Chapter 7
Discussion

As stated in the earlier chapters, results from the enhanced aeromagnetic data conform well with the previous field mapping by several DMR geologists (e.g.-(Chairangsee et al., 1990; MRDP, 1988; Chairangsee and Macharoensap, 1985; Sillapalit et al., 1984, and Chareonpawat et al., 1975). However, these enhanced data together with Landsat and airborne radiometric data yield more essential geological information, particularly those regarding contexts of tectonism and mineral exploration. In the discussion part, special emphases are placed on the relationship of the interpreted airborne magnetic data to geology and structure of the Loei area and their application to tectonic evolution and mineral deposits.

7.1 RTP correction

The problems can arise in the RTP process at magnetic latitudes less than 15° as discussed by Macleod et al. (1994). As stated earlier, the Loei area is at the latitude 17° -18°, and inclination angle 22°, the noise effects still exited upon the RTP process. So in this study, the experiment of RTP correction is using the formula calculation developed by Grant and Dodds (1972). The varieties of I' are trial and error using the Oasis Montaj and ChrisDBF software programs. Visualize of the results, which are low noise effects (NS stretching) and to have best geometry where dipoles become monopoles. The suitable I' for the Loei area is 30° for both OASIS Montaj and Chris DBF results. Experience has shown that this can be minimized by that using a slightly higher original or source inclination than the observed. However, this second inclination ($I'=30^{\circ}$) is suitable only for the Loei area and the other areas posing similar latitudes and inclination angles. For the other areas with different latitudes, experimentation on this subject is also required.

However, a basic assumption of the RTP process is that all bodies are magnetized by induction. Macleod et al. (1994) have demonstrated that smearing of anomalies can occur in transformed maps when significant remanent magnetism is present. In the study area, significant remanence appears to be relatively rare as shown in previous chapters and its possibly should not inhibit the uses of RTP. The analytic signal can provide a check on the presence of remanence because the computed analytic signal peaks, which occur above source bodies regardless of the direction of magnetism, can be correlated with the peaks of the RTP data to check for consistency (Milligan and Gunn, 1997).

7.2 Magnetic responses related to rock units

To correlate magnetic anomalies with rock units, it is noteworthy that sedimentary rocks are generally non-magnetic, whereas igneous rocks rich in iron and magnesium (mafic to ultramafic) tend to be very magnetic. Granite intrusions and hornfels contact aureoles can also be magnetic.

Based on the results shown as enhanced maps in the previous chapter, it is quite likely that magnetic quiet areas are widely distributed in the central and northwestern parts of the study area and usually exhibits magnetic relief of less than 50 nT. These areas (C2 sub-domain) correspond to basins filled with Carboniferous clastic and Devonian chert sediments (Chairangsee et al., 1990). These areas are faulted and folded as recognized both in the field and the geophysical and Landsat imagery interpretation maps. It is clearly observed from several magnetic maps (e.g. those of Figs 6.3, 6.5, and 6.6) that meta-clastic rocks in the westernmost part (mainly in the C1 sub-domain) also have low magnetic intensities similar to those of the Carboniferous sediments. Moreover, results on magnetic susceptibility indicate that several rock samples of both ages yield rather similar low values (see Table. 6.1 and Appendix II). However, it is generally accepted that metamorphic rocks have more magnetic susceptibility than sedimentary rocks. As reported by Telford at al. (1986), magnetic susceptibilities of average sedimentary and metamorphic rocks are about 75 cgs and 350 cgs, respectively. We, therefore, consider that the meta-clastic unit (in the C1 sub-domain) is likely to be the same geologic unit as the Carboniferous clastic unit. Otherwise, magnetic mineral contents decrease accompanying collisional process (Tof et al., 1993, Whitaker, 1994 and Wellman, 1998). Either burial pressure-dominated or weak dynamo-thermal metamorphism of Late Paleozoic clastic rocks associated with folding and thrusting may have formed in response to compressional subduction-related tectonics, similar to that occurring along the Nan Suture (see also Salyaponse and Putthapiban, 1997, Barr and MacDonald, 1991).

The magnetically moderate areas, such as those in the C2 and W2 sub-domain have accentuated magnetic relief with lineaments and anomalies having amplitudes of 100 to 400 nT. Most of the magnetic anomalies in these areas are observed over plutonic rock exposures. Magnetic field intensity increased by more than 200 nT over a poorly exposed granodiorite stock, so the small circular magnetic bodies in the southern part of the study area, particularly those of the C4 sub-domain, suggest that these features are caused by intrusive rocks correspond well with several of the known granodiorite stocks. Moreover, the results of this study show more extent and new granitoid intrusions than the previous geological mapping (see Figs. 2.3).

Narrow and higher amplitude anomalies in the north of the central part, particularly in the C3 sub-domain, indicate the existence of mafic volcanic rocks corresponding to those mapped as Carboniferous basalt and basaltic andesite by Chairangsee et al. (1990), and MRDP (1988). Field investigation reveals that the volcanic rocks in the C3-sub-domain are made up mainly of mafic pillow lavas, hyaloclastites and pillow breccias. These volcanic rocks have been assigned to those erupted in a mid-ocean ridge to back arc basin environment, and have a whole rock Rb-Sr isochron age of 341 $\pm$11 Ma (Intasopa and Dunn, 1994). Petrogenetic investigations on the volcanic rocks in the Loei area by Panjasawatworng et al. (1997), suggest that the Loei volcanic rocks comprise of mid-oceanic ridge basalts (MORB) and oceanic island-arc lava.

Additionally, volcanic rocks in the north of the E2 sub-domain show lower magnetic intensities than the volcanic rocks in the W3 sub-domain. Based on our field visits and geological maps by MRDP (1988) and Chairangsee et al. (1990), the volcanic rocks in the eastern part are dominated by more felsic variations and those of the western part are characterized by more mafic variations. This current interpretations on aeromagnetic data together with that of radioactive data strongly conform to the results on petrochemical analysis of volcanic rocks in the E2 and W3 sub-domains.

