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The Study of Folding in Calc-silicate Rocks of Pinle-in Area, Mandalay Division

Saw Ngwe Khaing

Abstract

The Pinle-in area is mainly composed of metasedimentary rocks with some igneous intrusions. It is situated between Sagaing Fault and Shan-Scarp Fault in central Myanmar. The present study has carried out the systematic measurements of the plunge directions, plunge angles, thickness and distance of the limbs of minor folds in the calc-silicate rocks of Pinle-in area, Madaya and Singu Township, Mandalay Division. Similar plunge directions of folds are grouped as the zones. These zones are matched to speculate the possible explanation for where the hidden major fold is situated. The type of folds may be more or less anticline preferably overturned natures in the area. The axis of overturned anticline, likely to be double plunging, may be located along the Thabyaw Range with the direction of NNW-SSE and the Yetkanzin Range may also be assumed as the southern continuation of the Thabyaw Range.

Key words: Minor folds, Calc-silicate rocks, Pinle-in area, major folds, overturned anticline, Thabyaw Range, Yetkanzin Range

Introduction

This paper is quite a very preliminary study of the minor fold structures in calc-silicate rocks (C.S.R). The usage of "C.S.R" is very familiar to the field geologists for its interbedded nature of silicate and carbonate bands as well as different competencies of each band. Due to these properties, plastic flow folding has readily existed at any phase of tectonism. Minor folds can be recognized at every exposure of calc-silicate rocks. Therefore, study on minor folds should be set in that unit as a preliminary stage to achieve to achieve the solution to the problem of major folds.

Ideally, the drag folds are systematically related to the major folds. The drag folds in an incompetent bed between two competent beds assume the attitudes. The acute angles between the axial planes of the drag folds and the main bedding planes point in the direction of differential movement.

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At certain areas that can interpret as a "homocline", the drag folds can be assumed as "minor folds" in the weaker units that are intercalating among the stronger ones. In the area under consideration, minor folds that are probably the drag folds of the partly-missing regional structure, are observed in precise and concise for further advance interpretation.

Study Area

The study area is situated in Pin-le-in area, Madaya and Singu Townships, Mandalay Division. According to topographic map No. 93/B-3, it lies beside the Mandalay-Madaya-Singu car road (Fig.1).

Topography

Physiographically this area is fairly rugged and mountainous terrains such as Bodawgyi range (1487′) in the south, Yetkanzin range (1320′) and Thabyaw range (1062′) in the middle and Nagamauk range (1110′) and Shwemyintin range (850′) in the north. The Bodawgyi range is E-W direction, the Yetkanzin range and Thabyaw range is nearly N-S direction, and the Nagamauk range and Shwemyintin range is nearly NW-SE direction.

