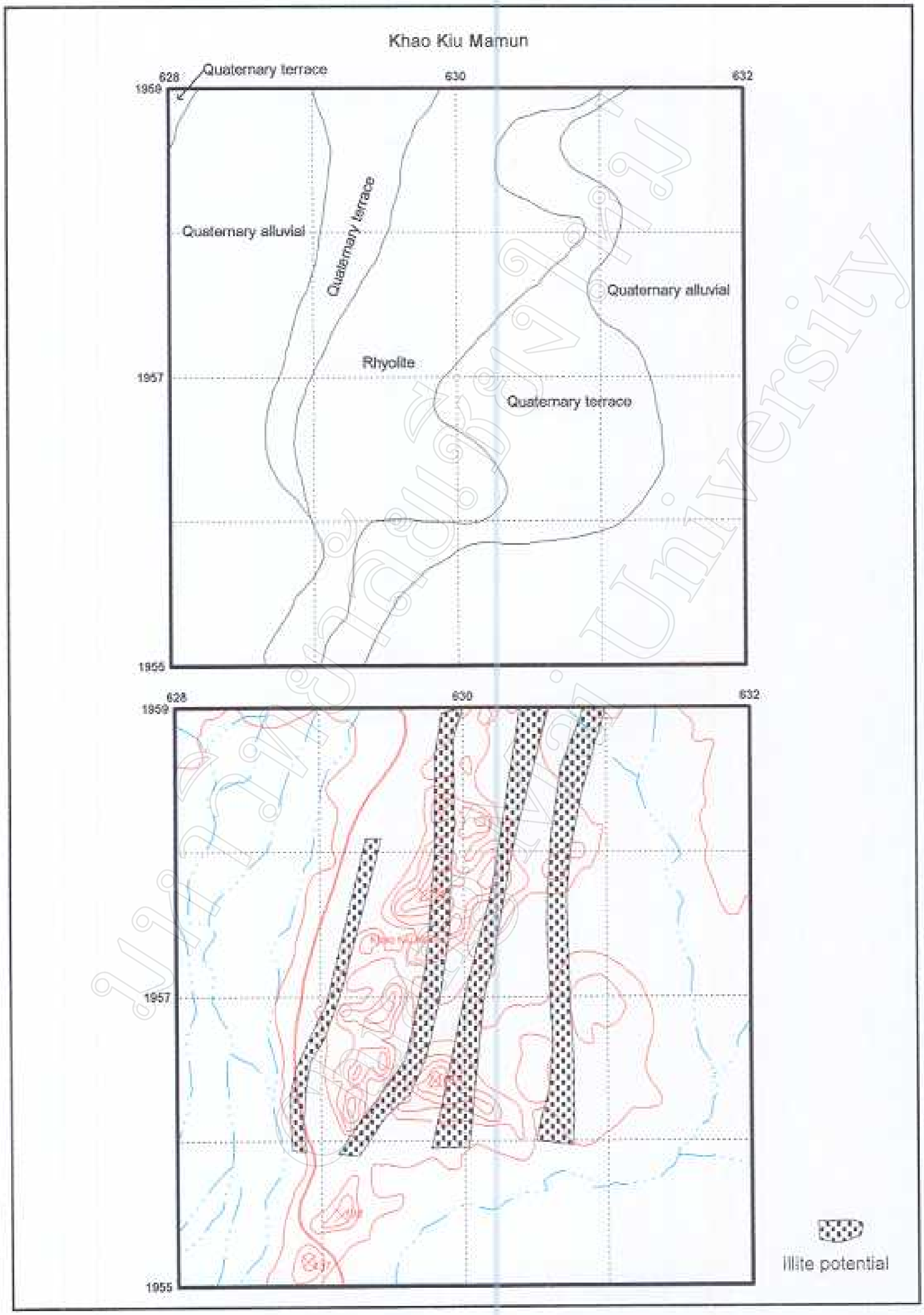


Figure 5.13 Potential area of illite in the selected area.

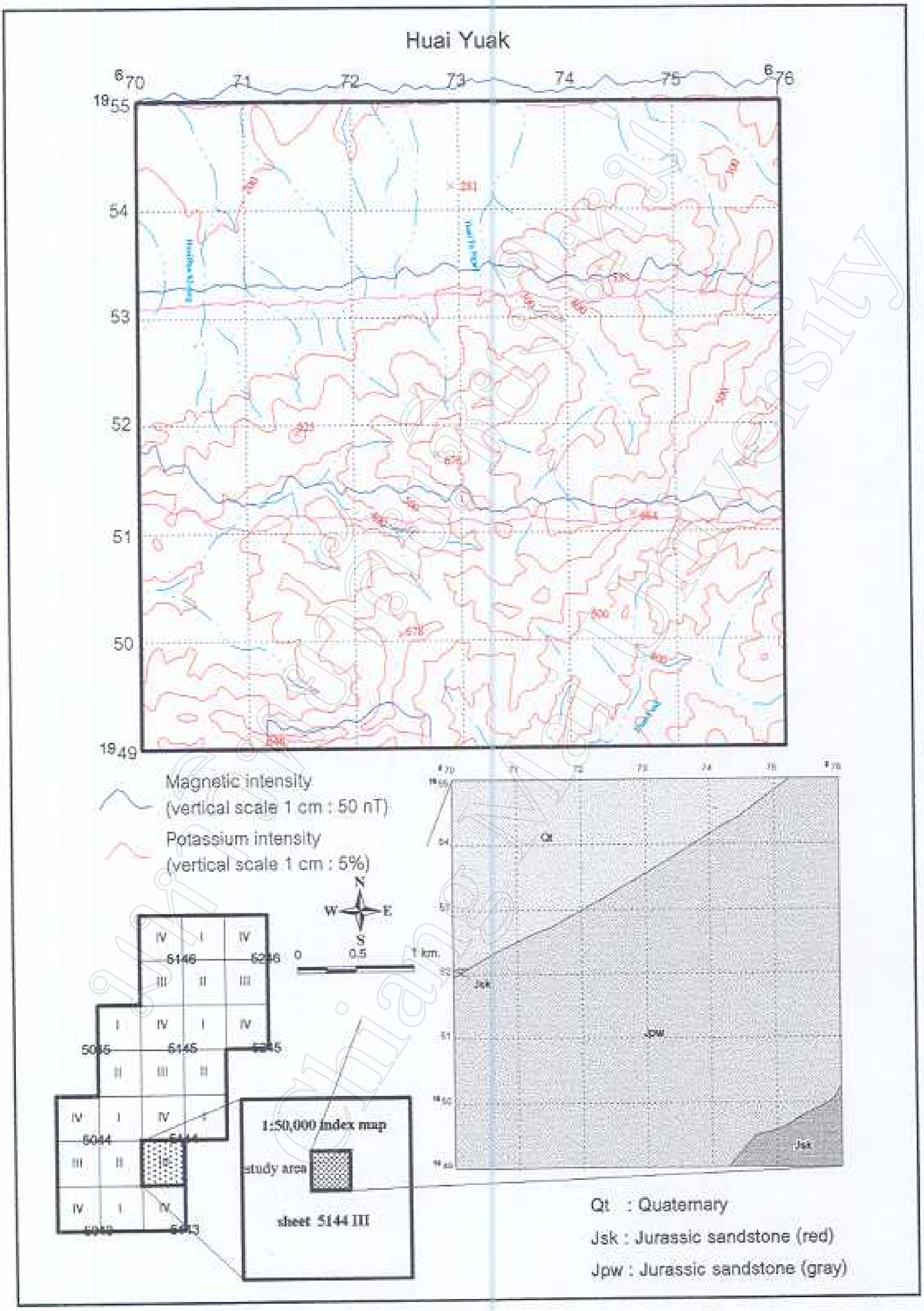


Figure 5.14 Potential area of mineral deposit related to hydrothermal alteration in Huai Yuak.
(geology : after Chairangsee and others , 1989)

Nok (Figure 5.15). Various ground surveys were applied over that anomaly and a zone of good bedrock conductor, graphitic zone, is outlined (Siripongsatian and others, 1991). The identified graphitic zone in this area was made by HLEM survey (Figure 5.16) and confirmed by drillings (Surinkum and Siripongsatian, 1992). Surinkum and Siripongsatian (1992) reported that the deposits at Khao Khee Nok occur in shear zones in carbonaceous shale and limestone cut by granite and andesite dikes. The graphite particles replace minerals in carbonaceous shale. Induced polarization survey indicates that there are sulphide mineralizations that indicated by high chargeability (20-120 mV/V) formed within the carbonaceous shale (Figure 5.17). Chemical analysis shows that fixed carbon in this zone is between 10-30 % and heating value is 400-2000 calorie/gram.