The magnetically high areas of the E1 sub-domain show magnetic anomalies with amplitudes of more than 500 nT, and are characterized by high wavelength anomalies. Large anomalies are situated close to the border of metamorphic and volcanic rocks in the southeastern part of the studied area. The magnetic intensities of this zone are higher than those of the metamorphic and volcanic rocks. It is very interesting that this zone is not shown in the geological map of MRDP (1988). These strong magnetic anomalies are oriented in a northwest-southeast direction. The surface geology mapped by MRDP (1988) and Chairangsee et al. (1990) does not show an obvious cause of the high positive magnetic anomalies. The results of our field data indicate that these intense anomalies correspond to the mapped mafic and ultramafic intrusions including serpentinite, peridotite and gabbro (Seusutthiya and Maopeth, 2001). The studies of petrological and geological characteristics of serpentinized rocks (Seusutthiya and Maopeth, op.cit) suggest that these rocks were retrograded or hydrothermally metamorphosed from dunite, pyroxinite and peridotite.

There are some correspondences between high, elongated magnetic zones and outcropping serpentinites along the fault (TF1) in the vicinity of Ban Bun Tan, Suwan Khuha District, Nong Bua Lamphu Province. However, the serpentinite is only exposed near the center of an anomaly, so the large magnetic anomaly suggests that serpentinite body is present below the mapped Late Paleozoic meta-sediments that are generally weakly magnetic. The high magnetic elongate patches oriented in the north-south direction within the E1 sub-domain are clearly considered to present the felsic plutonic rocks beneath the non-marine Mesozoic sedimentary rock strata. These strata are visualized in the MRDP (1988) geological map and are also shown by the presence of the moderate to high eU and eTh contents in the enhanced radiometric map (see Fig. 6.15)

7.3 Magnetic Interpretation related to structural features

Magnetic anomalies display several trends defined by alignment of gradients and shapes of anomalies, and are best illustrated in Figs.6.25 and 6.26. The most dominate trend or lineament is approximately in the northeast-southwest direction, followed by the northwest-southeast lineament, and the least dominant one is in a north-south direction.

The northwest-trending lineaments are cross-cut by the northeast-trending faults with a sinistral movement and a horizontal slip of about 500 m. Good examples are shown at Ban Pak Huai Na south of Pak Chom district. As seen in the central domain, the northeast-trending lineaments are younger than those of the northwest trends as they cross-cut the northwest lineaments. The north-trending lineaments mostly indicate major strike-slip faults in the eastern domain and the east-dipping thrust faults in the central domain (as C1 sub-domain). The western domain is mainly represented by minor north-trending lineaments and geophysical trends.

Some faults in the Loei study area either have no magnetic expression or such a small one that was not detected by aeromagnetic data. The extent and form of poorly magnetized shear zones and faults within similarly magnetized sedimentary rocks is difficult to determine from the aeromagnetic data. Weathering along some shear zones and faults is well delineated in conductivity anomalies in the AEM data.

The new processed AEM data (see Fig.6.12 to Fig. 6.14) show the long continuity of lineaments of the moderate to high amplitude anomalies with the roughly north-south direction in the C1 sub-domain, corresponding to the thrust fault in geologic maps (MRDP, 1987, and Chairangsee et al., 1990). This result is in a good agreement with the regional structure reported earlier by Galong and Tulayatid (1992), which showed the correlation of a conductor with the thrust fault from the geological map. However, their interest is mainly focused on the interpretation of the thrust zone mapped by MRDP (1988). Recently, the aeromagnetic study by Rangubpit (2003) in Ban Yunk and Ban Sup, located in the southern part of the central domain, show the multiple thrust faults at this location. In contrast with this study, there is only one northwest-trending, east–dipping major thrust faults (TF2) that can be observed at this location. This is perhaps due to the smaller scale applied in her study. However, our studies show that there are other thrust faults (TF1, 3, 4, and 5) of almost the same trend are also clearly identified. They are mostly parallel to the major thrust fault (TF2). It is interesting to note that in this region these faults have been mapped using AEM data, particularly TF2, 3, 4 and 5, and they are represented by a very shallow source down-faulted beneath the only sedimentary rocks. Additionally, because of a parallel magnetic contour pattern and magnetic modeling (Fig. 6.30), the thrust faults in this area are indicated to have east-dipping geometries.

In the northern parts of the central domain (C3 sub-domain), narrow magnetic highs are related to Carboniferous mafic volcanic rocks (Carboniferous basalt and andesite) surrounded with Mid-Paleozoic chert and limestone, and cross cut by the sharp and distinct northeast-trending faults. The regional magnetic amplitude of this zone is distinctively higher than those of the other sub-domains in the central domain. This zone is, therefore, interpreted to have formed in an ocean-floor environment during Middle-to Late Paleozoic period.

Fault and fracture zones at or near surfaces are generally expressed as linear magnetic lows because of the alteration of magnetite to more weakly magnetic minerals at low temperature, high oxygen pressure in the presence of water. In contrast, the faults occurring at depth within the crust at higher temperature and high water vapour pressure, Fe-bearing hydrous silicates (biotite) can form in the fault zone. Therefore, the associated fault is expressed by an increase in Fe-oxide (magnetite) contents, which show strongly linear magnetic trends (e.g., Airo and Ruotoistenmarki, 2000). In this study, the TF1 thrust fault is associated with the positive anomaly, so we believe that the fault is deep-seated that originated in a Permian-Triassic subduction system that accreted the crust in the study area. The TF1 boundary has been adopted as the suture zone or tectonic line (called the 'Loei suture') earlier described by Charusiri et al. (2002). In addition, the TF1 may be formed as a fault zone evidenced by magnetic modeling and may be a principal controlling structure throughout the geologic history of the area. Moreover, the fault systems with the main northwest trend seem to change their orientation to the north trend, especially in the northern part of the study area. This is probably due to a major change in tectonic stress and orientation, perhaps leading to the clockwise rotation of Southeast Asia by Indo-Australia collision (Bunopas, 1981 and Charusiri et al., 2002).

Within the eastern domain, the magnetic trends are characterized by relatively irregular patterns of magnetic anomalies containing the long segments with predominant northwestern and northern trends. Structurally, this domain is characterized by the north-trending shear zone in the E1 sub-domain as indicated by en-echolon features of high magnetic intensities. These structural imbrications may have been caused by the compressive tectonic stress roughly in the east-west direction due to the subduction of the oceanic slab beneath the amalgamated, mainland Southeast Asia terrain (Neawsuparp and Charusiri, 2000). Moreover, this domain contains a set of the northwest-trending minor lineaments that cut the north-trending shear zones and the TF1 and TF2 thrust faults in the northern part of the domain, conforming a younger sinistral sense of motion. The magnetic data also show that the domain consists of several discontinuous, north- to northwest-trending sinistrally side-stepping lineaments. This domain is represented by a zone of high strain, which may be influenced from the tectonic collision in this area.