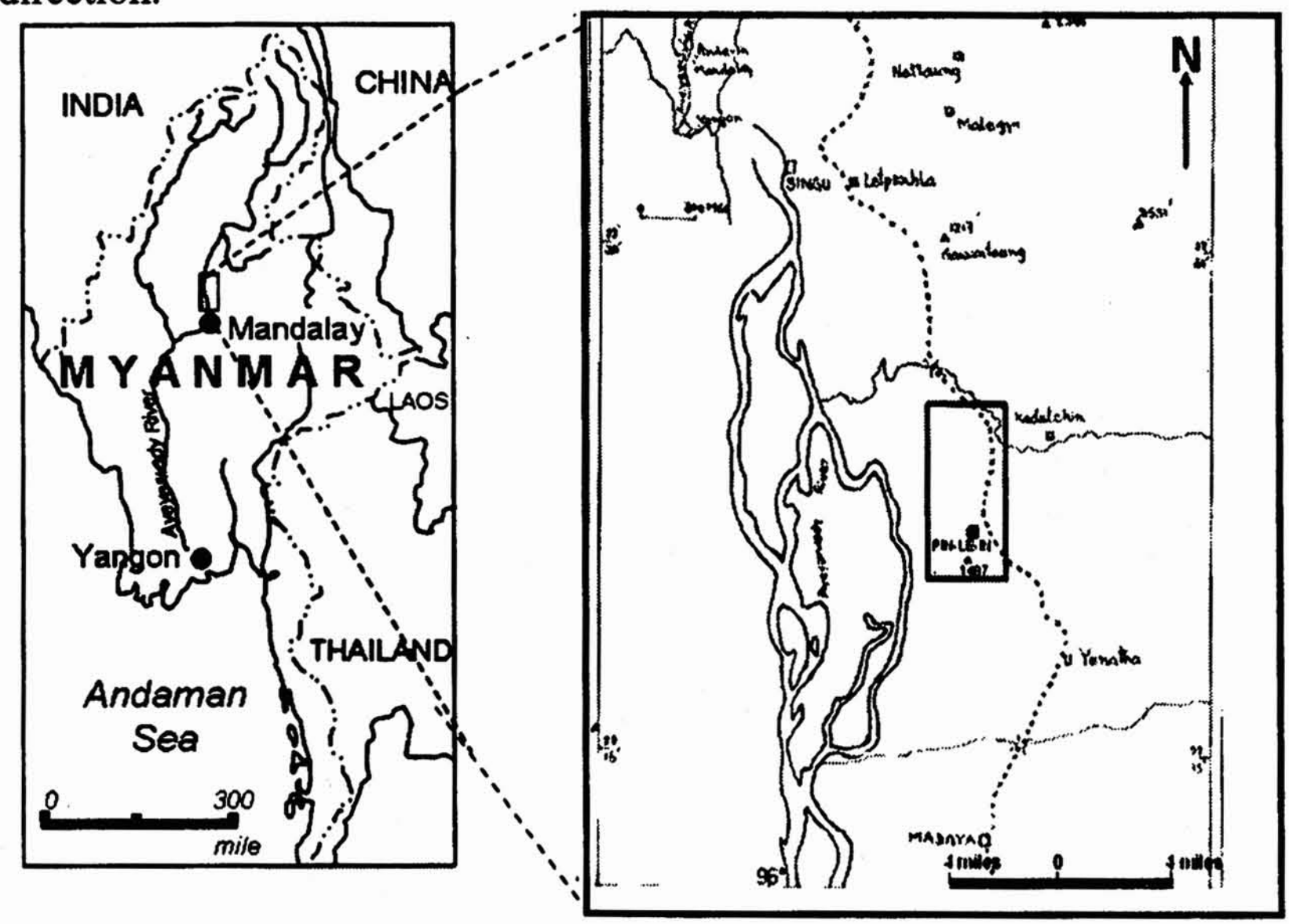

Figure 1. Location map of the Pinle-in area.

Aims and Objectives

The ultimate aim is to identify the major geological structure based on the minors. The purposes of this paper are to measure the minor folds and try to interpret them, to define the type of major folds and to locate its possible place based on the systematic measurement of the minor folds.

Methods of Study

Direct measurements on minor folds were made using with Brunton Compass and tape. Regular measurements of inclination and direction of fold limbs were done at every structure. Arbitrarily fold axis and axial plane were demarcated. Then, angles and directions of plunge along axial planes were measured. Thickness of each limb and distance between them were taped. Sketches were drawn and if possible, photo was taken.

Every measurement was plotted on the base map of four inches to a mile scale. Similar plunge directions of folds were grouped into a zone and then, zones were matched to speculate the possible explanation for where the hidden major fold is situated.

Regional Geology

In the eastern part of this region Chaungmagyi Group of Precambrian age composed mainly of phyllites, slates, metagreywackes, and quartzites, with minor amounts of schists and thin-bedded marble is exposed. The beds are tightly folded, locally faulted and regionally fractured. That Chaungmagyi Group is unconformably overlain by Mogok Group which is mainly composed of gneiss, calc-silicate rocks and marbles of possible lower Paleozoic age (Myint Lwin Thein, 1990). This immediate study area lies in the Mogok Group. Irrawaddy Formation of Upper Miocene-Pliocene overlies again on Mogok Group unconformably along the eastern bank of the Ayeyarwady River (Fig.2). Various phase of Granite intrusions emplaced in Mogok Group till the early Tertiary period, and sub-recent Plateau basalts in the Singu area also occurred (Fig.3)