5.2.4 Lateritic nickel

There are essentially three types of nickel ores. Primary ore is pentlandite ($(Fe, Ni)_9S_8$): massive, yellowish bronze colour, isometric crystal, hardness = 3.5-4 and specific gravity = 4.6-5. Secondary ore is garnierite ($(Ni, Mg) SiO_3.nH_2O$): earthy masses, apple-green to white colour, hardness = 2-3 and specific gravity = 2.2-2.8. The third type is non-oxide minerals such as nicolite (NiS), nikeline (NiAs), and meteorite (Ni, Fe). The average concentration of nickel in igneous rocks is about 80 ppm, and it is only well represented in the ultramafic rocks (Jensen and Bateman, 1979).

Nickel is normally associated with ultramafic and mafic igneous rocks. These rocks occur in several locations in Thailand: northern region in Uttaradit, Nan and Chiang Rai; northeastern region in Loei; eastern region in Prachin Buri and Sa Kaeo; and southern region in Narathiwat.

Nickel deposits in Thailand have been investigated since 1974. Nickeliferous laterite deposit is located at Si Maha Phot District of Prachin Buri. Ore of nickel is garnierite residually lying on weathered serpentinite with concentration of approximately 0.36-0.55%Ni (Suwanasing, 1974). In 1989, a geochemical exploration program was carried out in Prachin Buri over HEM anomalies and the results showed the existence of nickeliferous laterite deposits with nickel concentrations of 0.4-2.0 % (Yawichai, 1989). However, no nickel has yet been mined in Thailand (Department of Mineral Resources, 2000).

In the region where secondary nickel deposits are located, weathering process is a major activity to enhance nickel concentration. Factors in which influence the nature and rate of chemical weathering includes permeability, climate, relief and drainage (Jensen and Bateman, 1979). The products of weathering may give rise to mineral deposits formed *in situ*, called residual deposits. The formation of an *in situ* residual deposit requires deep and long-continued weathering, and then followed by lack of erosion.

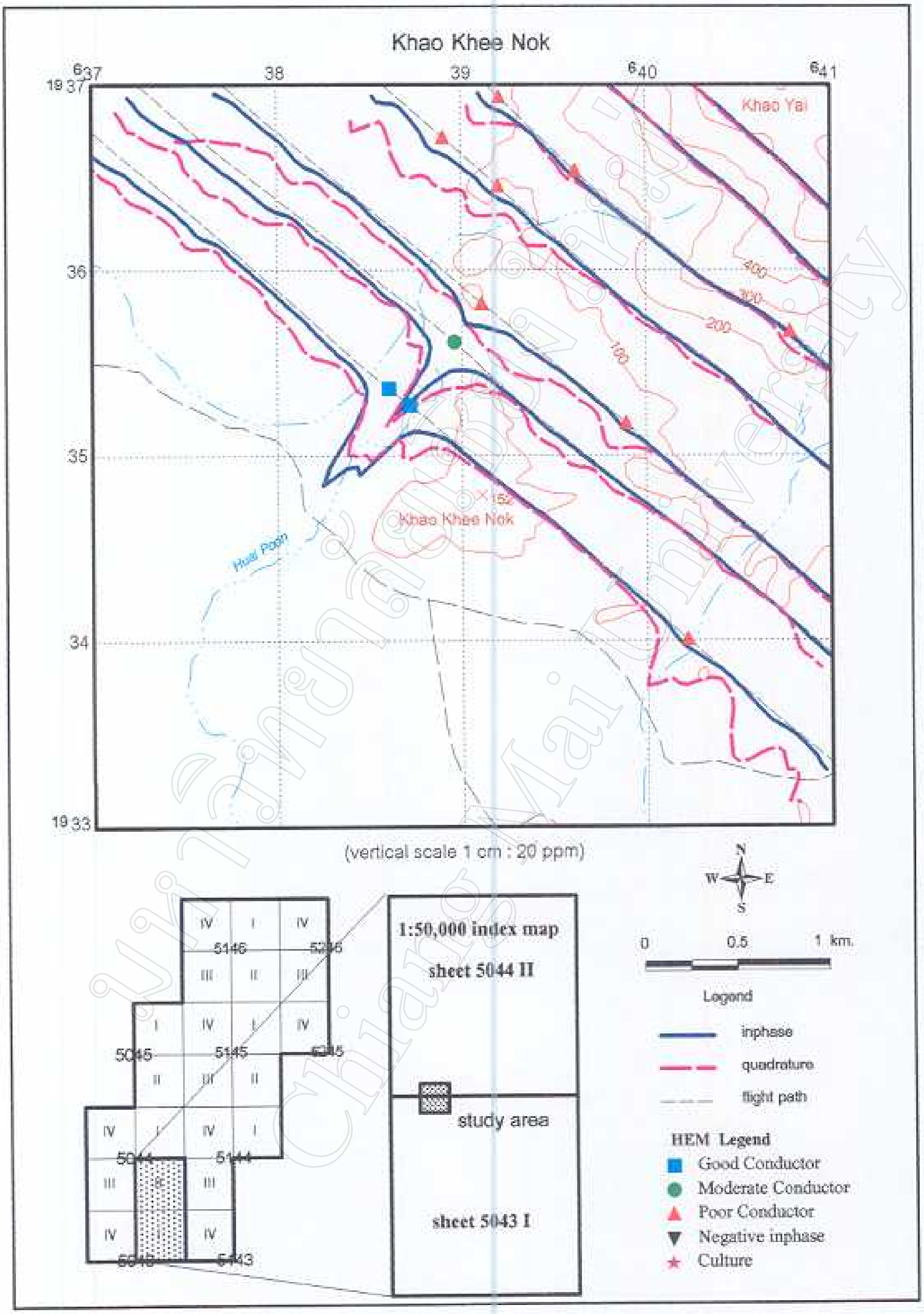


Figure 5.15 Selected area in Khao Khee Nok for graphite evaluation using geophysical survey.

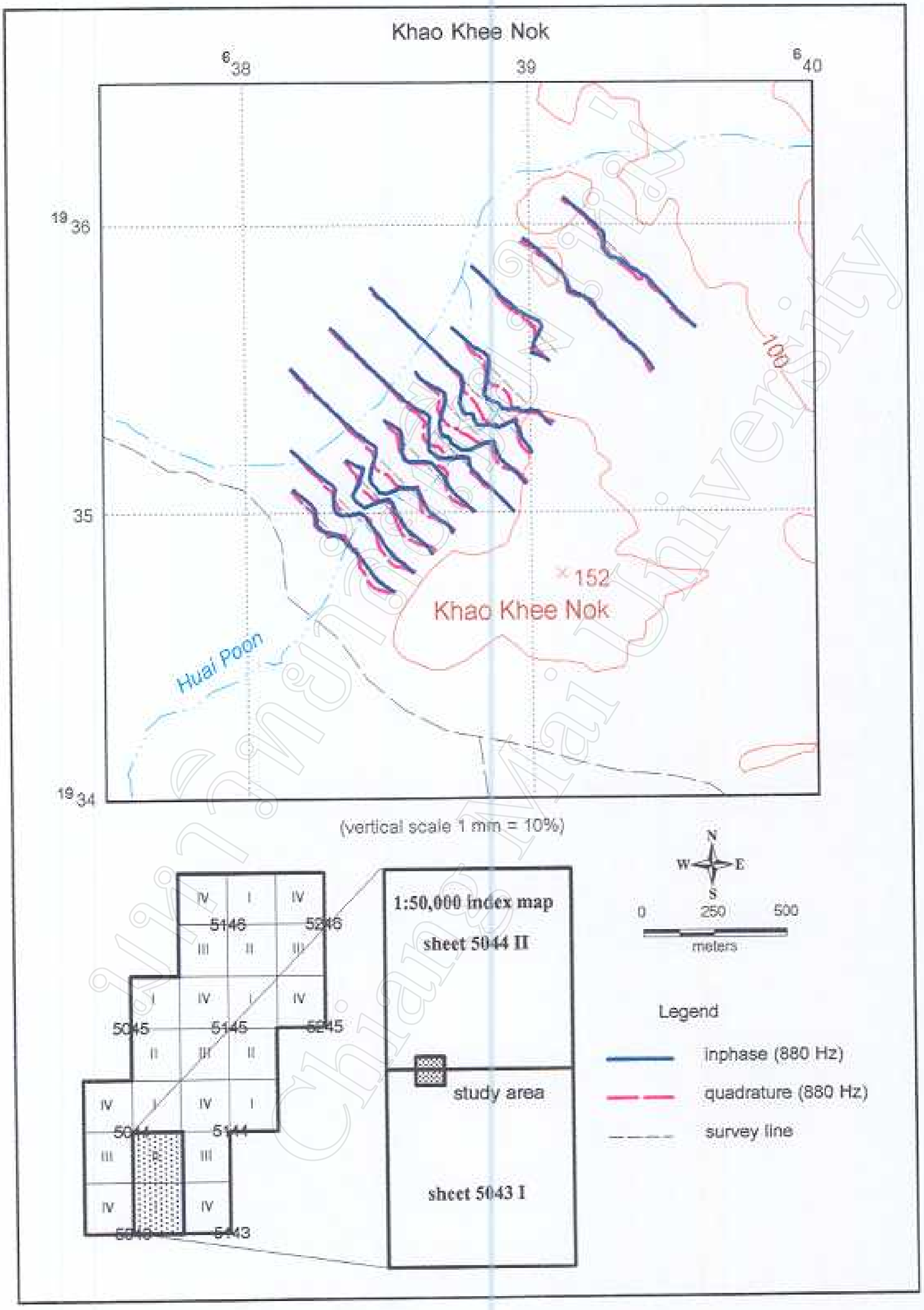


Figure 5.16 Ground electromagnetic surveys over graphite selected area.
(after Surinkum and Siripongsatian , 1992)