In general, there is a relatively good correlation between exposed geologic units and aeromagnetic anomalies, with many of the mapped faults displaying strong magnetic signatures. Moreover, a number of magnetic anomalies strongly suggest a number of significant faults are not shown on the existing geologic map, particularly, the northeast –trending faults in the central and eastern domains.

Comparison of the magnetic lineaments with the geologic map (MRDP, 1987 and Chairangsee et al., 1990, Fig. 7.1A) shows many of the magnetic anomaly trends (red color) coincided with geological contacts or faults (black color) or at least closely parallel them. However, the northeast-trending fault segments in the eastern and central domains are observed in both by magnetic lineaments and boundaries on the existing geological maps. Comparison of the major lineaments (cyan color) from Landsat TM5 (Neawsuparp and Charusiri, 2000) and aeromagnetic lineament (red color) maps (Fig. 7.1B) shows that the mapped lineaments have similar trends, but different in the locations that are mostly parallel to one another, suggesting that the sources of the two types of anomalies are different in depths. Additionally, the coincidence of the northeast-trending faults in the central domain of the enhanced aeromagnetic images with the Landsat images, likely indicate that these northeast-trending faults are invariably with the shallow fault sets continuing across the Loei basin, however, these lineaments are not shown on the geological maps.

As stated earlier, two kinds of fold systems are recognized in the Loei study area. One is the open fold system, which is mostly located in the western and central domains and the other is the tight fold system, which is situated in the eastern domain. However, most of the recognized folds have their axis in the north-south direction. These large scale open and upright folds dominated the central domain, are obvious in magnetic, electromagnetic and Landsat images. The southern part of the eastern domain is a zone of steeply dipping and tightly folded sub-domains consisting of sedimentary and serpentinite rocks, and defining an area with high magnetic intensities. The dominant northwest to north trends are clearly visible as the magnetic lineaments surrounding axial surfaces (green color in Fig.7.1) of the fold structures.

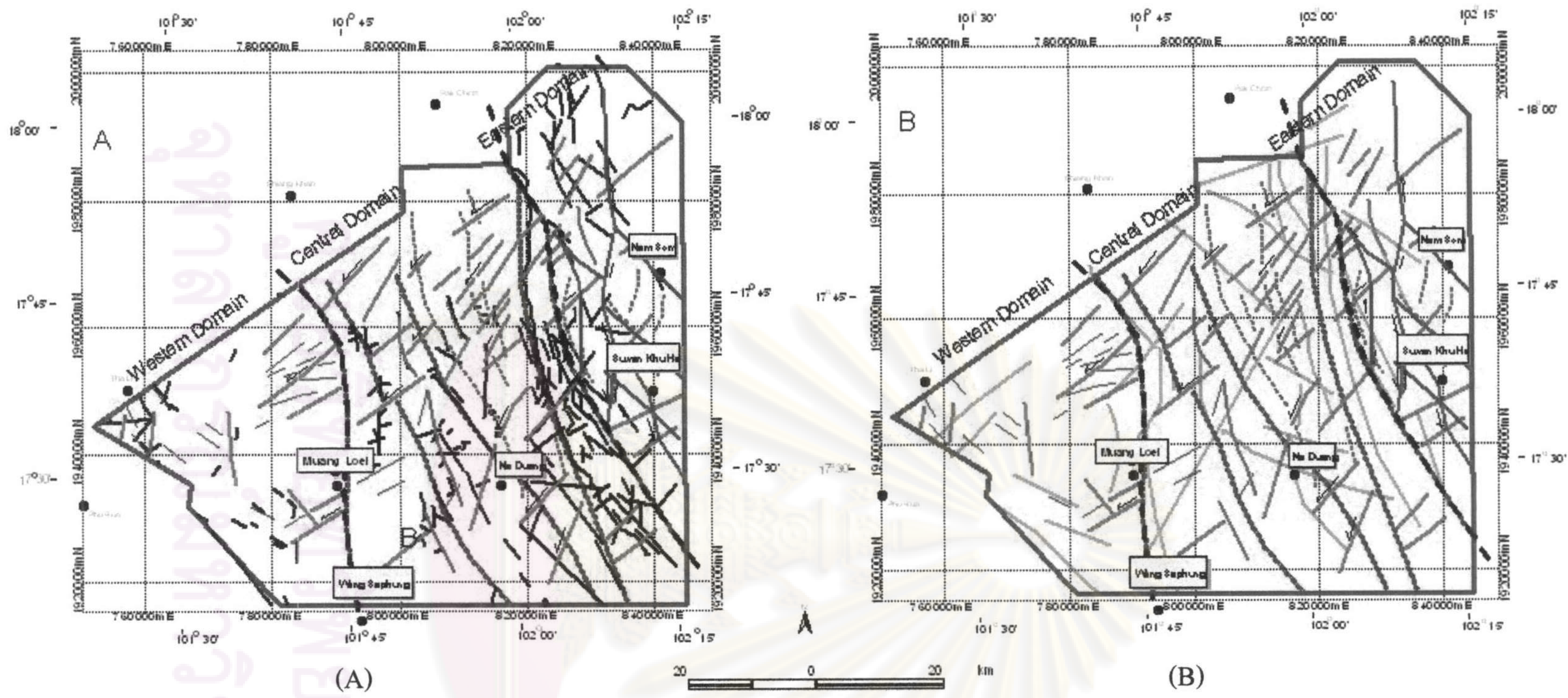

Figure 7.1 (A) Comparison of the magnetic lineaments (red color) with the geologic map (black color) modified from MRDP (1987) and Chairangsee et al.(1990), and

(B) Comparison of the magnetic lineaments (red color) with major lineaments (cyan color) from Land sat TM5 modified from Neawsuparp and Charusiri(2000).

As shown in 6.28 (D), there is an example evidence to suggest that at least two stages of folding in the Loei study area are well-recognized based on the axial plane orientation, particularly in the E4 sub-domain. The first- stage folding is dominated by the north-trending axial surface, such as at Suwan Khuha district. The second-stage folding is predominated by the northeast-trending axial surface. The first stage probably occurred as a result of compressive stress developed in a roughly east-west direction, and the second stage was developed in response to the northeast-trending compressive stress. This result corresponds with that of Neawsuparp and Charusiri (2000) for a major change in tectonic regimes during the India-Asia collision.

