# CHAPTER II

# GEOLOGY OF THE SONG TOH DEPOSIT

## 2.1 Regional Geological Setting

The regional geological mapping around the studied area were carried out by the German Geological Mission (1972), Koch (1973), and Hagen and Kemper (1976). The most recent geologic map (Figure 3) was compiled by Lumjuan and Lovachalasupaporn (1980).

The stratigraphic sequence comprises mostly of marine sediments and metasediments. The age of which ranges from Pre-cambrian to Jurassic, locally covered by fluviatile sediments of Cenozoic age (Figure 3). The marine sedimentary basin forms part of a geosynclinal tract extending from Yunnan in the north to west Malaysia in the south (Koch,1973). The main rock types and their geologic ages are summarized as follow : metamorphic complexes of gneiss quartzite, calc-silicate, marble and their metamorphic equivalents in Pre-cambrian (Koch, 1973); schist, quartzite, slate and phyllite with occassional intercalations of calc-silicates in Cambrian ; quartzitic rocks with locally increasing amounts of of shaly and calcareous intercalation in the upper part (German Geological Mission, 1972) in Cambo-Ordovician; thin bedded reef limestone (Koch, 1973) is often with finely intercalated argillaceous bands or streaks or even grading upward into nodular and massive limestone in Ordovician; a series of shale, sandstone, graywacke, limestone in Silurian-Devonian;

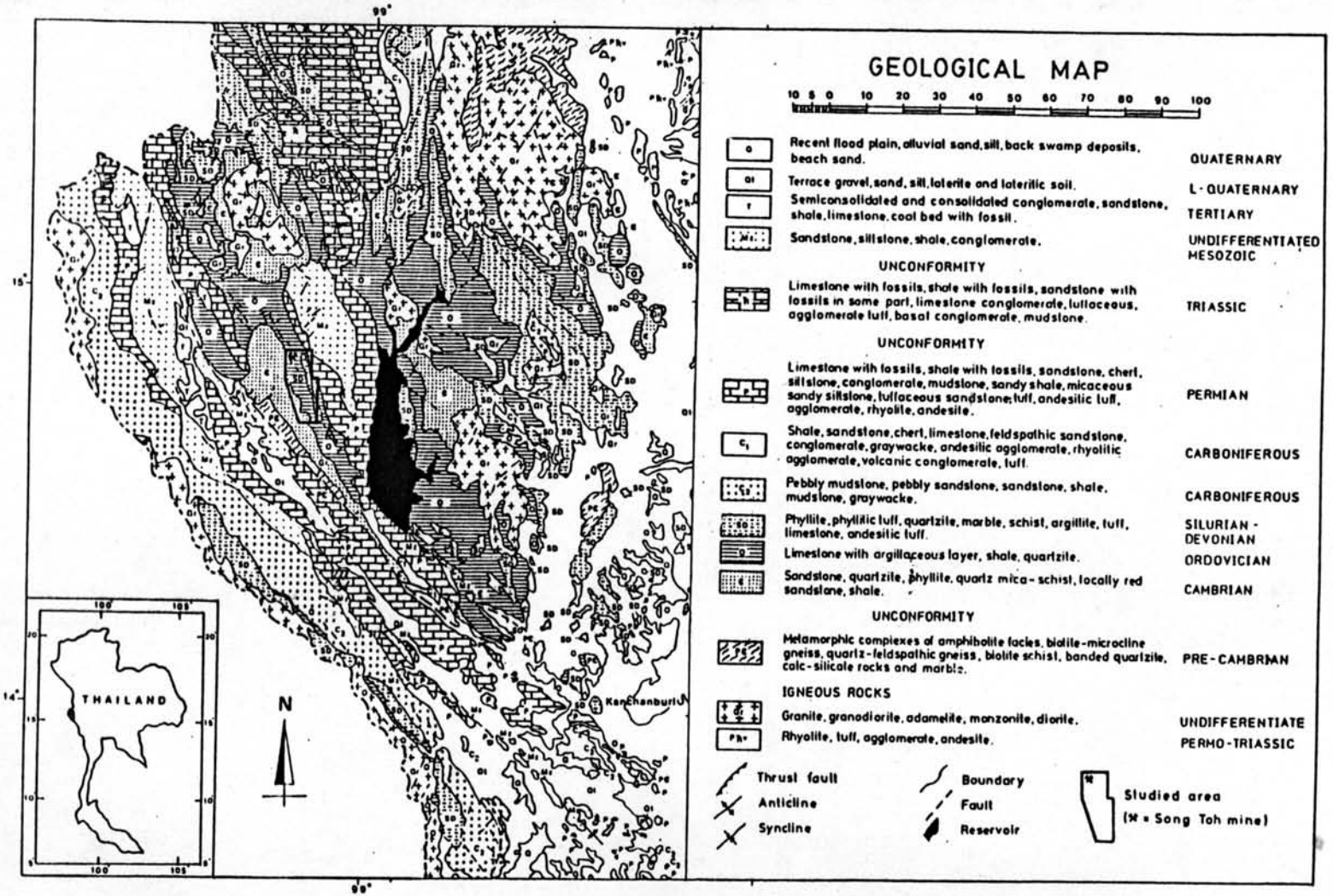


Figure 3 Regional geological setting in western Thailand and studied area. (Compiled by Lumjuan and Lovachalasupaporn, Geological Survey Division, Department of Mineral Resources, 1980).

marine chert, sandstone, shale, conglomerate, bituminous to dolomitic limestone, reef limestone, intermediate to acid lava and tuffs in Carboniferous to Permian ; red conglomerate and limestone in Triassic to Jurassic ; terrace-fillings in larger valleys consisting of gravel, sand, loam and calcareous tufa in Tertiary to Recent time. The Ordovician sequence contains some stratiform Pb/Zn depositions of probably primary sedimentary origin (German Geological Mission, 1972).

Several granite plutons occur around the studied area (Figure 3 ). At present, no radiometric dating for any of these granites has been reported. However, the granitoid rocks could be separated into three distinctive types. The first one has been referred to as the Kwae Yai Granite. It is fine to medium-grained, biotite granite located 20 to 30 km upstream from Sri Sawat to the east of the area. The second one has been generally referred to as the Central Granite. It is fine to medium-grained, occassionally porphyritic granite situated to the SE of Sangkhlaburi. The third one has been referred to as the Pilok Granite. It is medium to coarse-grained, porphyritic biotite-muscovite granite forming a NNW-SSE trending mountain range along the Thai-Burmese border. Tentatively, the age of the so-called Kwae Yai Granite, and Pilok Granite has been regarded to as of Triassic. However, the so-called Central Granite has generally been considered being older than the former and its age has generally been infered to Paleozoic.

