Chapter 7
Conclusion

Interpretation of geophysical data in the NUS zone reveals many geological aspects related directly and indirectly to geological information previously studied in this area. The relations can be used to define not only mineral potential areas but also how their formation during a continuous tectonic evolution. Three different aspects are summarized: tectonic, regional geology, and economic geology. The conclusions made are based on physical properties of the rock units detected by both airborne and ground measurements with a correlation to outcrops and mineral occurrences. Discussions on the formation of the NUS zone and its effect in the geological setting of the study area are summarized under the tectonic aspects. New evidences on geology from geophysical data interpretation are summarized under the regional geology aspect. Mineral potential areas together with recommended procedures for locating each type of ore deposits is summarized in the part of economic geology aspect.

7.1 Tectonic

Geological interpretation of the NUS zone using airborne geophysical data indicates that there are two major tectonic blocks: west and east (Figure 3.32). The west block is composed of terrain of ultramafic rocks thrusted over the igneous and sedimentary sequences toward the west (Figure 3.32). The volcanic rocks in the west form elongated bodies indicated by radiometric data, while the plutonic or shallow intrusive rocks form circular bodies indicated by magnetic data (Figures 3.29, 3.30, and 3.31). The east block is composed mainly of continental red beds. Some igneous rocks, indicated by radiometric and magnetic data, are observed but they are not expressed prominently as in the west block (Figure 3.32).

Multiple thrusting of the ultramafics are indicated by three parallel-elongated ultramafic units (Figure 3.33). These ultramafic units were located from an aeromagnetic anomaly as tabular magnetic bodies, buried at different depths (Figures 3.11, 3.18, and 3.19). Their outcrops should also be more widespread as indicated by non-anomalous zone of radiometric data, than previously mapped (Figure 3.22). Some of them are buried not very deep because their significant conductance are observed in helicopter-borne electromagnetic data (Figures 3.33 and 5.24).

The orientation of a tabular magnetic body with high magnetic susceptibility and confined shape, interpreted as an ultramafic unit derived from oceanic crust indicate that the suture strikes north-northeast (Figures 3.11 and 3.32). Magnetic modelling results show that the suture has a westward dipping orientation. The magnetic body of ultramafic unit is located deeper toward the west with a steeper dip angle (Figures 3.13 and 3.14). During collision, the west block slid toward the northeast, left-lateral faulting in a surface expression. This is interpreted from a dislocation of magnetic anomaly within a complex zone of the ultramafic rocks (Figures 3.10 and 3.32). Detailed mapping over a particular area of interest can be used to verify the displacement on the surface, and ground magnetic survey across that area will confirm the orientation at depth.

7.2 Regional geology

Surface mapping data indicate that the ultramafic outcrops are usually round-shaped. This is due to the lack of lineament observed from aerial photograph expression. The exposures cannot be confirmed previously because of a limited access. Aeromagnetic data, however, show that the ultramafic units are irregular in shape and not continuous. Some are round-shaped but most of them are tabular-shaped (Figures 3.10, 3.13, and 3.14).

Within the three parallel ultramafic zones, the degree of deformation increases toward the west. The deformation degree is reflected directly from the conductance of each ultramafic unit: more conductive westward as represented by helicopter-borne anomalies (Figures 2.11 and 3.33). However, this character should be considered together with its exposure. Ultramafic rocks generally contain limited radiometric minerals, therefore, radiometric data cannot be applied in this interpretation. However, the degree of deformation or alteration, in general, can be reflected directly by airborne radiometric anomaly.

An integrated data of aeromagnetic and helicopter-borne electromagnetic survey show that many ultramafic units are buried not very deep in many places. The presence of ultramafic rock is evident from aeromagnetic data while a shallow depth to the top (10m - 30m) of the ultramafic unit is reflected from a group of poor conductors (Figures 3.8, 3.9, and 5.24). Aeromagnetic data also show that the zone of ultramafic rocks extends toward the southwest and lies beneath Qt and Qa in Uttaradit (Figure 3.10). There is no doubt that the residual iron deposit found at a quarry west of Uttaradit was originated from a burial ultramafic rock.

Intrusive activities are more widespread than it was previously outlined. There are some intrusions underneath the redbeds in Nam Pat District and Fak Tha District of Uttaradit. The airborne radiometric and aeromagnetic data show that a distinct intrusion is located just south of the intersection of highway numbers 1239 and 1212 southwest of Nam Pat District (Figures 3.10, 3.26, and 6.9). The airborne radiometric data also reflects over a zone of redbeds outcropping between Nam Pat District and Fak Tha District. However, there is no aeromagnetic data supporting the intrusive activities in this area (Figures 3.9 and 3.25).