From the results of the magnetic and electromagnetic interpretation, the dominant structural features in each domain are summarized below.

The Eastern domain consists of a series of major strike- slip faults in a north-south direction. The E1 sub-domain shows small folds with shear zones represented by en-echolon features. Additionally, the eastern domain demonstrates many small folds particularly, in the E4 domain they displays two stages of folding represented by different direction of axial planes. The central domain is represented by many northeast-trending faults especially in the C3 sub-domain. Geophysical trends show a curvi-linear pattern where folds are associated with major thrust faults in north to northwest trends. The western domain is represented by a large circular feature with fault and geophysical trends in a north-south direction.

7.4 Magnetic response related to tectonic evolution

7.4.1 General Discussion

Based on the result on the current geophysical interpretation, there are several north-to northwest-trending, east-dipping thrust zones that are dominated in the study area. Two north-trending volcanic zones of Permo-Carboniferous ages are recognized geophysically and geologically in the eastern and western domains whereas the central part is characterized by mafic volcanic rocks in the north and limestone terrain in the south.

As stated earlier, the Loei study area is located with in the so-called Loei suture. The suture marks the boundary between the Indochina continental lithospherical block in the east and the oceanic lithosphere in the west.

Fig. 7.2 shows magnetic profile lines AA', BB', and CC' on the reduction to the pole map. Based on these three profiles it is very likely that in the southeast westward up-thrusting of the strong magnetic Middle to Late Paleozoic mafic/ ultramafic rocks in the eastern domain may have been in response to east-dipping subduction of the oceanic plate moved from the central part of the study domain (e.g., northern part of the central domain). Strongly folded and thrusted Late Paleozoic (meta) sedimentary sequence in the central domain may have been occurred in response to the compressive tectonic activity of the Indosinian orogeny. The low magnetic Late Paleozoic carbonate and clastic sequences which rested upon the underlying oceanic sediments and mafic /ultramafic rocks may have been subject to mild folding afterward. Contemporaneously, continue eastward oceanic subduction with an oblique right-lateral sense, which can be seen in the BB' profile and geophysical map may have occurred during Permo-Triassic period as shown by calc–alkaline arc magmatism in the northern part of the eastern domain which may extend northward in central Laos (Vientian).

To the west of the study area, particularly in the western domain, it is clearly observed that there exists the oceanic subduction with east-dipping direction toward in the central domain. Such subduction may have produced calc-alkaline arc related volcanism in the western domain. Several calc-alkaline to alkaline intrusions, particularly in the western parts (C2 sub-domain) of the central domain and the eastern part (W1 sub-domain) of the western domain, may have taken place during Early to Middle Triassic period due to paucity of subduction and relaxation of the crust.

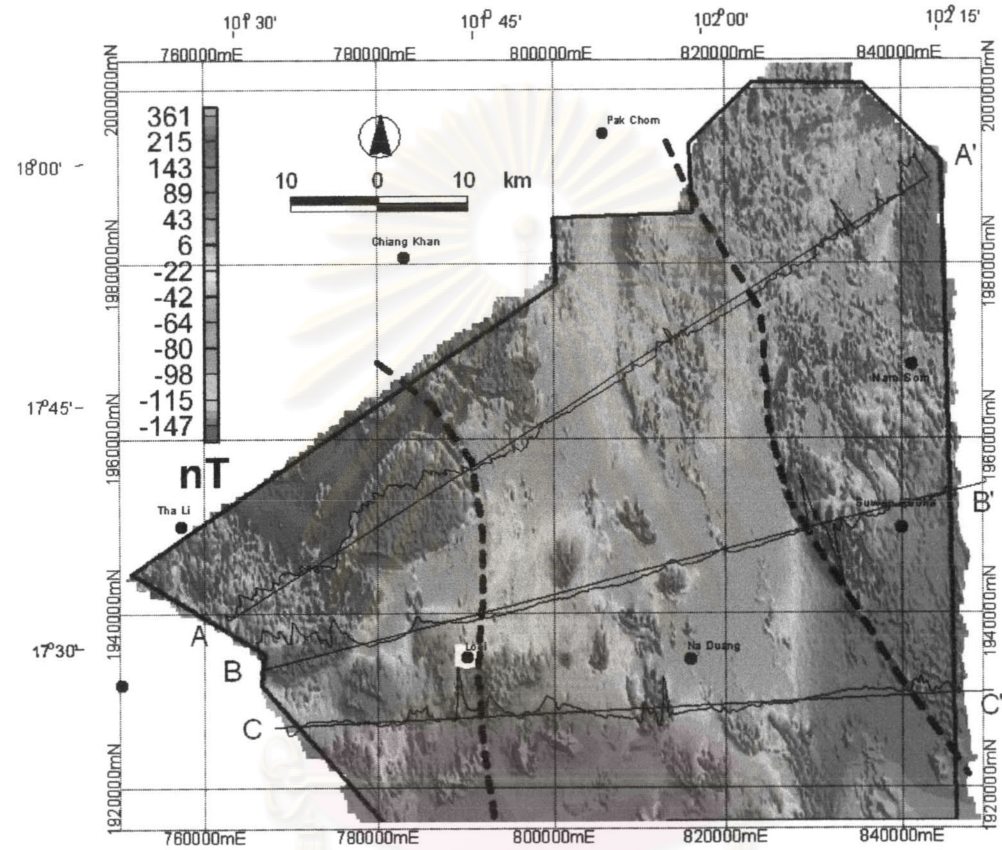

Figure 7.2 Magnetic profiles lines AA', BB', and CC' showing the high magnetic anomalies corresponding with the igneous intrusive rocks in the Loei study area.

Major structures developed after intense compression tectonics, include north-trending folds and conjugate sets of northwest-and northeast-trending faults. The long and discontinuous faults with the approximately northeast strikes seemed to be reactivated afterward. These left lateral faults cut across the northwest-striking geophysical and structural trends and deformed the high magnetic trends during the Late Mesozoic period. Perhaps this strike-slip movement may have been responsible for the development of the small elongate north-trending basins in the Loei and nearby areas.

The following model for the tectonic evolution of the Loei and nearby areas (Fig. 7.3) incorporates geophysical and geological constraints presented here and previous studies (Bunopas, 1981, 1988, 1991; Bunopas and Valley, 1992; Chuaviroj, 1990; Mesook, 1994; Intasopa,1993 and Charusiri et al.,1994, 1997, 2002).