The present structural features of the area are the result of at least two orogenic events of varying intensity as well as of post

subsequent faulting, the latter having been active in some areas until the very past (German Geological Mission, 1972, Koch, 1973). The clastic sequence underlying the Ordovician limestone indicates an erosional cycle, following such an orogeny. The turbidites of Carbonifereous age indicate tectonically unstable conditions developed during that time, probably starting already in the upper Devonian. Considerable erosion must have been taken place as indicated by the coarse clastic sediments of components in turbiditic sediments. During a late phase of the Carboniferous orogeny at least certain parts of the former basin area were effected too, as indicated by strongly terrestial influenced sediments and the coarse lacustrine conglomerate sequence, deposited during the lower Permian time. During middle and upper Permian time the basin area seem to have been rather flat and rather stable. By the end of the Permian, conditions in the sedimentary basin seem to have become definitely unstable again. The last and major orogenesis took place during upper Jurassic or Cretaceous time, creating the majority of the present day structures. The result of this orogenesis is an intricate pattern of folding and faulting. The strike of the fold axis varies from north to northwest. Locally, northwest-southeast structures are of importance especially in the Thong Pha Phum area. The strike of the faults dominate along a north-south trend and can be traced over long distance. Scissor- and normal strike faults are considerble important.

As a conclusion the Paleozoic rocks have been folded during late Paleozoic period. In general, the rigid Cambrian quartzite was

only slightly folded but the less rigid Ordovician and younger rocks were thrown into broad folds. The result was a system of northwest striking synclines and anticlines of Paleozoic rocks which inturn was covered transgressively by the Mesozoic sediments (Hagen and Kemper, 1976).

Post-Tertiary fracturing, marked by antithetic faults, runs parallel to previous thrust-folding, thus sometimes forming graben-like structures. The younger fault system strikes normal to the older one. In the Kwae Yai and Kwae Noi valley zones the younger fracturing seems to be a rejuvenation of 'scissor-faults" of the Mesozoic orogeny. This result in a mosaic of tectonic blocks, the subsided parts of which form local basins. Locally, the vertical displacement is considerable. Subsequently, a peneplain had presumably been formed during the lower Tertiary (German Geological Mission, 1972).

## 2.2 Geology of the Song Toh Deposit

The Pb-Zn Song Toh deposit is situated within a moderate easterly-dipping, north-south trending sequence of marine Paleozoic sedimentary rocks forming the eastern flank of an anticline. The sedimentary sequence is intruded, in places entirely outside the studied area, by several masses of granite of probable Permo-Triassic age. The sedimentary rocks exhibit low- grade greenschist facies metamorphism (Figure 3).

Sedimentary rocks and their stratigraphy :

Four major lithostratigraphic units are recognized within the studied area. These are, in the ascending order, from west to east : the Tarutao Group, the Thung Song Group, the Tanaosi Group and the Ratburi Group and their nomenclature is adopted from Javanaphet (1969) (Plate 1).

2.2.1 The Tarutao Group

The Tarutao Group of Cambrian age is composed predominantly of sericite-chlorite schist and phyllite with intercalated and interbeded quartzite. The low grade metamorphosed sediments mainly occupy the southwestern part of the studied area and extend further to the west forming low lying country. Koch (1973), Hagen and Kemper (1976) suggested that the thickness of this Cambrian rocks would have been about 500 to 1,000 meters.

Sericite schist usually shows brown,yellowish brown on the exposed surface, soft, planar structure or schistosity is defined by sericite dominate with having the strike of 350° dipping 45° to the east.

The petrographic characteristics of the rock are distinctively foliated. The schistosity is defined by thin patches of ferric oxide (hematite) rhythmically parallel to layers of quartz and chlorite. The rock is composed predominantly of sericite, chlorite, granular quartz and iron oxides (Figure 4).

This rock appears to be a low grade metamorphic rock as

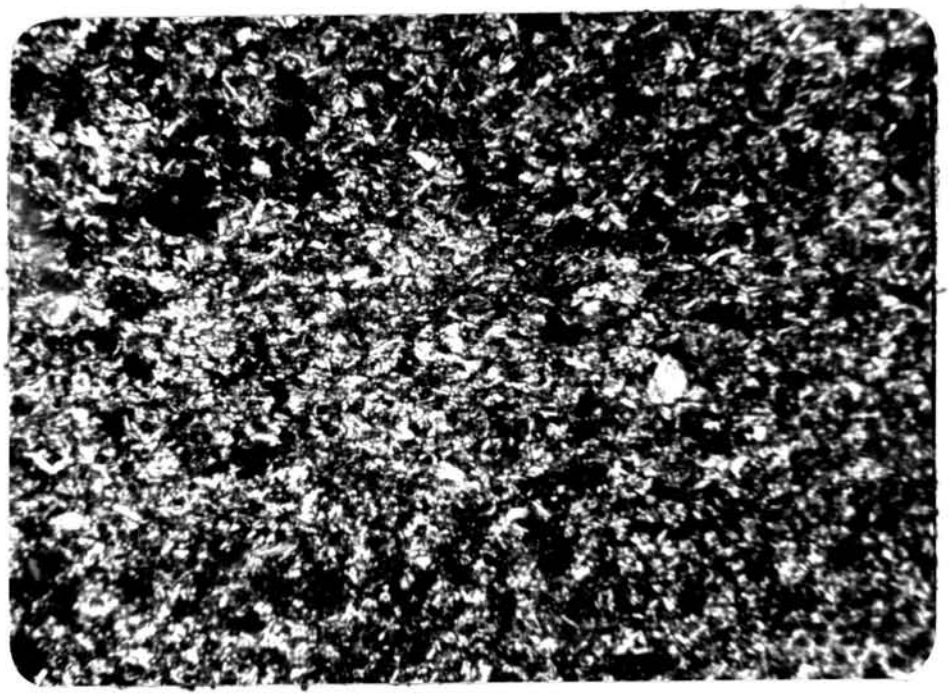

Figure 4 Photomicrograph of Cambrian sericite-chlorite schist showing schistosity defined by the alignment of sericite and chlorite rhythmically parallel to iron-oxide rich layers.
(Thin section, 160 x, crossed nicols).

indicated by its mineral assemblage and stratigraphic position which is underlying the Ordovician limestone.

### 2.2.2 The Thung Song Group

In general, the Ordovician sediments comprise mainly argillaceous limestone with minor shale overlying the Cambrian pelitic rocks. The thickness of Ordovician limestone is about 450 m (Kock, 1973). Evidences of both microfossils and megafossils indicate that the age of this rock unit probably ranges from lower or middle to upper Ordovician (Koch, 1973).

It should be noted that the contact between the Cambrian and Ordovician sediments can not be observed because of extremely poor accessibility in the western part of the studied area.