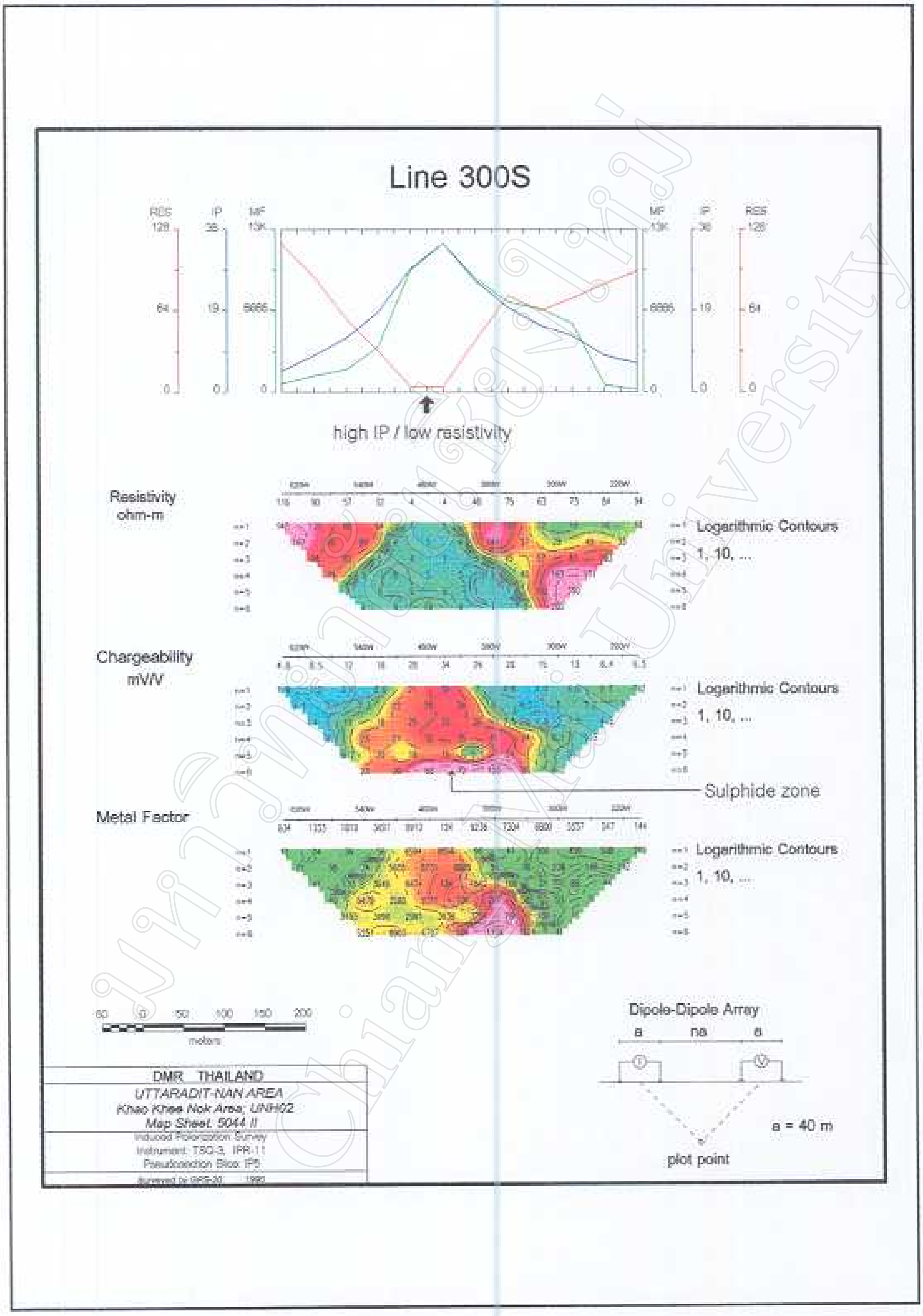


Figure 5.17 Induced polarization survey result in Khao Khee Nok area. (after Surinkum and Siripongsatian , 1992)

In 1998, ground check on the aeromagnetic anomaly, associated with ultramafic units in Mae Charim, was made, and occurrences of lateritic nickel were found in Doi Kaew area of Nan (Figure 5.18). Paopongsawan and others (2000) studied stream sediment characteristics and rock chemistry over that area and found that the nickel concentration reaches 2.8 % in some rock samples. Geochemical exploration was then carried out in detailed scale and not only the nickel potential area but also chromite and gold potential areas are located. The result shows that there is a wide area of nickeliferous laterite deposit over weathered serpentinite and the metal content is 1.5%Ni on average (Yawichai and others, 2001). There are also some other deposits that occur outside this area, including those at Ban Huai Lao in Na Noi of Nan and Nam Pun in Mae Charim of Nan.

Conductivity measurements using terrain conductivity meter were made to determine the thickness of the lateritic nickel layer in Nam Pun area that was expected to be approximately 20m below surface (Paopongsawan and others, 2000). Above the lateritic nickel layer, a comparatively good conductor, is a zone characterized by silica boxwork. The silica boxwork acts as a local resistance hence is easy to recognize on the ground. The silica boxworks are sometimes used as gemstones, or common opal.

Ground geophysical surveys which have confirmed the presence of nickel laterites overlying the ultramafics in Doi Kaew area make it possible to extrapolate through the recognition of topographic, structural and vegetation features beyond the immediate known area to interpret similar occurrences of nickel laterites. In general, the lateritic nickel is a residual product of the ultramafic units found in a high relief terrain where hydrological condition is favourable (Figure 5.19).

5.2.5 Nickel chrome iron

Unlike the lateritic nickel that was formed in the high relief terrain, nickel-chrome iron is concentrated as a secondary deposit in the low-lying terrain. Buravas (1941) made a survey on nickel-chrome iron in an area southwest of Uttaradit. He found that the ore is formed as limonite, enriched locally within a folded quartzitic sandstone. Limonite is a field term used to describe a rock made up of a mixture of mainly amorphous mineral-like substances. The basic constituent is goethite, an amorphous iron hydroxide. The term limonite is often applied generally to any iron hydroxide, which cannot be defined compositionally, or mineralgocially without elaborate tests. It generally occurs as botryoidal, stalactitic, oolitic or pisolitic, earthy or porous masses, or in the form of a crust, yellowish brown when loose, blackish when more coherent. If heated in air it alters to hematite and becomes magnetic.