North of the illite production area, circular magnetic features are associated with granitic stocks (Figure 3.10). The association indicates that there should be more intrusions in that area and more hydrothermal activities are expected. Therefore, more alteration products originated from the volcanic rocks is a very good target for clay mineralization. These similar associations are located toward the north within the Zone B of the tectonic map presented in Figure 3.32. However, the volcanics are of different rock types, therefore, other clay mineralization areas are not yet found in the northern extension of this zone. Lithologically, for these volcanic rocks, some are parent rocks for illite and some are host of hydrothermal mineral deposits. Moreover, there is one intrusion associated with a circular feature of aeromagnetic anomaly over the northeastern most part of the airborne geophysical survey (Figure 3.8). No further interpretation can be made because the airborne geophysical data is limited due to security reasons along the Thai-Lao border. However, that area is proved to be one of the promising area for gold exploration (Paopongsawan and others, 2000).

Interpretation made from this study indicates that some Mzv units are basaltic andesite which are parts of the melange. These units are distinguished from the other volcanic rocks by their very low radiometric expression and their conductance.

The granite of Khao Yai mapped by Sukvattananunt and Prasittikarnkul (1985), southeast of Uttaradit may just be a big block in the melange (Figure 3.32). The aeromagnetic data indicate that this granitic unit does not have a deep root (Figure 3.11) and radiometric anomaly due to radioactive element is less active than other granitic unit found elsewhere, such as granitic rocks found along the Thai-Malaysia border (Surinkum and Paiyarom, 2000). Helicopter-borne electromagnetic data also show that this granitic unit is a poor conductor (Figure 3.34) while granitic rocks are generally good conductors (Palacky, 1988). However, the conclusion on this should be confirmed by further detailed study.

7.3 Economic geology

It is known that many types of mineral deposits occur within the NUS zone. Therefore, it is not a matter of their existence but how they can be located and how extensive they are. Some of them can be classified as promising if a million tonnes of reserve is expected, but some contain only a few tonnes. The promising areas for mineral deposit should be outlined by means of systematic and scientific procedures based on their properties. Their economic potentials are also based on how cost effective they can be mined and extracted. In this study, the mineral deposits are outlined by geophysical data and their economic geology will be presented.

The most promising mineral deposit in this study area is chromite. Chromite potential areas are located by HEM anomalies. HEM anomalies, indicating magnetic associated conductor, are associated with chromite occurrences because chromite is a ferromagnetic mineral (Carmichael, 1982). By means of the ground geophysical survey, chromite is outlined over zone of strong magnetic anomaly within a less magnetized zone of tectonized ultramafic rocks. Therefore, the isolated negative inphase HEM anomaly, with a strong ground magnetic expression, lying beside a zone of hydrated ultramafic rock is a place where a chromite deposit could be located.

On the other hand, talc is a non-magnetic part of the ultramafic units. Serpentinization process changes original ultramafic rocks, in this area, to be hydrated ultramafic rocks and then to become talc. Talc can also be detected by electromagnetic survey but its conductance is not much different from hydrated ultramafic rocks, however they are difficult to be distinguished from each other. Another alteration product of the ultramafic rock is chrysotile asbestos. Chrysotile asbestos is located along a linear HEM anomalous zone. The asbestos occurs in a limited zone due to mineralization process that concentrated the mineral only in a fracture system within the ultramafic rocks. Therefore, only an economic evaluation for talc is being considered, and both magnetic and electromagnetic can be used efficiently.

Parts of the ultramafic rocks in this study area are weathered and their residual products are significant. Some geochemical data (Paopongsawan and others, 2000) reveal that lateritic nickel is located on the top of ultramafic rocks, especially on a highland where hydrological condition is favoured. Terrain conductivity measurements were applied to differentiate a saprolite from a layer of nickel residual concentration (Paopongsawan and others, 2000). Integrated data of geomorphology and chemical analysis can be used to outline economic potential areas for nickel and ground geophysical data can be a depth estimation technique (Figure 5.19). On contrary, nickel chrome iron is located over the ultramafic rocks in a lowland morphology. Geologically speaking, these iron deposits are located within the Quaternary terrace deposits. Aeromagnetic data indicate that ultramafic rocks lie underneath these deposits and HEM anomalies are associated with iron deposits (Figure 5.20). Ground geophysical surveys can also be applied to locate locations of the iron deposits but signals are not significant enough to be useful definitely (Figure 4.22).

Airborne radiometric and aeromagnetic data indicate that there are many shallow acidic intrusive bodies in this study area. The so-called, Nam Phang, Huai Yuak, Ban Tham, and Fak Tha areas are recommended potential areas for hydrothermal mineralization such as gold and copper (Figure 6.10). Detailed investigation over these areas must rely on geological mapping and geochemical surveys rather than geophysical surveys. Some of them, Huai Yuak and Nam Phang, were proved to be promising areas and were recommended for further studies (Carrel, 1964 and Paopongsawan and others, 2000). However, the geophysical applications can be used to locate mineralized zone within the area already selected from anomalous zone by other applications (Surinkum and others, 1987).

Illite, white clay of Uttaradit, is also a product of hydrothermal alteration process. Both aeromagnetic and radiometric data can be used to define a definite potential area of illite. The radiometric data indicate area of potassic alteration while aeromagnetic data show the intrusive locations (Figures 3.31 and 5.11). Illite zones and their depth estimation can be outlined by electromagnetic data (Figure 5.12). Their lateral extensions may continuously follow a weak zone within the volcanic rocks.