According to Charusiri et al. (2002), in the Paleozoic Period, Thailand consisted of four microplates: Shan-Thai, Indochina, Lampang-Chaingrai and Nakhon-Thai. The Shan-Thai and the Indochina microplates were continental microplates and were located in the most western and eastern parts, respectively (Bunopas and Vella, 1992). The younger microplates, Lampang-Chaingrai and Nakhon-Thai are in eastern part of the Shan-Thai microplate and western part of the Indochina microplate, respectively, and are represented as oceanic microplates.

7.4.2 Middle Paleozoic age

During the Silurian period, all plates were covered by seawater of the paleothethys (Charusiri et al., 2002), so the sedimentary framework of the Loei area was established in an oceanic environment. These sedimentary rocks are represented by the Ban Nong Formation (Silurian-Devonian) that consists of shale and limestone (MRDP, 1988). The almost disappearance of thick sandstone beds lead to consider the rather deep- water environment of sedimentary deposition extending onto the sea floor.

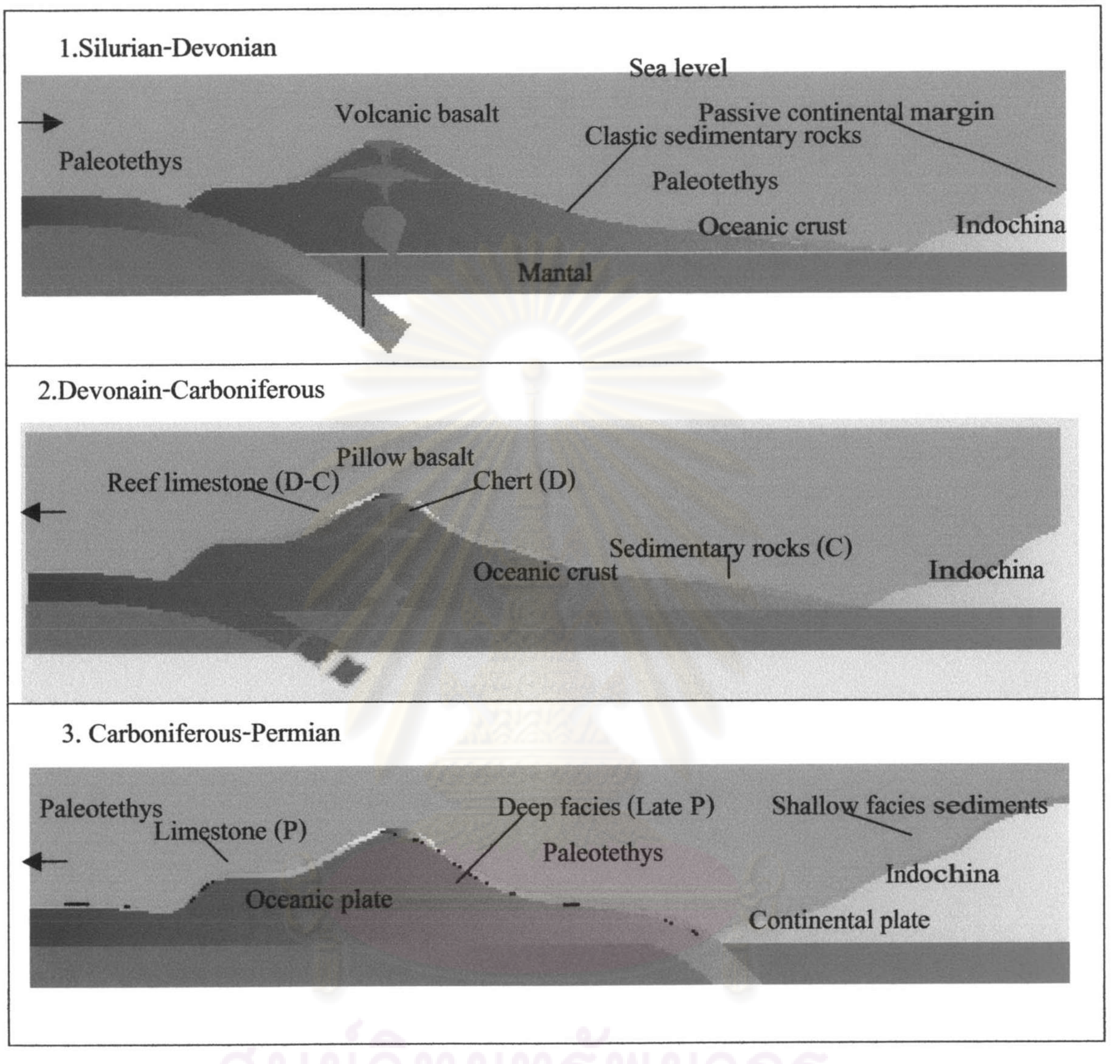

Figure 7.3 Model for the tectonic evolution of the Loei and nearby areas.