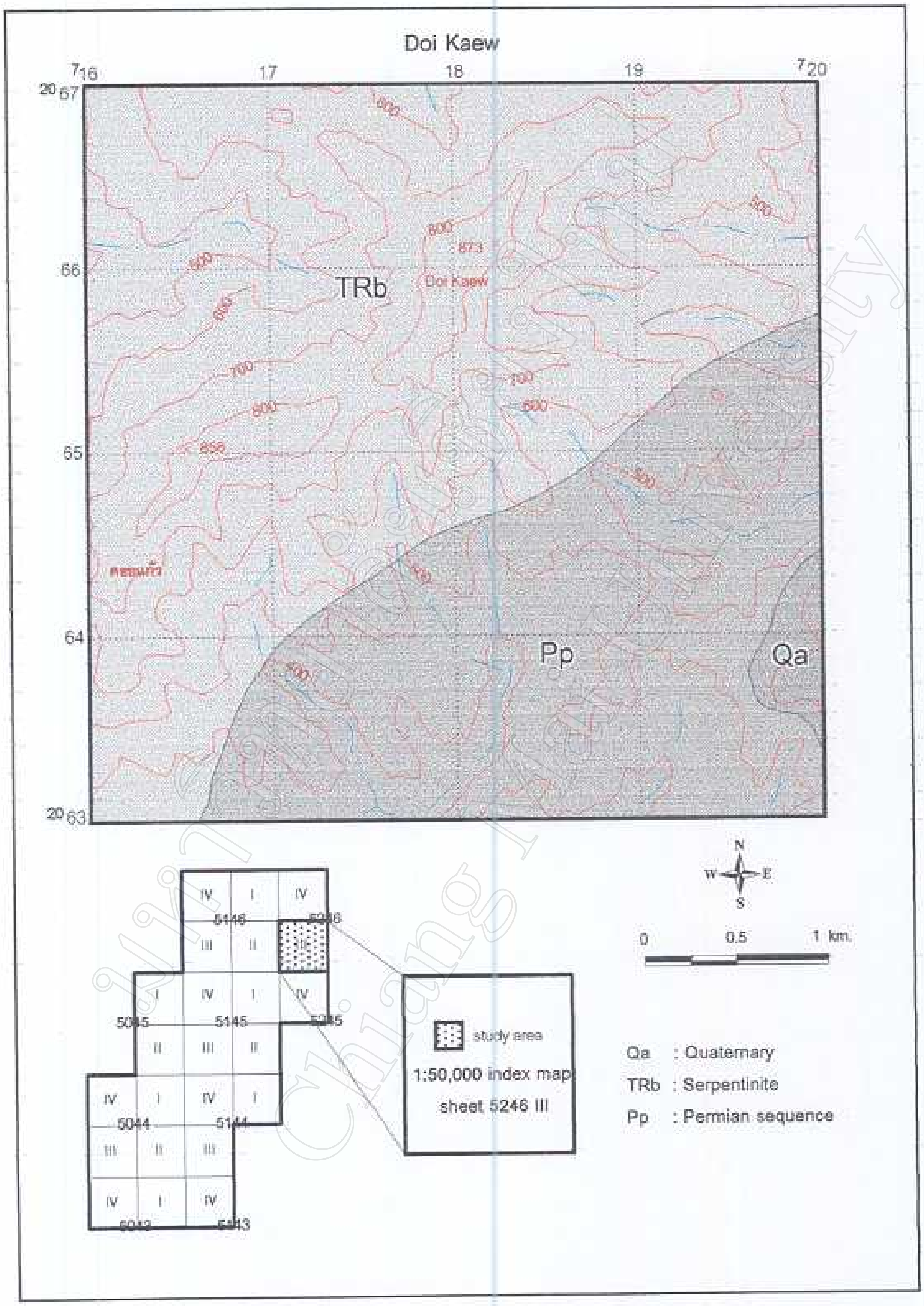


Figure 5.18 Selected area in Doi Kaew for lateritic nickel evaluation using geophysical survey.
(geology : after Wunapeera and Kosuwan , 1987)

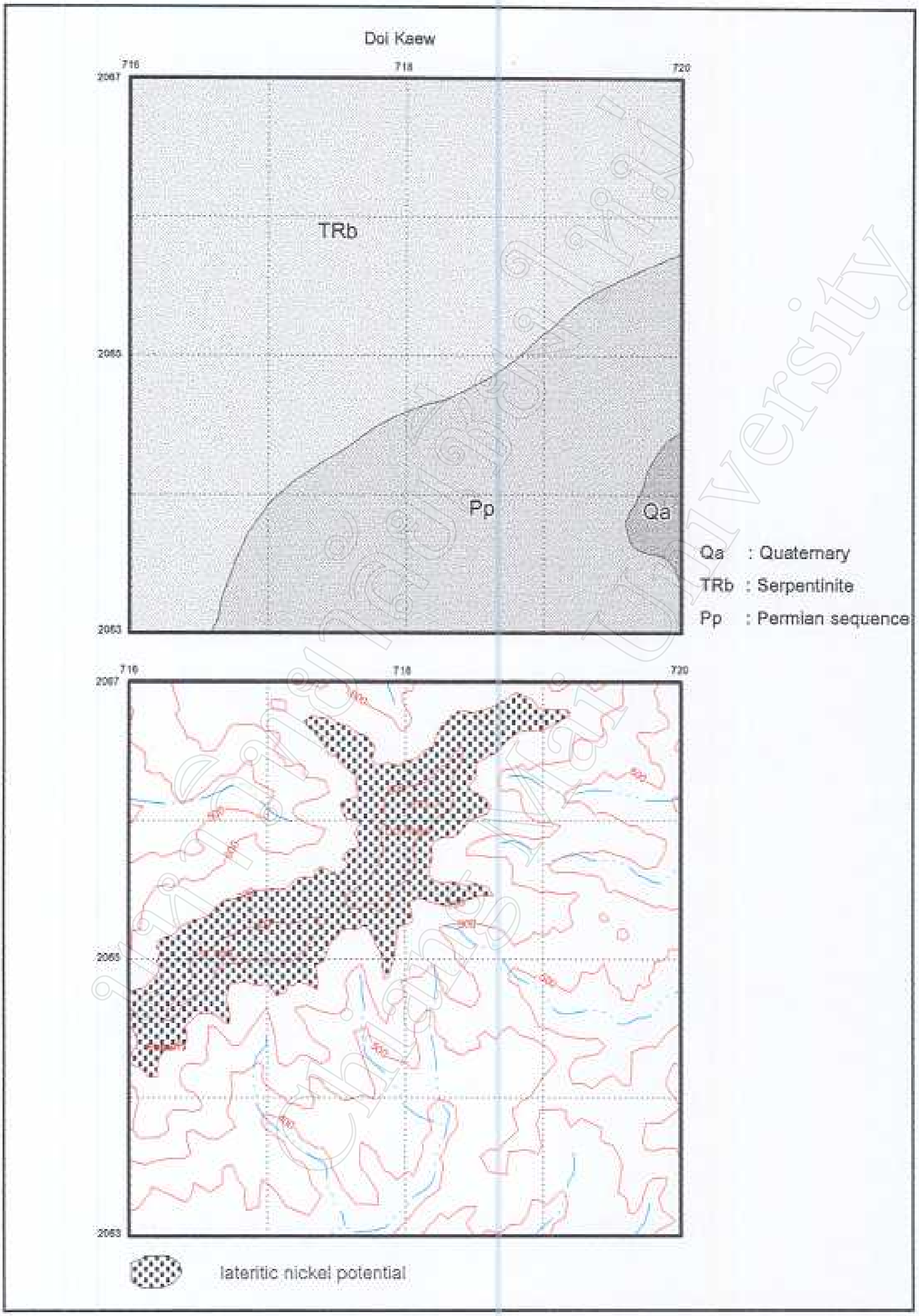


Figure 5.19 Potential area of lateritic nickel in the selected area.
(geology : after Wunapeera and Kosuwan , 1987)

Nickel-chrome iron ore in this NUS zone is found proximal to the well-known ancient iron deposit southeast of Uttaradit. The ancient deposit is located at 638250E/1936474N. In general, this iron mineral can be found in many places close to the ultramafic units and is related to HEM survey results, a negative inphase (Figure 5.20). The HEM anomalies indicate that these iron deposits are scattering in the hilly terrain (Figure 5.21).

In the ground survey, electrical conductivity dominantly changes as step function in the area containing floats of nickel-chrome iron. It changes from resistive zone to moderately conductive of nickel-chrome iron deposit and low magnetic susceptibility. This is different from the responses from magnetite deposits in Lop Buri and in Phetchabun where strong magnetic responses are observed (Prasittikarnkul and others, 1997).

5.2.6 Dimension stone and construction material

Present–day structural operations create large demands for bulk materials of rock and mineral. Mostly they are the stone, clay, and sand used by early man. Some are used directly; some are dressed; and others undergo considerable preparation. Even though, this area is neither an industrial zone nor a material production zone. The demand for these products has increased so greatly that the economic evaluation of dimension stone and construction material must be considered carefully.

Despite the abundance of rock outcrops, few rocks satisfy the requirements for dimension stone. The important ones are ease of quarrying, strength, colour, hardness and workability, texture and porosity, and durability. Transportation is also an important economic factor. Many types of dimension stone and construction material in this NUS zone are marble, andesite and sandstone. They are mined by open quarrying, rarely from underground. Wire saws are used in many quarries to cut out blocks. For cut stone, saws, planes, and rubbing and polishing machines are used. The main production site of dimension stone (Figure 4.11) is in Ban Pha Tung of Uttaradit (Figure 5.22). This area produces materials supporting all neighbouring provinces: Phitsanulok, Nan, Sukhothai and Phrae. The ground geophysical surveys were made over the HEM anomalies and only saprolite layers and fault zones are identified (Siripongsatian and others, 1991).