Aeromagnetic data and HEM anomalies are also associated with localities of construction material used in this study area (Figure 5.24). These construction materials are mined from the quarries of basaltic andesite. Their proposed localities can be defined by the associations of both airborne geophysical data found over a hill closed to the developed quarries (Figure 5.25). Locating more of them over the recommended areas can fulfill future demands on these materials. Construction material bodies with less depth but wider coverage should be the best target and ground electromagnetic surveys can be used to map them efficiently (Figure 5.25). The areas with good accessibility, i.e. close to road and power supply should be rated as a prime location.

7.4 Proposed working procedure

Exploration is the only way to determine the extent of the ore reserve that is the raw material necessary to keep downstream industry alive. It may require up to 10 years of intensive fieldworks before one mineral deposit can be found with enough potential to become a mine. Technical information concerning the area of interest will be gathered as maps or digital data. The search for an ore deposit should be systematic and scientific. It should ensure the services of professional geoscientific personnel in order to produce reliable results and quantitative, economic-based recommendations for management.

Exploration procedure is different from one type of mineral deposits to another. Stages of conventional practice are not necessary because some of the deposits located within the study area have already been classified. However, proper procedure and personnel are essential and therefore, criteria of each deposit type must be considered carefully.

Chromite, the most promising mineral deposit in the study area, is embedded in ultramafic rocks marked by aeromagnetic and HEM data. Ground magnetic survey can be used to pin point location of a chromite ore body (Figure 4.13). Therefore, two magnetometers (Figure 2.12) together with a global positioning system can be applied over a selected location within the proposed areas of chromite (Figure 6.1) and chromite location will be identified.

Measurement of conductivity over HEM anomalous areas can lead to finding of talc and asbestos locations, in spite of poor correlation between conductivity contrast of talc and other hydrated ultramafic rocks. Since talc is a non-magnetic body an integrated interpretation of electromagnetic and magnetic data must be used to successfully locate a talc ore body (Figures 4.18 and 4.19). In the talc proposed area (Figure 6.4), traverse lines, perpendicular to the strike of the linear HEM anomalies, close to the talc outcrop can be laid out and a terrain conductivity meter (Figure 2.16) together with two magnetometers (Figure 2.12) should be applied. Talc deposits will then be located by interpretation of both geophysical survey techniques.

Weathered ultramafic rocks located on high relief terrains are sources of lateritic nickel (Figures 4.9 and 6.6). Geochemical study over well-drained area is recommended and geophysical surveys should be applied for depth estimation. On contrary, secondary iron ore is located over the ultramafic rocks in low relief terrains as local enrichment of limonite. Ground magnetic survey and terrain conductivity measurements are suitable procedures for locating the iron deposits. However, these geophysical data are not definite answers because the iron ore does not give a distinct signal.

Fresh ultramafic rocks located on low relief terrains are associated with basaltic andesite. The basaltic andesite, in a certain favourable locality, is the prime target for construction material (Figure 6.14). The rock, overlying the specific HEM data on an area without conflict of land-use interest can become future supply of construction material. Simple geophysical surveys such as electromagnetic (Figures 2.13, 2.15, and 2.16) and resistivity surveys (Figure 2.19) will be useful to determine whether these HEM anomalies are appropriate exploitation targets.

Over the potential areas of copper and gold, geological mapping and geochemical surveys should be applied in a regional scale. Semi-detailed scale surveys should be applied over the area where both structure-controlled mineral occurrences and airborne geophysical anomalies are associated (Figure 6.9).

Illite is derived from volcanic rocks as hydrothermal product mineral deposits distributed within volcanic zones. The associations of radiometric anomaly, magnetic anomaly and outcrop of these volcanic rocks can be used as the prime targets (Figure 6.11). Different types of ground electromagnetic survey can be applied depending on the detailed study being made. Terrain conductivity measurements are suitable for locating the illite zone while HLEM is suitable for illite zones orientation (Figures 4.15 and 4.16). Through these exploration activities, more potential areas for illite can be outlined over the volcanics and proper development programmes can be executed.

The evaluation of mineral deposit in the NUS zone using geophysical data was made in this study. It has been proved that geophysical data can be used not only to pin point the locations of the known type of mineral deposit but new types of mineral deposit can also be defined. Sub-surface investigations can be made by diamond drilling in these specific locations. While drilling is being executed, other surface activities such as detailed geophysical surveys or bore-hole geophysics, trenching and pitting can be implemented in order to identify the aerial extent of the deposit.

Finally, size and volume of each prospect can eventually be calculated and exploitation started. Data gathered from all previous stages of the exploration can be used to represent individual layer control for both exploration programmes and development planning. Interpretation made in this study is not only reasonably successful in determining lithologic boundaries and locations of mineral deposits but it also provides systematic operation procedures. Information obtained from subsequent exploration programmes for individual mineral deposits at various stages can be used to improve further economic evaluation using geophysical data in the NUS zone.