Regional structures

This region is located in Sagaing Fault zone which is assumed as a right-lateral strike-slip fault (Win Swe, 1981) at the west and the Shan-Scarp fault which is generally a normal step fault at the east. Precambrian stable landmass is situated at the east, and Mogok Group is bounded as well

as overthrusted by the Chaungmagyi Group (Myint Lwin Thein, 1990). Therefore, lying between unstable and stable landmass caused the region deformed and metamorphosed.

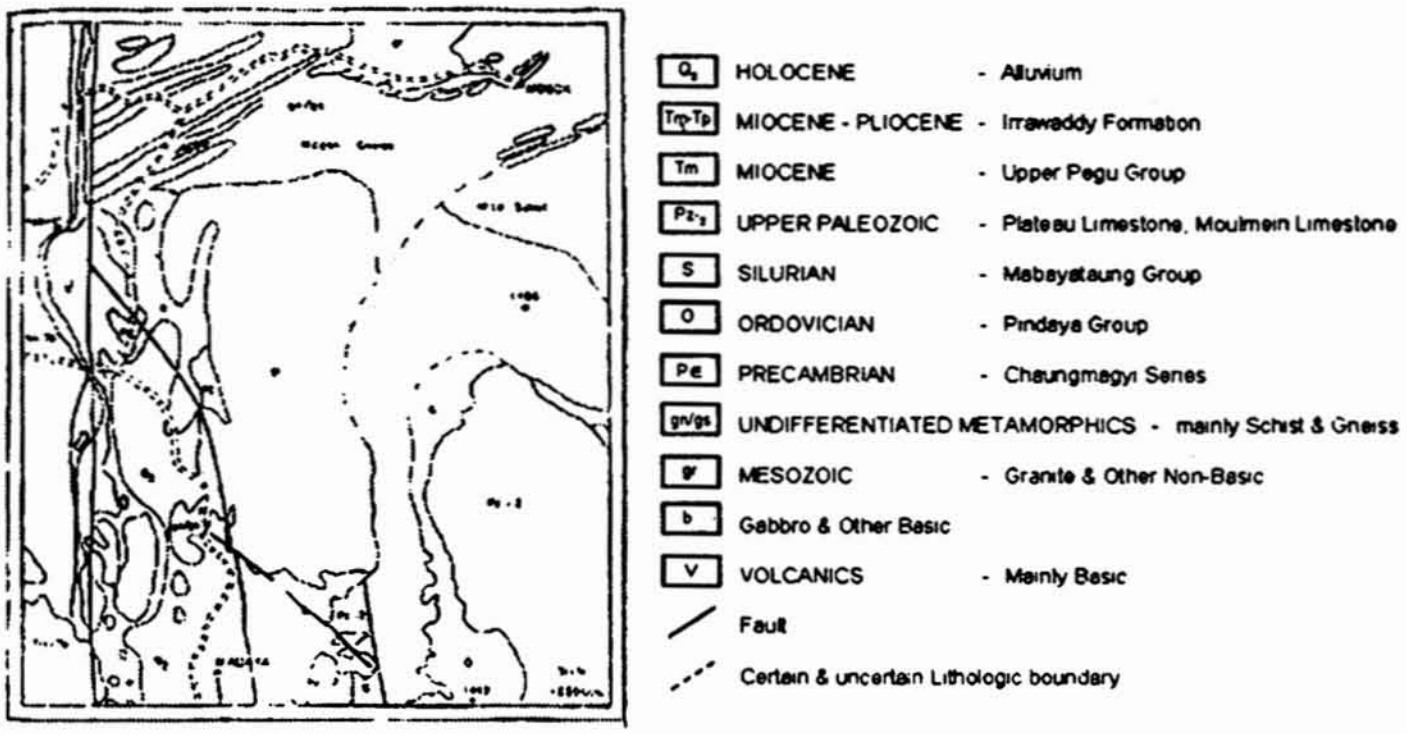

Figure 2. Regional geological map of Madaya and Mogok area. (Modified from one million scale Geological Map of Burma, 1977)

Many types of folding reflecting westerly directed strong lateral force occurred in this region. Many types of folds especially asymmetrical folds, overturned folds and recumbent folds are abundant. Among them minor overturned folds are common. These were dominant in the calc-silicate rocks. The branch faults of the Sagaing wrench fault system and composite faults of strike-slip and normal movements are also observed (Fig. 3).