For railroad and road construction, riprap and broken stone of basaltic andesite are used as ballast (Figure 5.23). The area in Ban Rai Huai Phi was selected to correlate HEM anomalies with this ballast site (Figure 5.24). It was found that a group of negative inphase HEM anomaly in this area is associated with the outcrop of basaltic andesite and small hills nearby. Therefore, the associations of HEM anomalies and hilly terrains are definitely the potential areas for future construction material reserves (Figure 5.25).

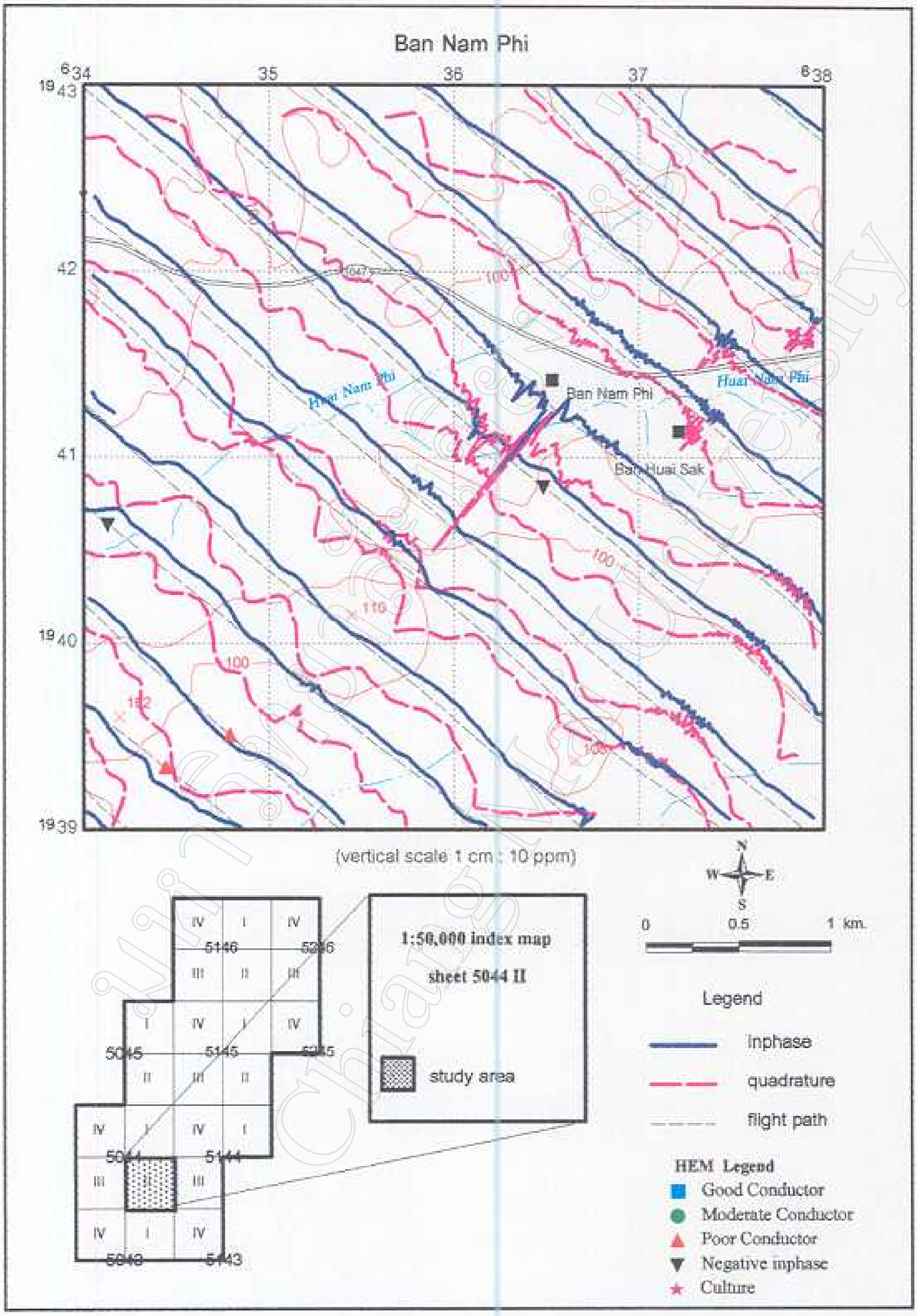


Figure 5.20 Selected area in Ban Nam Phi for nickel chrome iron evaluation using geophysical survey.

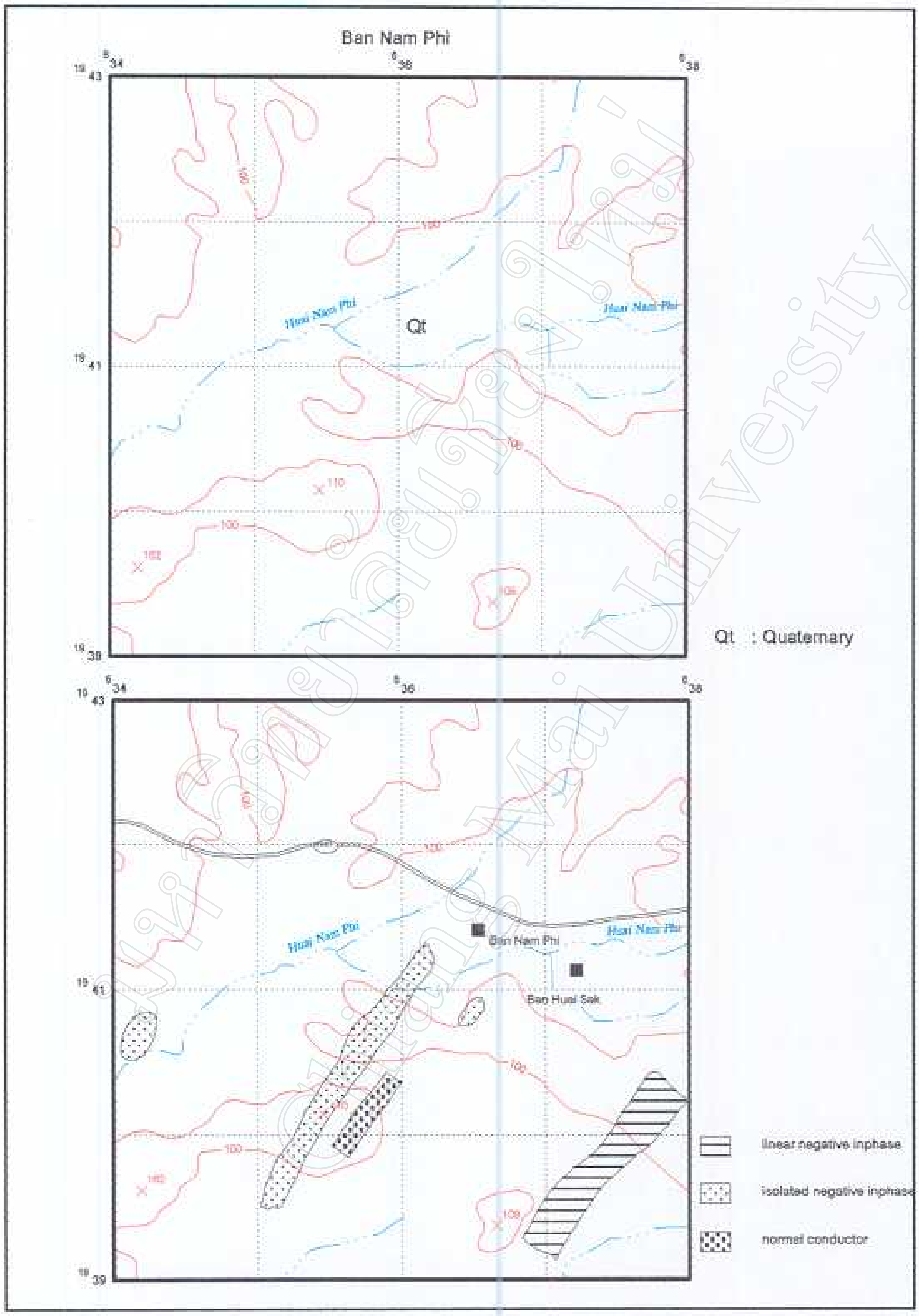


Figure 5.21 Potential area of nickel chrome iron in the selected area.
(geology : after Sukvattananunt and Prasittikarnkul , 1985)