Though tightly complex folds and faults complicate the field relationship, in general, it appears that the carbonate facies can be subdivided into two units and the lithostratigraphic order of the limestone can be determined from both general structure of the area and the paleontological evidence.

#### 2.2.2.1 Lower Ordovician

Rocks of this sequence cropped out mainly in western part of the Bo Yai and Bo Noi mine forming a mountain range. They are consisted of interbedded phyllitic or argillaceous limestone and shale. (Figure 5)

Generally, the phyllitic or argillaceous limestone is dark gray, thin-bedded, very fine-grained, often intercalated

Figure 5 Exposure of lower Ordovician phyllitic or argillaceous limestone cropped out about 3 km to the northwest of the Bo Noi mine.



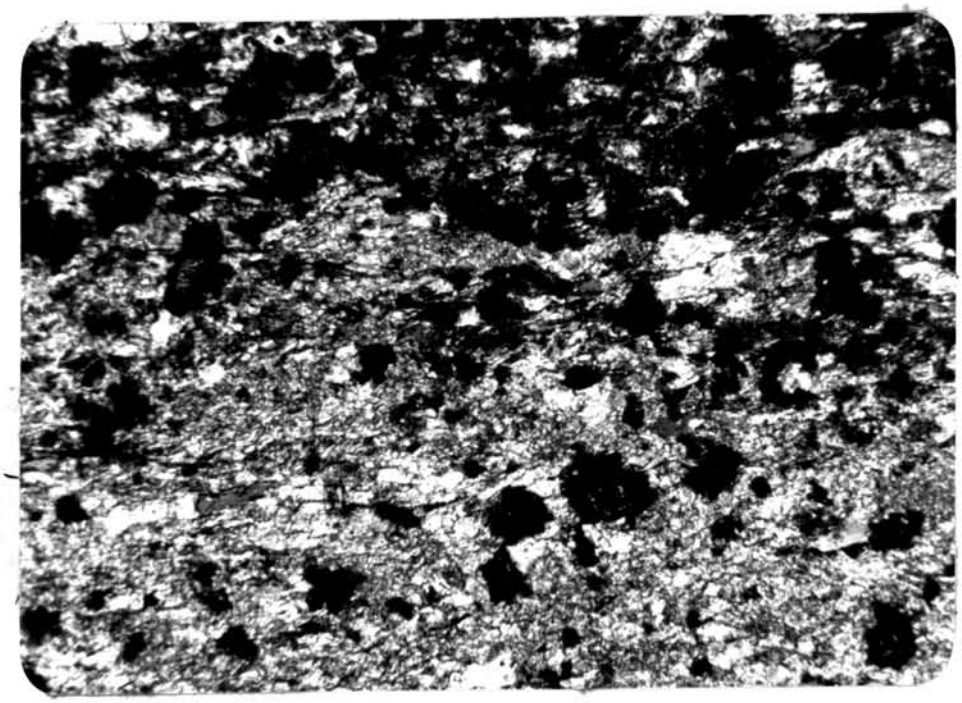

Figure 6 Photomicrograph of sheared argillaceous limestone showing linear texture of stetched calcite and patches of hermatite. (Thin section, 160 x , crossed nicols).

with very finely argillaceous bands. The pelitic beds vary from 1 to 20 cm in thickness but are generally less than 1 cm thick. Petrographically, this rock is composed mainly of finely crystalline calcite (generally less than 0.05 mm) with minor microcrystalline quartz, sericite and chlorite. Patches of iron oxide probably hematite of various sizes are scattered throughout the matrix. The bedding is laminated, defined by the aligment of platy minerals and partly by reticulate flow structure. In places, isolate euhedral quartz is found lying along the lamination. Occassionally, minor amount of detrital biotite are also present.

In the vicinity of fault zones sheared argillaceous limestone (Figure 6) is quite common. The rock is composed mainly of stretched calcite with minor platy minerals,i.e., sericite and chlorite, and patches of hematite. The ferric-oxides appear to rim around other mineral grains. In places, calcite shows recrystallization texture while sericite and chlorite still exhibit fibrous aggregate fabric.

Towards the top of the unit, the argillaceous limestone appears to have an increase in carbonate content with a decrease in clay and iron oxides constituents.

2.2.2.2 Middle to Upper Ordovician

This rock sequence comprises principally of light to dark gray, very thin-bedded, pure to partly dolomitic limestone, argillaceous limestone with interbedded shale and minor

intercalated dolomite. Much of the argillaceous rocks is often distributed in the discontinuous beds and lenses in conformity with the bedding of the limestone (Figure 7 and 8). The stratabound lead-zinc mineralization with accompanying barite is situated with the broad group of this unit.

Towards the top of this sequence is terminated by interbedded limestone and shale with minor siltstone. Some megafossils were collected from the limestone outcrops about 1 km to the east of the Bo Noi mine and identified by Mrs. Rucha Ingawat of the Paleontological Section, Department of Mineral Resources. They include Rhombifera's plate, stem and arms; stony Bryozoa (Trepostomata); and Gastropod (Figure 9). The Rhombifera's plate and stem is quite similar to Echinoencrinites sp. indicating ages ranging from lower to middle Ordovician.

Moreover, it should be noted that the argillaceous limestone showed various types of contact with the dolomite including sharp vertical contact, locally gradational contact and lateral facies change contact. In general, the dolomite is dense, light gray to gray, thin to moderately thick bedded, fine-grained crystalline rock (Figure 10) containing several cracks partly filled with quartz.

For the descriptive purpose the middle Ordovician carbonate sequence can be subdivided into three units in accordance with their colors, i.e., white to light gray limestone,

Figure 7 Lower part of the middle Ordovician limestone interbedded with very thin argillaceous bands. The outcrop exposed to the north of the Song Toh South mine.

Figure 8 Dolomitic limestone exposed on the top of the mountain 1 km to the north of Song Toh South mine. White patches are quartz occuring in fractures.