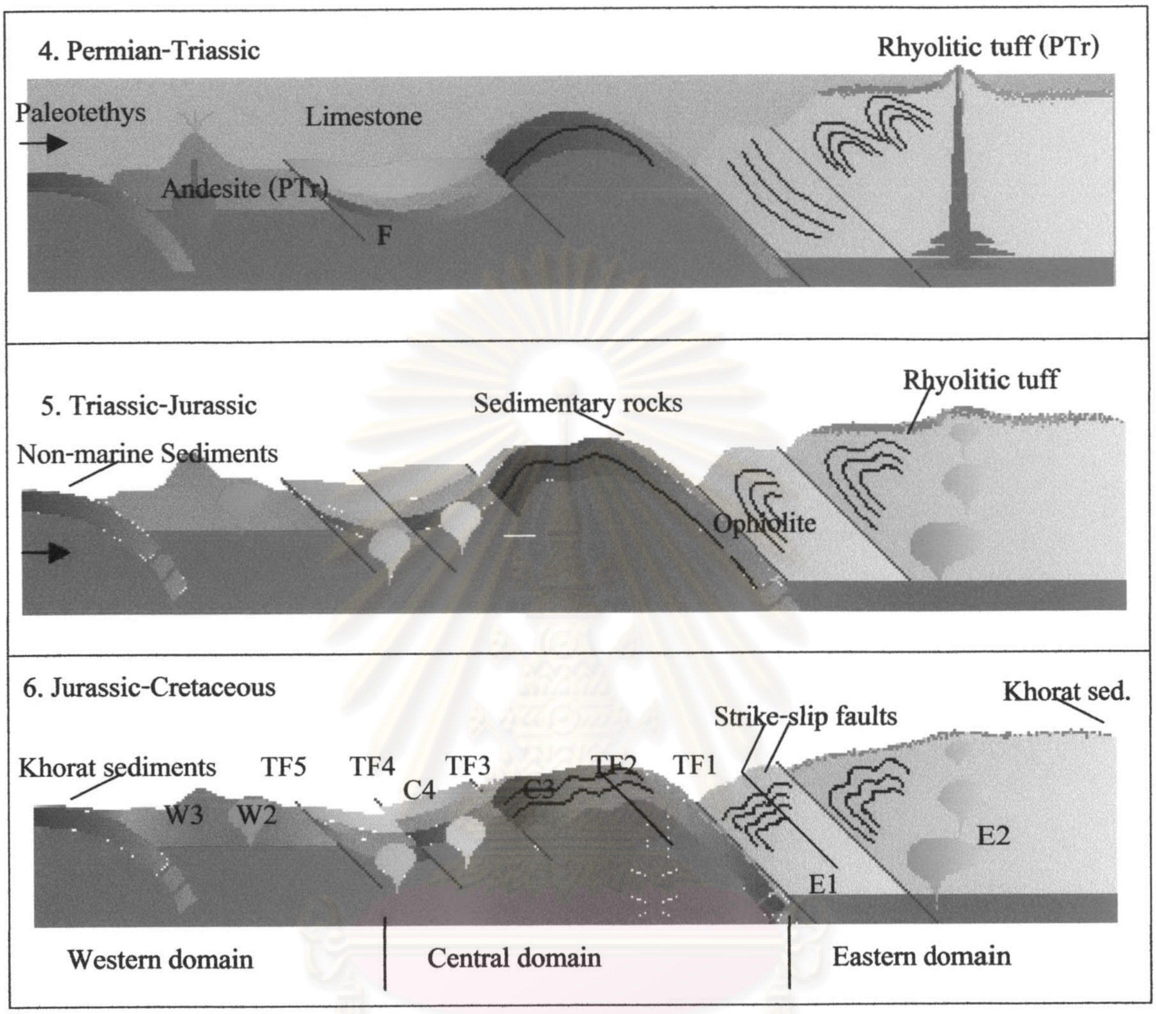

Figure 7.3 (cont.) Model for the tectonic evolution of the Loei and nearby areas.

However, the thick sedimentary beds with massive corals in shale reveal that sedimentation may have taken place in warm climate (Chairangsee et al., 1992).

In the early Devonian ocean floor was covered with thin pelagic to semi-pelagic sediments (Chairangsee et al., 1992), forming the Pak Chom formation in the northern part of the central domain that consists of mainly chert, reef-limestone and volcanic tuff. The volcanic tuff in this formation indicates volcanic activity occurring in this period. In addition, a local distribution of pillow basalt in middle Devonian in the northern part of the central domain is observed (Intasopa and Dunn, 1994). Furthermore, the petrochemical study of basalts at this location by Panjasawatwong et al. (1997) showed that the basalts in Pak Chom district are MORB and oceanic island basalt. Based on this assemblage of rock types, the first tectonic activity in Loei area occurred in the Devonian period. Subduction of oceanic crust, occurring near the Nakhon-Thai microplate, thought to be of island-arc type, was created in the western part of Loei area (Fig. 7.3).

7.4.3 Late Paleozoic age

In the Lower Carboniferous period, the subduction ceased, and passive margin back-arc basin was created while the island arc crust gradually subsided and moved away to the east from the subduction zone. In the Carboniferous to Middle Permian period, tectonic activity stopped and the sedimentary rocks continued to be deposited in both fore-arc and back-arc passive margins that are represented by the Wang Saphung Formation, which consists of sandstone and conglomerate in the Lower Carboniferous (Nong Dok Bua Member) and shale and limestone lens in Upper Carboniferous (Wang Saphung Member). The shallow sea carbonate-platform environment developed onto the massive limestone with coral fossils was deposited in Lower Permian (Tham Nam Mahoran Formation) indicated a warm climate environment. In the Middle Permian, the environment changed to a typical marine shelf indicated by the deposition of thin-bedded limestone, shale and chert (Huai E-Lert Formation).

The Upper Permian clastic rocks of the Pha Dua Formation consists of clastic rocks such as shale, silstone, sandstone and volcanic tuff, all of which indicate the second development of a tectonic activity in back arc basin. Intense folding and thrust faulting are observed in the central part of Loei area. In some areas, the sedimentary rocks are metamorphosed to quartzite and phyllite, and ophiolite remnants that include serpentinized pillow basalts occur in north-south sheared and strike-slip zone near metamorphic rocks. This period should have occurred in the Late Permian, as the seduction zone existed between the back-arc basin and the Indochina continental pate (Fig.7.3).

7.3.4 Permian-Triassic age

Subsequent oceanic subduction, calc-alkaline volcanism, and collision were responsible for rise of geothermal gradients with production of regional metamorphism, and contraction and deformation of the sedimentary rocks along the subduction boundary zone. From the evidence of the metamorphic rocks and ophiolite zone, felsic volcanism in Permo-Triassic time, followed Late Paleozoic shallow marine deposition (MRDP, 1988) in-ward by a thick accumulation on the continent Indochina plate margin. In addition, in the area of fore-arc basin, andesitic volcanic rocks are found on top of Permian clastic sedimentary rocks. The former presumably indicate a closure of paleotethys in this period. Folding and faulting, particularly in the eastern part of the study area were developed in Triassic period. These felsic magmatism are developed in response to cessation of subduction and beginning of rifting in these areas

7.4.5 Triassic-Jurassic age

Finally, these microplates collided in the early Triassic time when the alkaline to calc-alkaline granites were intruded in several areas, particularly the western and central parts of the study area. Paleotethys became completely close. Subsequently, the tectonic activity of this area ceased, and the accretionary complex of fold and thrust belt underwent final uplift and intense erosion. Folding and faulting may have formed mainly in the central part of the study area, probably in Late Triassic to Jurassic times. This perhaps caused the deposition of the mollasse-type non-massive sediments during Jurassic-Cretaceous times. The tectonic model evolution in the Loei area is shown in Fig. 7.3, and a summary of tectonic activities in Loei area is shown in Table 7.1.

Table 7.1. A summary of time interval related to tectonic setting in Loei area.