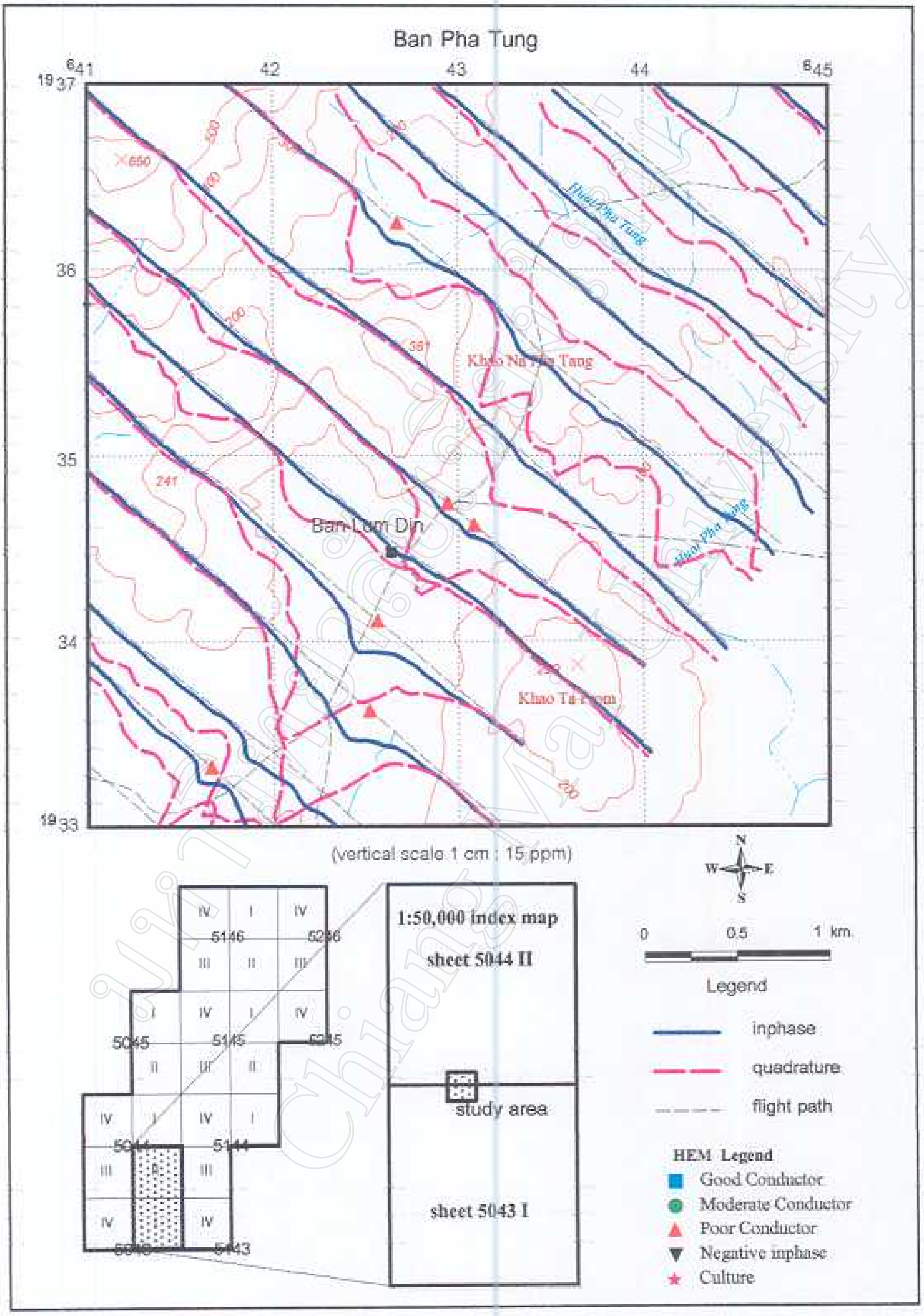


Figure 5.22 Selected area in Ban Pha Tung for dimension stone evaluation using geophysical survey.

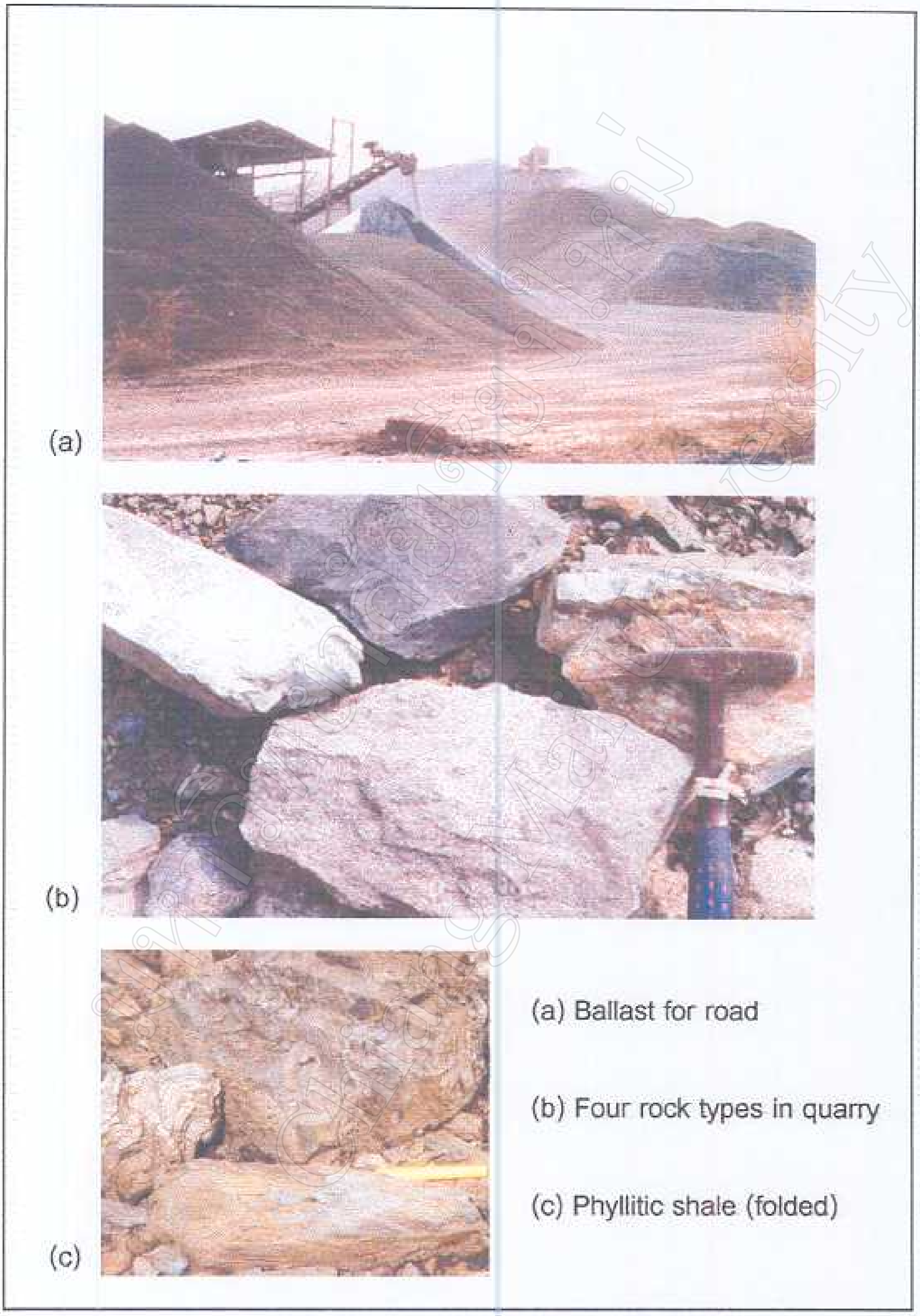


Figure 5.23 The construction materials in Ban Rai Huai Phi.