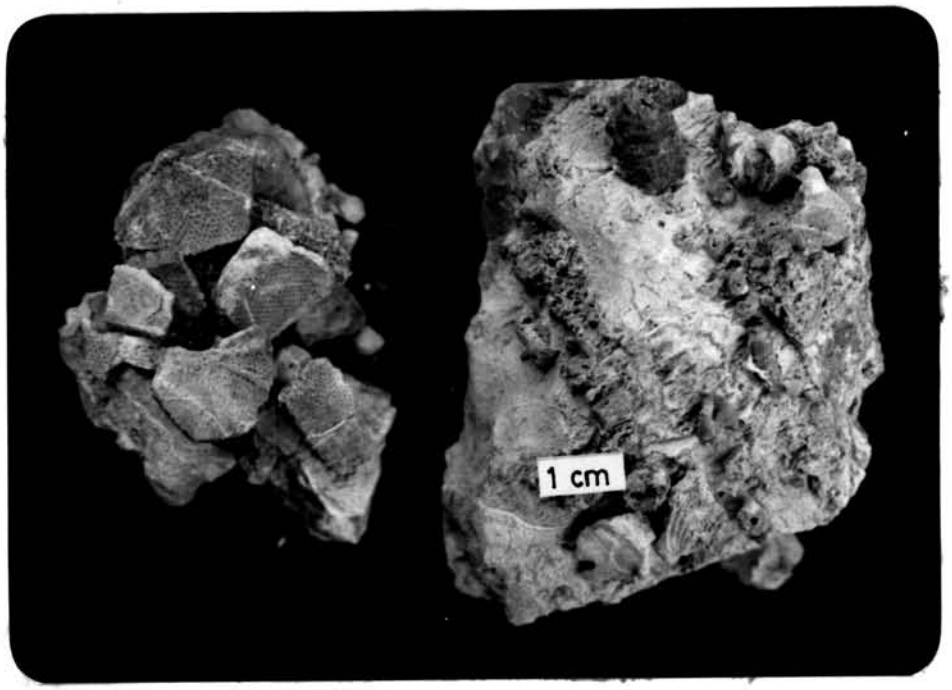


Figure 9 Fossils of Rhombifera's plate, stem and arms; stony Bryozoa (Trepostomata); and gastropod in the middle Ordovician limestone were collected 1 km to the east of Bo Noi mine.

gray limestone and dark gray limestone which, in the present study, will be described in more detail in CHAPTER 3.

A minor mass about 20 m high and 30 m long of gray, laminated shale dipping to the east beneath the mineralized limestone occurs at the Song Toh North mine. Petrographically, the rock is fine-grained, consisted predominantly of quartz, sericite and chlorite with patches of hematite distributed throughout. Its bedding is generally defined by variation in their mineral constituents (Figure 11).

### 2.2.3 The Tanaosi Group

The dominant rock types of this unit are black shale, graywacke, mudstone with minor intercalations of lenticular limestone. On the basis of paleontological evidence this rock unit can be further subdivided into two major formations, i.e., the Kanchanaburi Formation and Kaeng Krachan Formation having the relative age in Silurian and Devonian respectively (Javanaphet, 1969).

#### 2.2.3.1 The Kanchanaburi Formation

Field evidence indicates that the Silurian sedimentation continued without any major change of facies from the Ordovician. The Silurian sequence is approximately 450 m thick, The unit comprises mainly of black, laminated shale, siltstone, mudstone and minor intercalated argillaceous limestone. However, Koch (1973), and Hagen and Kemper (1976) indicated that this rock unit is about 120 m, and 150-200 m thick respectively.

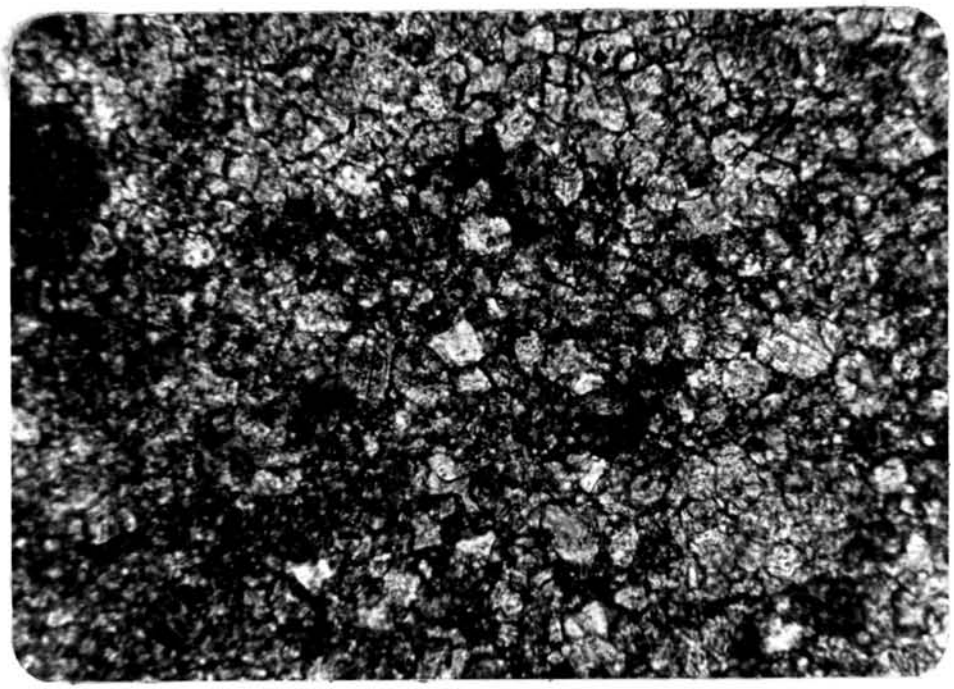



Figure 10 Photomicrograph showing dolomite in Ordovician limestone, 1.5 km SE of Song Toh North mine, displayed a foam texture. (Thin section, 160 x, uncrossed nicols).

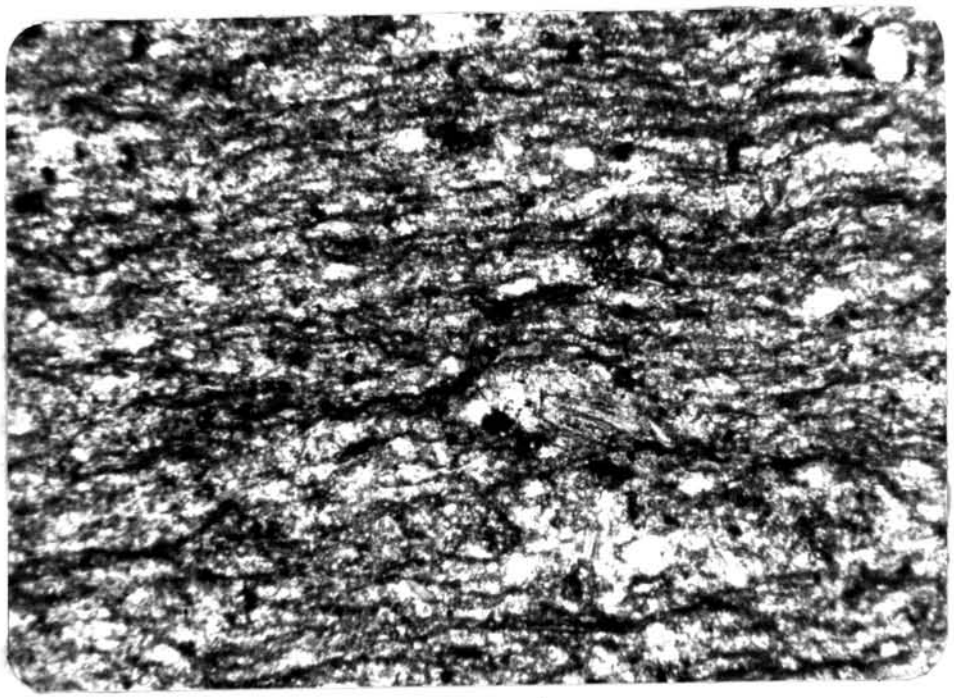

Figure 11 Photomicrograph of Shale occured in the upper part of middle Ordovician sequence showing slighly folded laminations. (Thin section, 160 x, crossed nicols).