Geologic Age	Tectonic setting
Silurian-Devonian	-Subduction-related island arc -Volcanic eruption -Deposition of arc-related sediments
Devonian-Carboniferous	-Generation of volcanic island -Development of passive continental margin -Development of (back-arc) ocean floor in the Paleotethys. -Carboniferous clastic deposition
Carboniferous-Permian	-Land mass uplift and denudation -Carbonate deposition (P) -Commence of oceanic subduction
Permian-Triassic	-Violent subduction and collision between island arc and continental plates -Development of strong folding and faulting -Development of mélange zone -Arc magmatic activity (P-Tr) -Arc-related felsic magmatism
Triassic-Jurassic	-Development of post-collision tectonics with rifting and gravity magmatism. -Uplift, degradation and erosion (Tr) -Aggradations of non-marine clastic deposition (J) - Continuing fracturing and folding
Jurassic-Cretaceous	-Non-marine clastic deposition of Khorat-Group red bed

7.5 Magnetic units and structures related to mineral deposits

Mineralaization (such as Au, Cu, Fe, Ba, Mn and Pb) in the Loei area is shown in Fig. 7.4, with the sub-domains of the geophysical interpretation. It is obvious that most of the mineral occurrences are located in the central and western domains, however, some mineral occurrences are located outside the studying area, especially in the northern part of the central domain. These mineral deposits are, therefore, inferred herein to extend northward to the Lao PDR, particularly Au deposits. It is quite clear that mineral occurrences, particularly Cu, Fe and Au, are significantly related to circular features associated with felsic arc-related calc-alkaline to alkaline intrusions. Elsewhere in Thailand circular features were interpreted to represent granite intrusions producing several regular fractures (see Charusiri et al., 1994). Such fractures are believed to have served as conduits or channel ways for hydrothermal mineralizing fluids as discussed by Sawkins (1976), Mitchell and Garson (1984), and Hutchison (1988). In the enhanced Landsat TM 5 investigation in the Loei and nearby areas, Neawsuparp and Charusiri (2000) suggested that most mineral occurrences were related to the northeast-southwest short lineaments, and are concentrated in areas where lineaments tend to have both high density and continuous length, especially in the central domain.

Mineralization in this area is related temporally and spatially to post- collision island-arc tectonic activity, which may have developed since Permo-Triassic time. Therefore, mineralizations in the study area tends to be generally conform with the model of Mitchell and Garson (1984) as shown in Fig.7.5. From the figure, tectonic setting exert a major control on the type of mineralization. Sithithaworn and Wasuwanich (1992) found that in the Loei study and nearby area several sulphide deposits may have formed in island arcs system and can be correlated with the main calc-alkaline stage of arc growth. However, no sulphide deposits were developed in the early tholeiitic stage (see also Evans, 1980 and Sillitoe, 1980). The volcanic rock association in the C3 sub-domain consist mainly of tholeiitic basalt and calc-alkali basalt/andesite (Panjaswatwong et al, 1997) containing high Cu-content of sulphide mineralization in zones of calc-alkalic basalt/andesite (Yeamniyom, 1985).