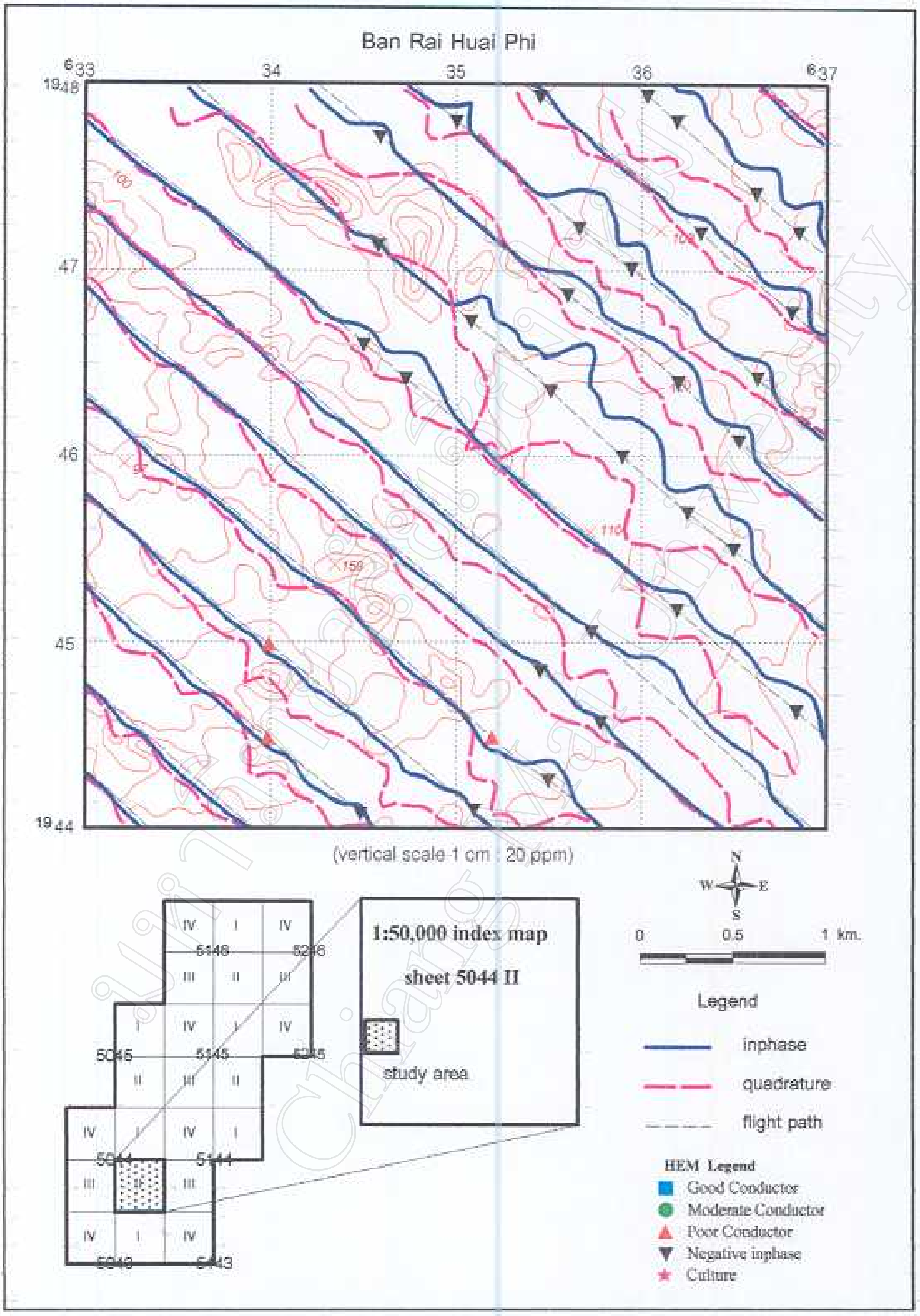


Figure 5.24 Selected area in Ban Rai Huai Phi for construction material evaluation using geophysical survey.

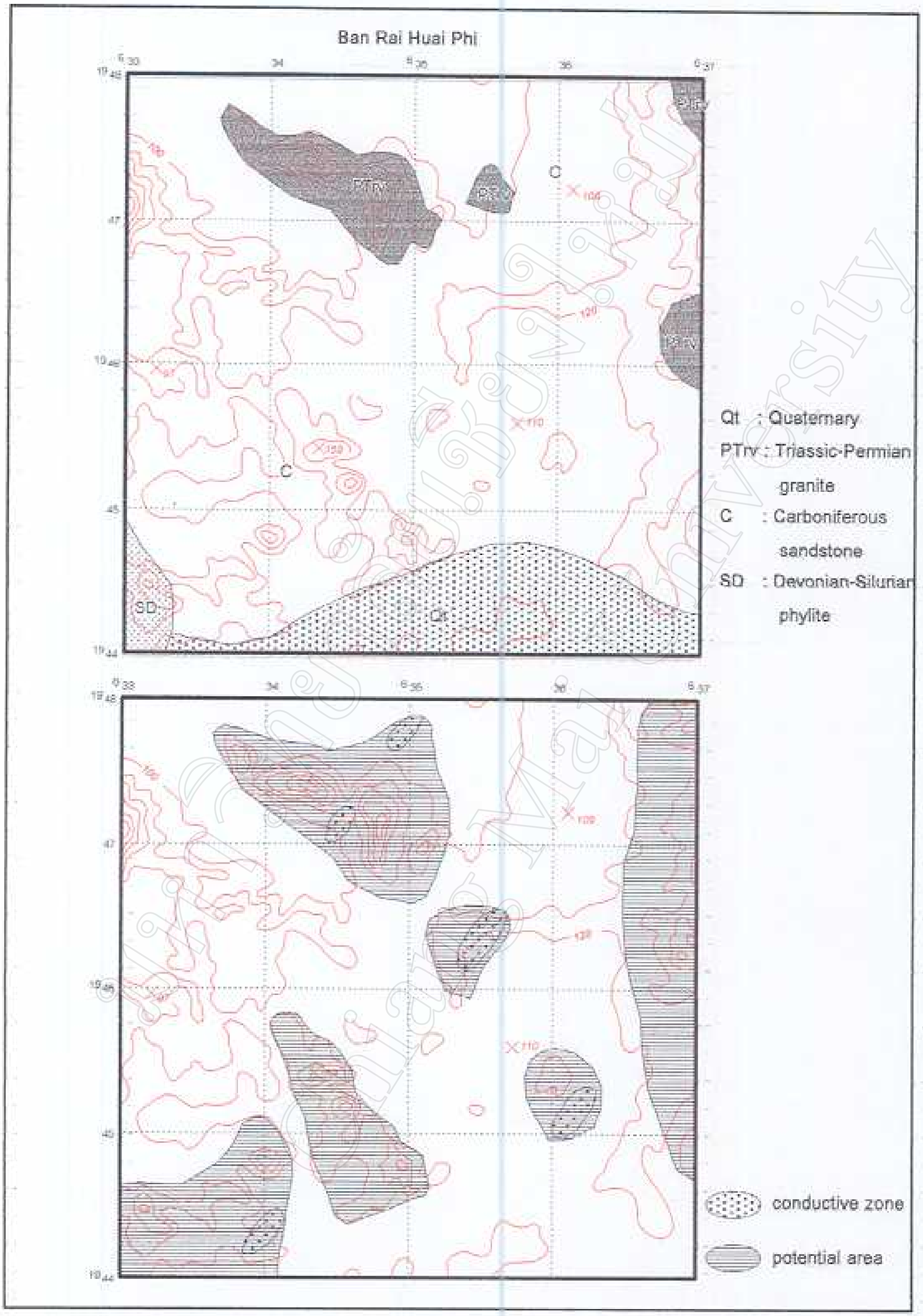


Figure 5.25 Potential area of construction material in Ban Rai Huai Phi.
(geology : after Sukvattananunt and Prasittikarnkul , 1985)

Sand is a broad term used to cover almost any comminuted rock or mineral, but technically it is restricted to quartz sand with minor impurities of feldspar, mica, and iron oxides. All are of detrital origin and sorted, cleansed, sculptured, and transported by water. Sand and gravel occur as stream-channel and floodplain deposits lying at or near the Nan River in Uttaradit and Nan and Sa River in Nan, consisting of irregular sizes and impurities necessitating screening to size. They are the normal weight aggregate used with cement to form concrete.

5.2.7 Other mineral deposits

Even though other mineral deposits are not significantly well known but some of them are worth considering because they could be related to geophysical means. They were considered as economic mineral deposits in this study area but limited accessibility prevents any further detailed studies.

5.2.7.1 Copper

There is no production report of copper in Thailand during the 20th century. Most of copper used in Thailand is imported from overseas (Department of Mineral Resources, 2000). It is a principal metal used in several industries particularly electronic. It is also extensively used in alloys such as brass (copper and zinc) and bronze (copper and tin with some zinc). There are more than 100 copper minerals but only a few can be economic ores. Large copper deposits of economic class are mainly hydrothermal deposit and porphyry types (Jensen and Bateman, 1979).

Carrel (1964) made the first report on geological and economical study of the copper prospects in Thailand. He explained that only two groups emerged as potential copper-bearing deposits to be worth of detailed semi-systematic investigation. The first is in Pak Chong District, Nakhon Ratchasima and the second is the Nam Tron –Nam Sum Group of Uttaradit.