The whole sequence forming a long, narrow north to northwest trending mountain range occupies the eastern part of the studied area. The unit generally dips northeast-wards at an attitude of 45°.

Outcrops of interlaminated shale and siltstone usually yellowish brown, black, orange red, deep purple and greenish gray on weathered surface comprising well developed and slightly curve laminations dipping usually, steeply to the east (Figure 12). Petrographically, the siltstone is laminated, very fine-grained, composed of quartz, sericite, and chlorite with substantial amount of ferric-oxide cement. The grain size of quartz is usually less than 0.01 mm. The lamination is about 1-2 mm thick and defined by preferred orientation of clay minerals (Figure 13). Whereas shale and mudstone is greenish gray, composed mainly of chlorite and subordinate isolate detrital quartz having grain size about 0.003 mm. Minor detrital flakes of biotite and muscovite are not uncommon. Ferric-oxides are the dominant cementing material. The lamination is defined by preferred orientation of quartz, chlorite and patches of iron oxides. Fossils of spirifer, moulds of worm tubes, tentaculite, graptolite and crinoid stems are commonly found in these argillaceous sediments at various locations such Khao Rang Nam and the eastern part of Khao Daeng. The graptolites are Climacograptus cf. medius and Rhaphidograptus tourquiste indicating lower Silurian age (Koch, 1973).

Figure 12 Silurian siltstone (looking SW). The outcrop is exposed by road cut. It is located 2 km from Song Toh South and extend to the south along the road to Bo Yai mine.

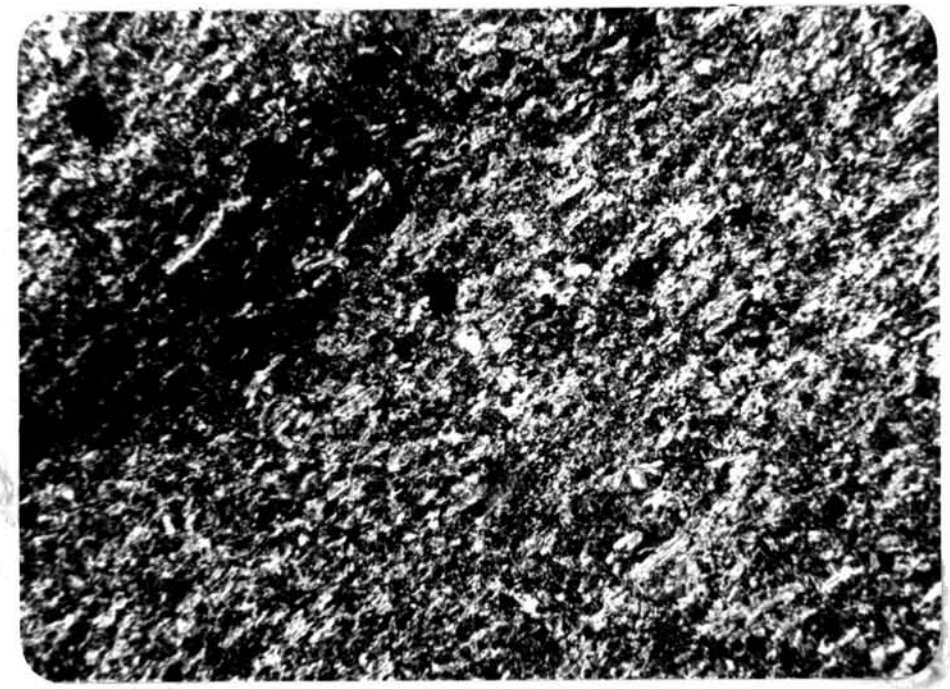

Figure 13 Photomicrograph of the Silurian siltstone showing preferred orientation of sericite and chlorite.
(Thin section, 160 x, crossed nicols)

The argillaceous limestone occurs as a single lens about 1 km to the north of Khao Rang Nam. Petrographically, the rock is gray, microcrystalline biomicrite (Folk, 1968). Bioclasts are consisted predominantly of fragments of brachiopods with subordinate bryozoa and crinoid stems having grain size about 0.1 mm. Minor amount authigenic quartz and muscovite flakes are not uncommon. Stylolite is commonly developed along the soluble weak planes in the limestone.

### 2.2.3.2 The Kaeng Krachan Formation

The Devonian sequence comprises mainly of greenish gray, shale and mudstone with minor silty shale and sandstone conformably overlying on the Kanchanaburi Formation. The thickness of these argillaceous rocks varies from 10 to 450 m. They are commonly terminated by soft, brownish, reddish brown, deep purple shale or mudstone.

Exposures of these rocks are generally found in creeks or streams occurring in the area about 3 to 4 km to the east of Khao Daeng. Size of the outcrop is small usually less than 10 X 10 $m^2$, having reddish brown to red, dark brown to black, greenish gray and purple colours on the weathered surface. The bedding of mudstone is generally obscure. Petrographically, the argillaceous rocks are fine-grained composed predominantly of sericite, chlorite, quartz and minor detrital feldspar. Iron oxides are the main cementing materials (Figure 14). Whereas the laminations in shale are generally defined by preferred orientation of clay minerals.