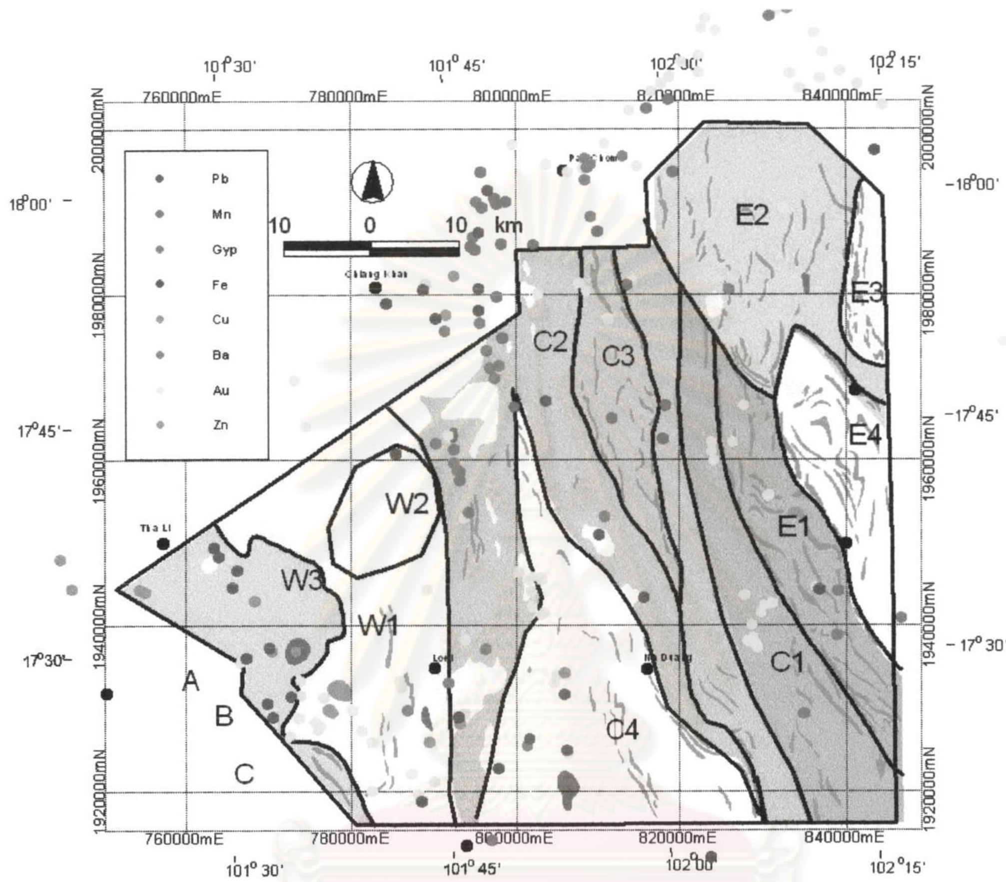

Figure 7.4 Mineral occurrences in the Loei study area

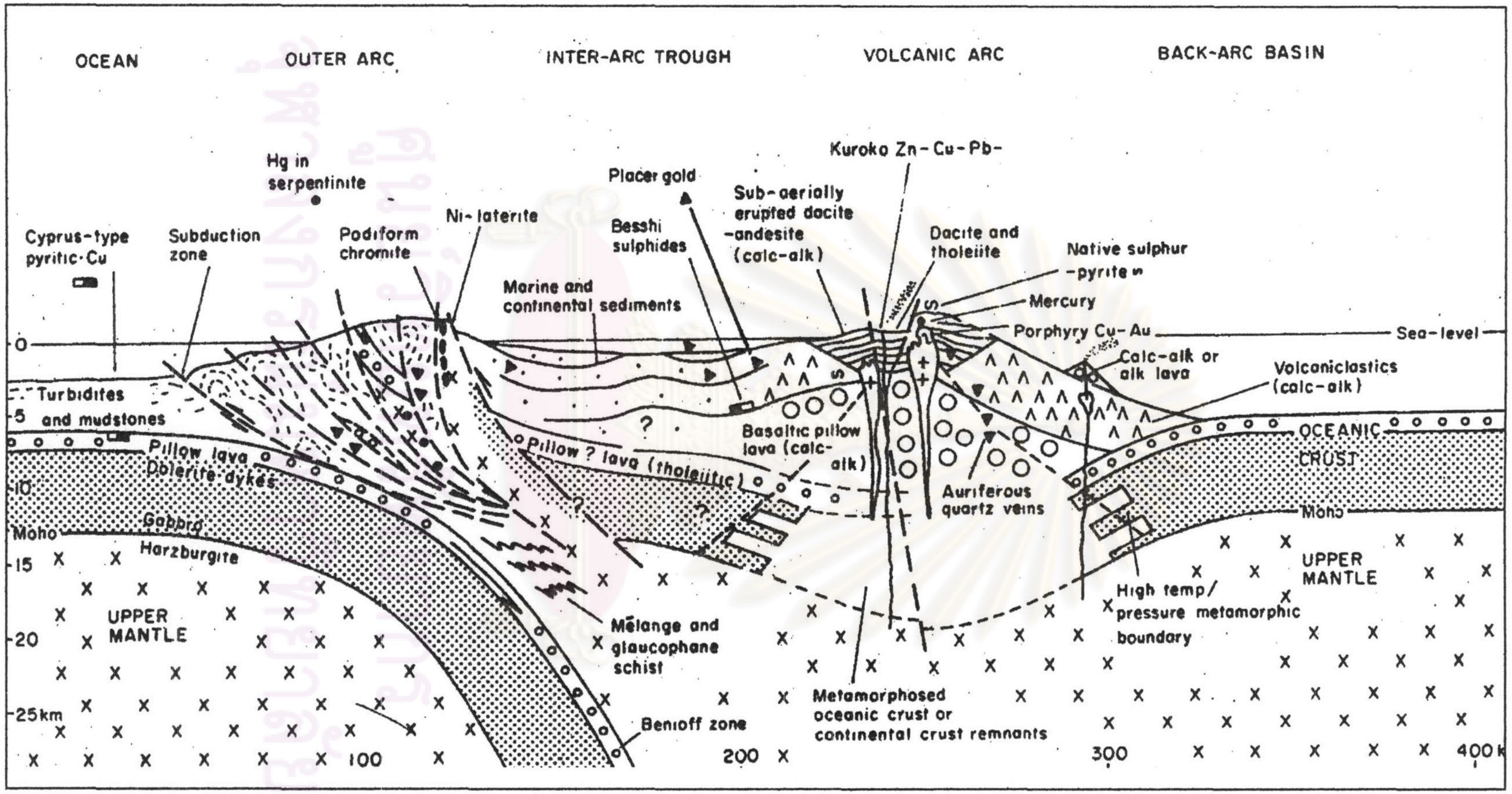

Figure 7.5 Schematic cross-section through on island with a well-developed outer arc showing principal type of mineralization

(Mitchell and Garson, 1984).

Additionally, many barite deposits are mainly confined in the C3 sub-domain, especially in areas dominated by shallow-water marine carbonates and andesitic pyroclastic rocks (Chairangsee et al., 1990). Usually enriched zones of Zn-Pb-Cu ores are invariably associated with barite deposits (Sillitoe, 1982). The C3 sub-domain is, therefore, interesting to prospect for base metal deposits, particularly in zones of calc-basalt/andesite.

Fig. 6.27 shows many intrusions of granitic and granodioritic compositions in the western and central domains, which are related to late-stage tectonic events. The porphyry copper type, granites and granodiorites formed as Triassic stocks intruding into Paleozoic carbonate-rich sedimentary rocks, may have been associated with mineral deposits form in a type of skarn environment. The major skarn mineralization, such as Fe, Au, W, Cu, Zn, Mo and Sn, of both exo-and endo-skarn types, usually occurs in adjacent to and partially inside deep-seated intrusive rocks respectively. So major host rocks for skarn mineralization are carbonates and occasionally in hornfels. The mineral occurrences of Fe, Au, Cu and Zn ores are well recognized on Paleozoic sedimentary rocks, near the intrusive stocks, especially in the C2, C4 and W1 sub-domains. A good example of gold skarn deposit is at the currently operated Thug Khum mine, just west of Wang Saphung District, is located within the W1 sub-domain. The Thung Chum deposit is regarded as to occur in a reduced skarn environment and the main sulphides include fine-grained arsenopyrite and pyrrhotite (Yamned, 1999). Therefore, the small magnetic circular features, within carbonate strata may give rise to skarn mineralization, which herein is regarded as a useful key for exploration model in the Loei area.

The discovery of the ultramafic zone in the E1 sub-domain is important to explore for the orthomagmatic deposits, e.g., chromium, platinum, titanium and nickel ores. These metals are usually found almost exclusively in association with mafic and ultramafic plutonic igneous rocks (Evans, 1980). Field investigation reveals that chromite was found near contacts between serpentinite and gabbro (Seusutthiya and Maopeth, 2001). The mineralization rocks are observed within narrow zones of the E1 sub-domain, which run parallel to the regional north- to northwest-trending thrust zones so elongated chromite deposits are likely to follow the thrust zones, However, it must be noted that the ultramafic rocks may be related to obducted blocks of ophiolite suites, which are invariably related to the compressive tectonic activity.

Based on the aeromagnetic and AEM interpretation related to the model of tectonic setting, four areas are target for mineral prospecting as following:

- E1 sub-domain for podiform chromite, nickel and platinum,
- two area in the C3 and W1 sub-domains for base metals (Cu, Zn, Pb), porphyry copper and gold, and
- are between W2 and C4 sub-domains for Au- iron and skarn mineralization.