Based on the study of Carrel (1964), the second one consists of a 120 km elongated strip of land marked by numerous secondary copper minerals. These occurrences are impregnated exposures of sandstone found in the lower part of the deep valleys of Nam Pat District and Fak Tha District of Uttaradit near the Thai-Lao border. These prospects are the result of the deposition of secondary copper-bearing solutions on local parts of sandstone beds (Figure 5.26a). Its trend is recognizable in the field by sills of porphyry, many parallel stockworks of quartz veins and important shearing zones. A few are mineralized with copper minerals in the form of massive covellite in scattered small aggregates, malachite and azurite in the joints. Granitic intrusion was found in many exposures along creeks and ravines close to the copper prospects (Figure 5.26b). The rock is coarse-grained and oriented with abundant biotite or many amphiboles. These intrusions are related only to airborne radiometric

a) 

b) 

a) copper occurrence

b) granite outcrop

Figure 5.26 The mineral and rock found in Huai Yuak.

anomalies, not aeromagnetic, and more intrusions are expected toward the northeast with respect to this relationship. Aranyakanont (1972) reported secondary copper deposits east of Fak Tha where airborne radiometric anomalies are also evident.

Compilation of aerial photograph and airborne radiometric data interpretation should provide a good guide where to start the exploration. Reconnaissance fieldwork in relation to the interpretation with known prospects may the first likely procedure. The resulting information would thus permit the limitation of the generally mineralized area. The second phase would consist of focusing tactical geochemical surveys over the privileged zones, and ground geophysical survey of induced polarization electromagnetic may be applied. The results obtained by the above techniques would be counterchecked using deep hole drilling. Thus completely hidden lenses of copper impregnated sandstone might be located and approached through thick capping.

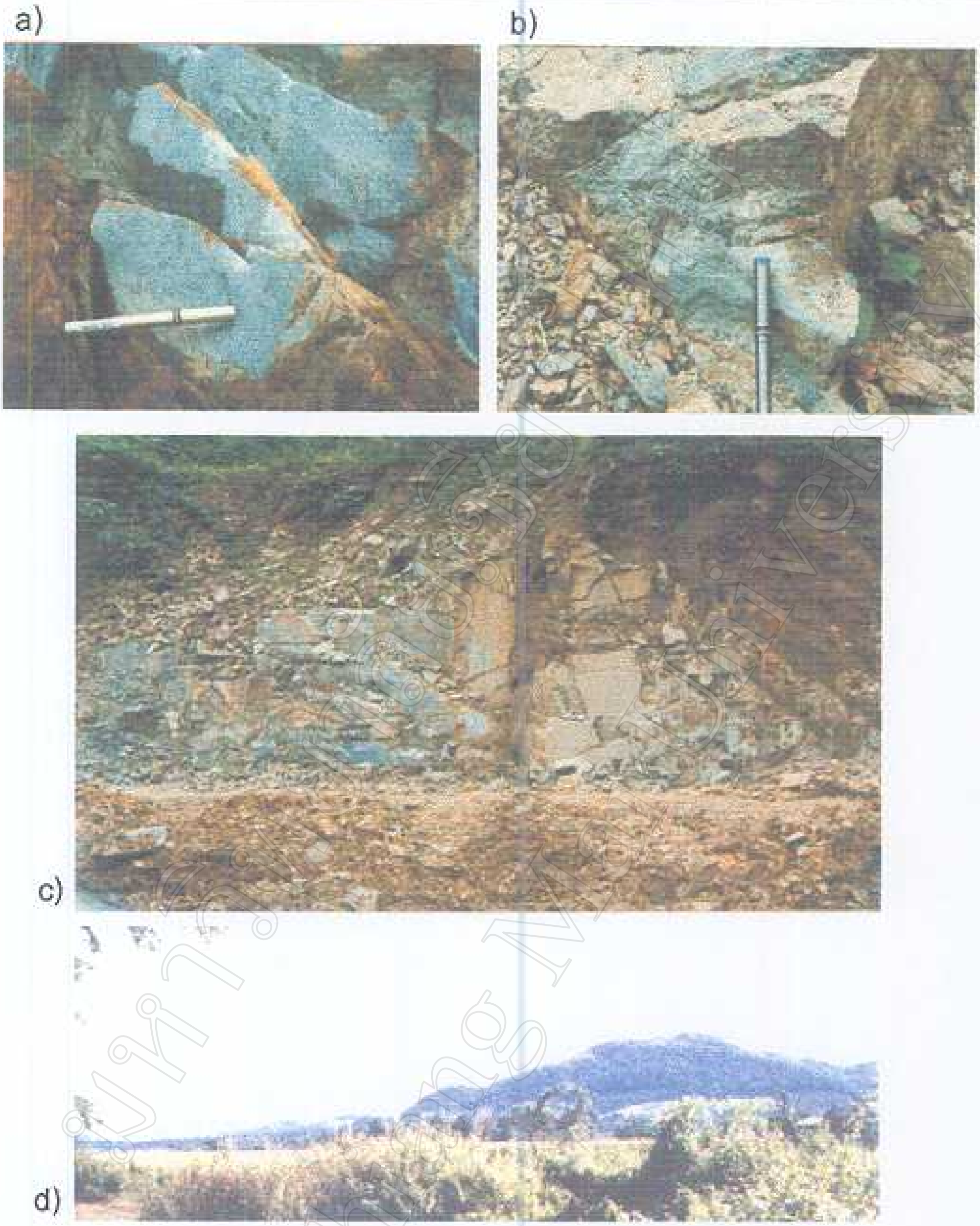
To the west of the proposed suture zone, copper mineralization was found within sedimentary sequences (Chaleechan, 1954). Malacite and azurite, secondary copper ores, are found both in shale beds and in andesite dike. Generally, the andesitic dike is cross-cutting the Triassic formations near Ban Na Khian in Sa District of Nan. Chemical analysis showed that shale and andesite consist of 0.13 % and 0.24 % of copper respectively. It was concluded that the possible ore reserve is less than 100,000 tonnes at 1 % copper which is not economic. Suwanasing (1963) reported other similar occurrences of copper mineralization but no economic evaluation were made because of their limited expression. Minor copper mineralization (Figures 5.27a and 5.27b) is also found within volcanic rocks (Figure 5.27c), especially in the western flank of Nan basin where the communication stations are located (Figure 5.27d).

5.2.7.2 Gypsum

There are two common evaporite minerals, gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$), that are widely used in the construction industry and agriculture. Gypsum, by far the more important of the two, is used to retard the setting time of portland cement, and as an agricultural soil conditioner and fertilizer for which anhydrite is also used. Gypsum is calcined to form "plaster of Paris" for use as plaster for construction and industrial purposes, and for manufacturing wallboard.

Gypsum occurs as an evaporite in regular beds or lenses, in various states of purity, and in a great range of thickness from a few feet to hundreds of feet. Gypsum may occur singly or with anhydrite as a primary deposit, or as a surficial hydration product of anhydrite.

There are five varieties of gypsum: (1) rock gypsum; and (2) gypsite, an impure earthy form, both of which are used commercially; (3) alabaster, a



a) disseminated copper sulphide

b) fracture filling copper sulphide

c) andesitic tuff

d) area of volcanic rocks

Figure 5.27 The mineral and rock found west of Nan.

massive, fine-grained, translucent variety; (4) satin spar, a fibrous silky form; and (5) selenite, a transparent crystal form.

Since gypsum occurs chiefly in flat or gently dipping beds, most of it is mined by open pit methods. Their geological setting is best suitable for electrical survey, a layered earth model. It was later found that electromagnetic with a specific configuration was even better (Utha-aroon and Surinkum, 1995).

In term of gypsum occurrences in this study area, they are neither simple flat nor gently dipping beds. They form as a concretion of satin spar and hypogene selenite (Figure 4.10). The first one was once mined from the deposit near the Nam Pat River, north of Nam Pat District of Uttaradit. The second one is found distributed within the Mesozoic sequences where water table is leveled. Both are not of economic interest but indication of promising area for gypsum is pronounced.

5.2.7.3 Magnesite

Magnesite along the Nan-Uttaradit suture zone is fine-grained massive and commonly intergrown with quartz (Jeenawut, 1996). The known deposit occurs on the hilltops, with elevation 400 m above mean sea level at Doi Puk Sung, and covers 200X300 m^2 with 20 m thick. Due to its high silica content (19-39 %), this magnesite deposit cannot be economic. Unfortunately, there is no HEM data over that deposit, therefore aeromagnetic and airborne radiometric cannot be correlated directly.

There are also other occurrences of magnesite reported by Munyue and others (1991), Pintawong (1998), and Paopongsawan and others (2000) but neither is of economic interest. However, they are found close to chromite occurrences and further surveys from the known chromite deposits may lead to a new magnesite deposit. The electromagnetic and resistivity surveys applied for gypsum deposits (Utta-aroon and Surinkum, 1995) may be used to locate magnesite because both have similar physical properties.