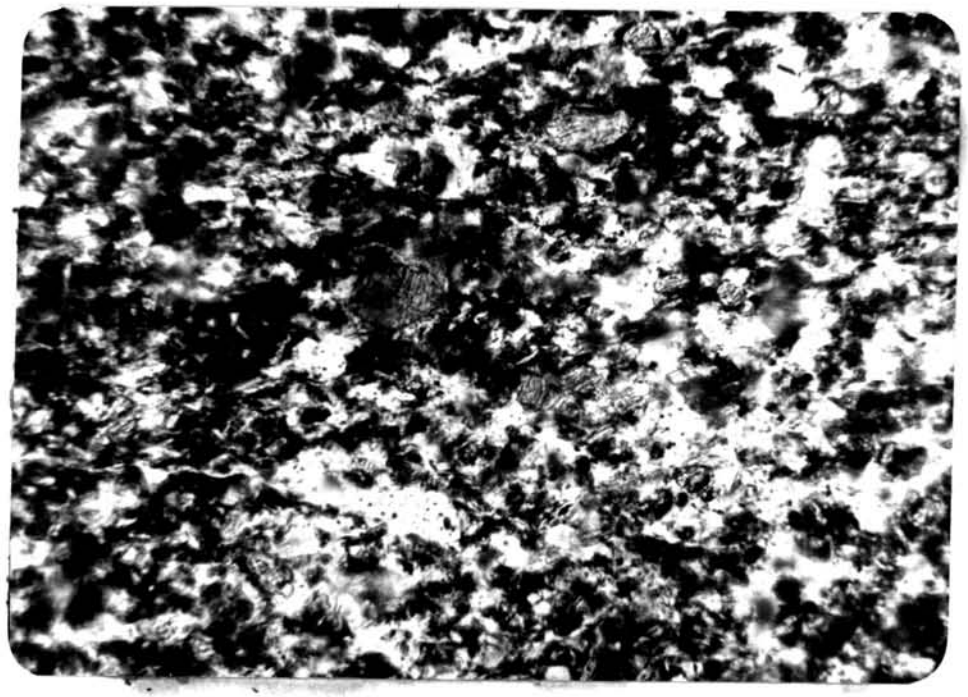

Figure 14 Photomicrograph of mudstone of the Devonian sequence. (Thin section, 160 x, uncrossed nicols)

The arenaceous rock is fine-medium grained, moderate sorted, brown to gray, composed mainly of subangular quartz with minor detrital feldspar and muscovite. Iron oxides are the dominant cementing material. This sandstone may be classified as Protoquartzite (Pettijohn,1957). It usually occurs as thin lenses intercalated within the finer sediments.

### 2.2.4 The Ratburi Group

The Carboniferous-Permian sedimentary rocks mainly occupy the eastern most part of the studied area. However, a minor mass of this unit is also cropped out in the western part of Khao Tu Kalo. Its total thickness can not be ascertained, however Koch (1973) estimated that the sequence is about 200-400 m thick. The unit generally forms a cliff-faced north to northwest trending mountain range. It is predominantly consisted of gray, massive, fossiliferous limestone. Numerous chert nodules of various sizes (up to 20 cm long) commonly occur along the limestone bedding planes. The attitude of the bedding is 325° dipping 60° towards northeast direction.

Petrographically, the limestone is slightly dolomitic, light gray to gray, crystalline biomicrite and minor biosparite. Fusulinids and, debris of coral, molluscan shell, crinoid stems and bryozoan are the dominant bioclastic components and commonly occur together (Figure 15 to 16). Euhedral dolomite of varying size ranging from 0.825-0.175 mm scatterly distributes throughout in the calcite matrix. In addition, minor microcrystalline quartz is not uncommon.

Figure 15 Fossils of corals in the fossilliferous, massive Ratburi limestone occurred at about 5 km to the southeast of the Song Toh North mine.

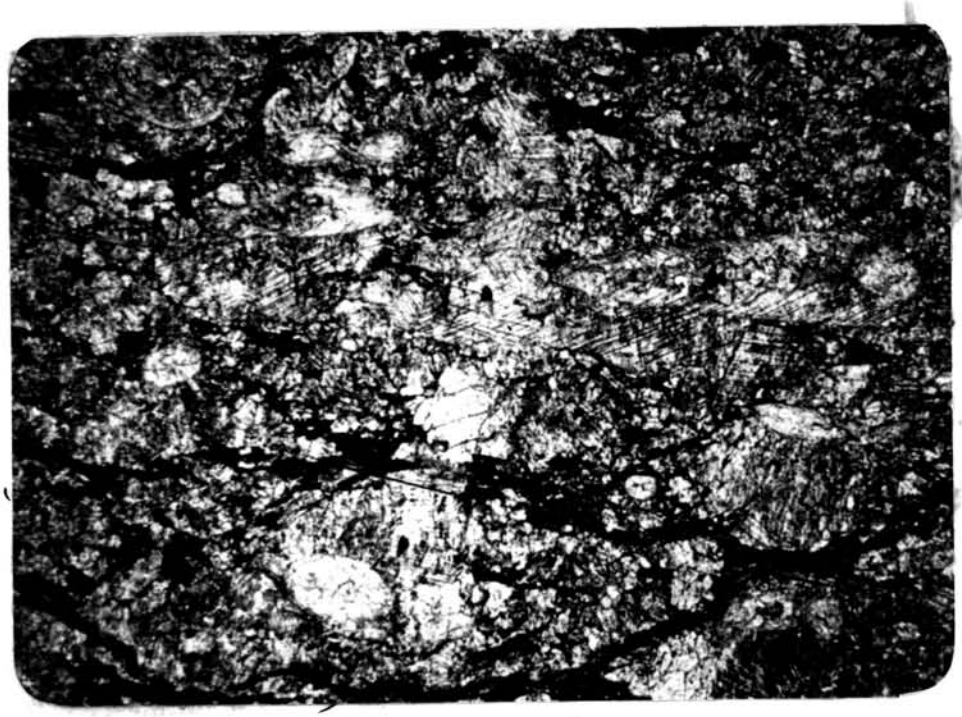

Figure 16 Photomicrograph of the Ratburi Group showing fossils of fusulinids and other bioclasts.
(Thin section, 50 x, uncrossed nicols).

In the studied area the Ratburi carbonates rest unconformably on the older sediments with fault contact indicated by the occurrence of brecciated limestone along the fault zone. However, it should be noted that, in general, there is a major stratigraphic break exist between the Ratburi Group and the Tanaosi Group occuring in other places (Koch, 1973). The similar hiatus has been recognized in various places throughout the Indochina (Workman, 1975).

## 2.3 Geological Structure of the Song Toh Deposit

The Pb-Zn of Song Toh deposit occurs within a north-northwest trending rock sequence generally dipping moderately towards the east and northeast forming the probable northeastern limb of a northwest-southeast trending anticline. The present structural interpretation is that the folding in the mapped area is en echelon in type displaying changes in plunge from southeast to northwest direction. Two sets of minor folds are recognized : one with an axial surface to the NW - SE of the Song Toh paralleling to the axial surface of the regional folds, and a second set trending northeast-southwest nearly perpendicular to the first one.

Moreover, measured bedding attitudes of the Paleozoic sedimentary sequences from the studied area are collectively compiled and graphically represented in a rose diagram as illustrated in figure 17. Interestingly, the north-northwesterly striking characteristic feature of the older sedimentary units is clearly recognized both in the field as well as in the structural analysis. The general trend of folding,

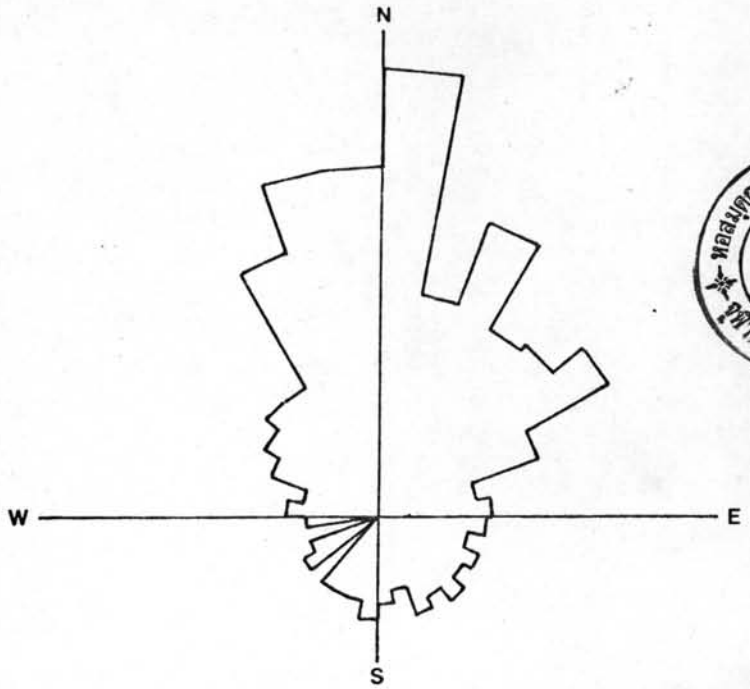


Figure 17 Showing bedding plane attitudes of regional direction of the studied.

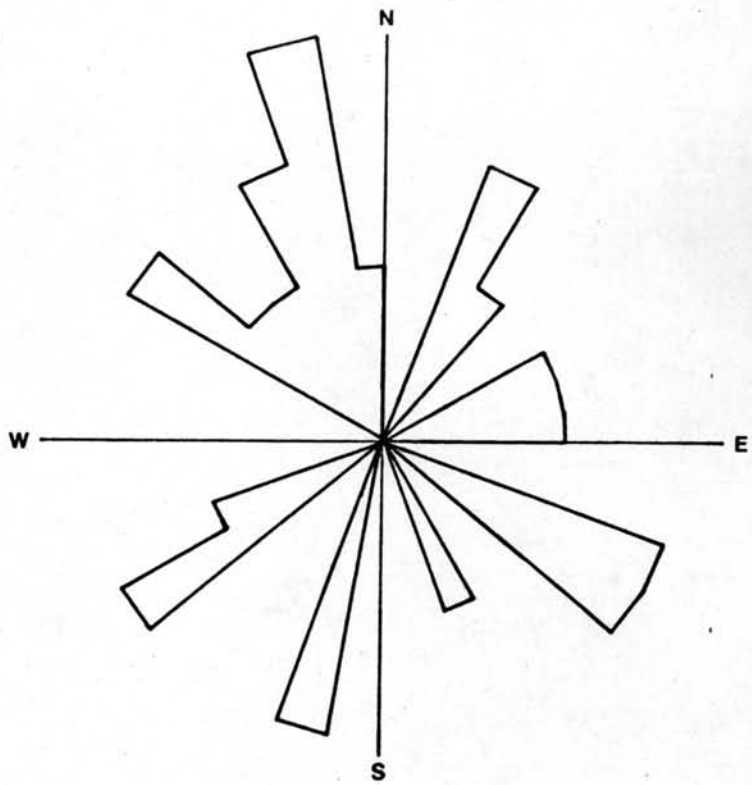


Figure 18 A directional frequency rose diagram of folding axes occuring in the Song Toh underground exposures indicating two minor folds system : the first one trending in the northwest-southeast and the other in the northeast-southwest direction.

indicated by the diagram, varies from northwest to north direction. However, the nature of this fold is interfered by a subsequent folding event. This superimposition could be recognized, especially in the underground exposures, by the northeast-southwest trending fold as indicated in figure 18 .

In addition, the Paleozoic sequences have been fractured and distorted, in places, by several north and northeast-southwest trending, steeply dipping faults. Faults with small displacement are numerous and being a characteristic structural features of the studied area. On the basis of their relative movement and attitude related to that of the associated rock types, faults observed in the studied area can be classified as normal faults, reverse faults and bedding-plane faults as illustrated in figure 19, 20 and 21respectively. It is noteworth to point out that the reverse faults are commonly associated with the regional northwest-north trending minor folds localizing usually along their axial surfaces. The fault plane is usually opened and filled by calcite and, in places, sulfidic ores. The bedding-plane and reverse faults are believed to be formed by the local compression and/or extension mechanism during or after the main folding event. Furthermore, their measured attitudes are graphically represented in the rose digrams as shown in figure 22 A and B. Apparently, the diagrams suggest that there are at least two main alignments of fault: the first one trending along the north-south direction whereas the other striking along the northeast-southwest trend. These directions appear to be parallel to the

Figure 19 Normal fault showing a small vertical displacement of the mineralized horizon.
(Lower ore zone, Song Toh South mine, +620 m level)



Figure 20 Low angle thrust fault occurs in light gray massive limestone. (Near the northern end of upper ore zone, Song Toh South mine, + 620 m level)

Figure 21 Bedding-plane fault with associated sheared ores.
(Song Toh South area, old open-pit mine)

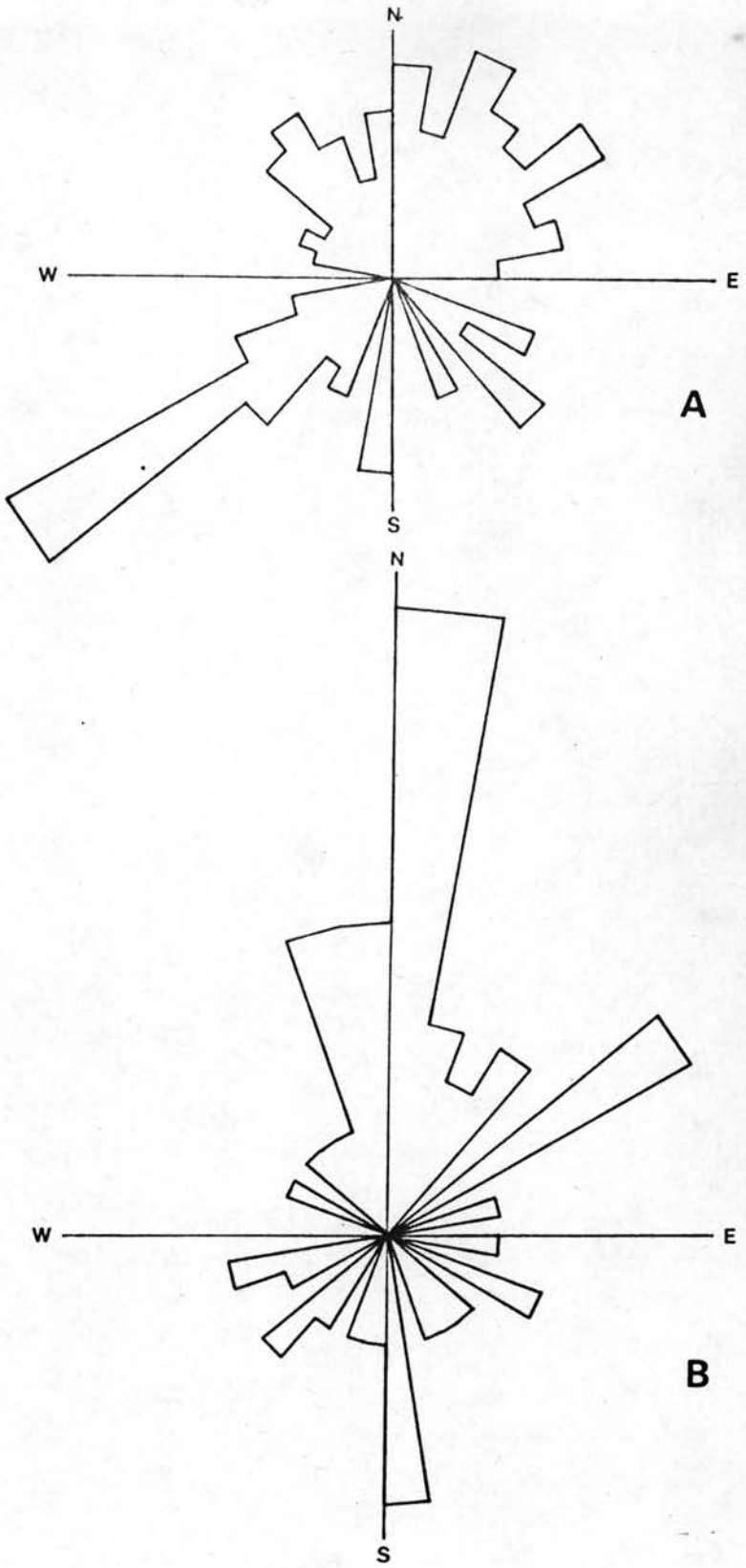


Figure 22 Rose diagrams of fault system in Song Toh orebodies. A. Song Toh South; B. Song Toh North.

directions of folds. Similarly, the normal faults are believed to be formed by the local extension mechanism during or after the folding events.

Regionally, all the rock sequences occuring in the studied area contain well developed, steeply or vertically dipping joints. Again, their measured attitudes were collectively plotted and represented in rose diagrams as shown in figure 23 and 24 A and B. Obviously, two zones of maximum concentration could be recognized suggesting that there are at least two main alignment of the joints : the first one trending northeast-southwest and the other striking northwest-southeast. These are presumably release and ac joints, and believed to be formed during or after the folding events.

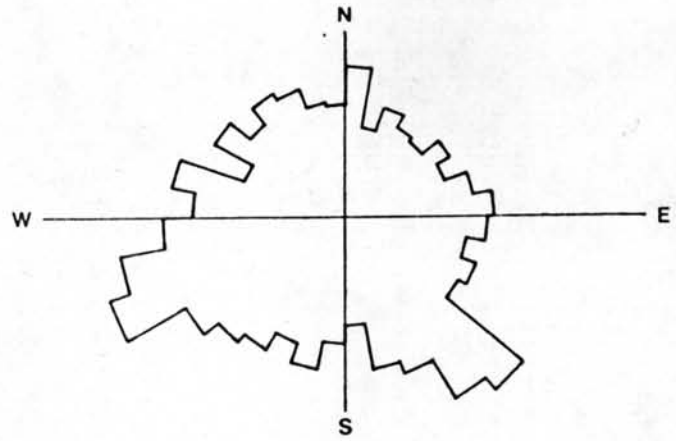


Figure 23 A rose diagram of joints in the studied area.

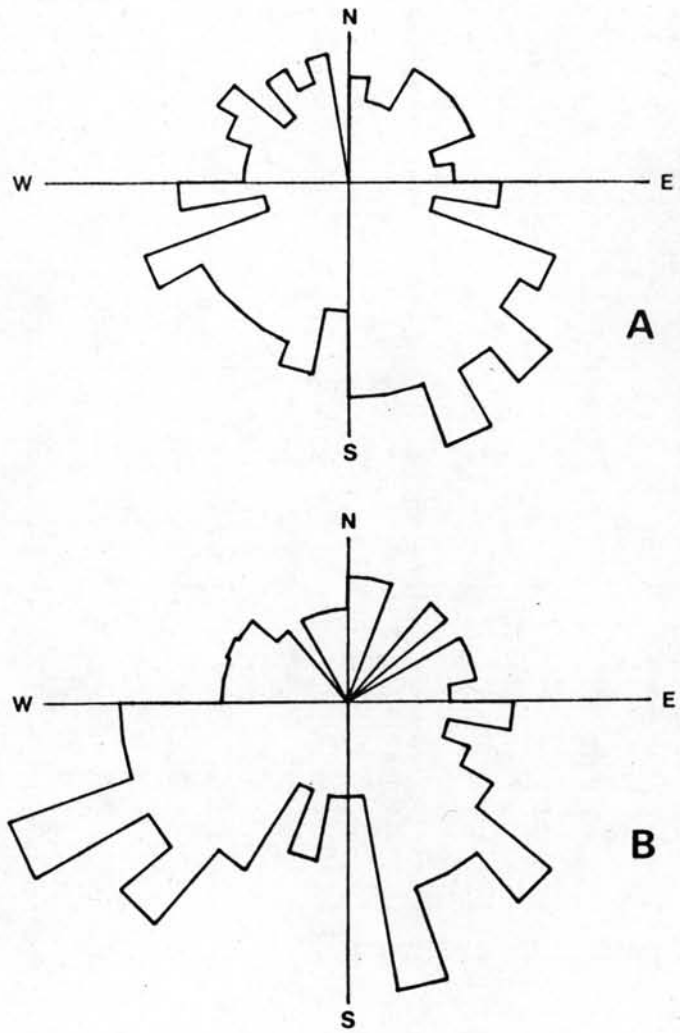


Figure 24 Rose diagrams of joints occuring in the carbonate host rocks, in Song Toh South mine (A); and in Song Toh North mine (B).