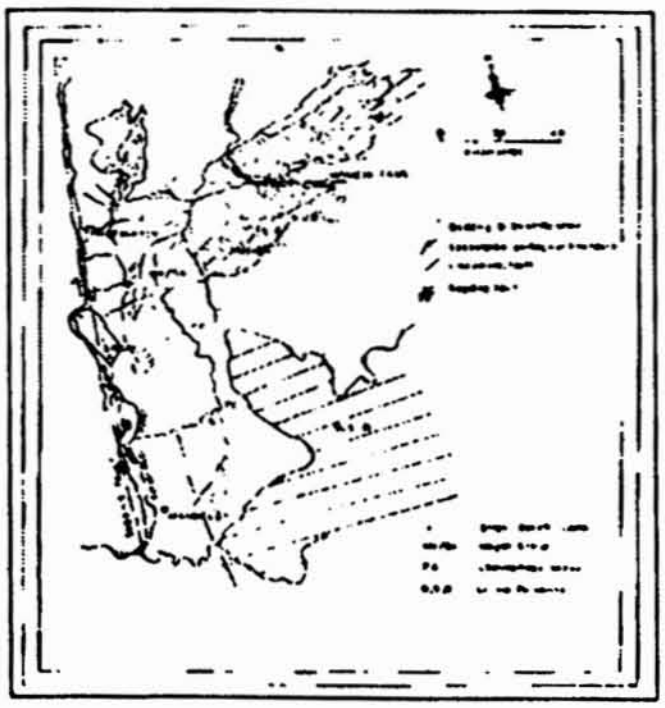

Figure 3. Landsat structural map of the area between Mandalay and Mogok. (after Myint Lwin Thein, 1990)

Geology of Pinle-in Area

Rock sequence of the studied area is as follow:

Metasedimentary Rock Units

gn	—	Garnet bearing hornblende-biotite gneiss	Lower
C.S.R	—	Calc-silicate rocks intercalated with banded diopside marble and minor diopside-phlogopite marble, black spinel-chondrodite marble and graphite	
M_W	—	White marble intercalated with minor bands of phlogopite marble Paleozoic ruby bearing marble, Paleozoic graphite marble and diopside marble	
M_p	—	Phlogopite marble intercalated with minor bands of diopside marble, white marble and spinel-chondrodite marble	

Igneous Rock Unit

P	—	Pegmatite with minor aplite dykes and Leucogranite dykes	Tertiary
mG_b	—	Biotite microgranite with almandine bearing granite	
G_b	—	Biotite granite	
Gr. gn	—	Biotite—hornblende granite gneiss	
G_h	—	Hornblende granite with aegirine augite granite	
G_l	—	Leucogranite	

The best exposures of Mp unit occur in western flank of Yetkanzin range and central past of Thabyaw range. It obeyed the regional trend and formed alternately with White marble unit. It faintly occurs foliated and in massive nature (Pwint Phue Lwin *et. al.*, 1995).

The type area of M_W unit is Yetkanzin valley and exposed at the western part of Bodawgyi Taung, western flank of Yetkanzin range and southwestern part of Thabyaw range. They are formed alternately with phlogopite marble. It also occurs at northern portion of Shwemyintin range (Loc. LA 599204). Nature of exposure is massive and crystalline. It can also be seen as pitted nature, but having even surface (Mya Thidar *et. al.*, 1995).

The type area of C.S.R Unit is Nagamauk and Shwemyintiri ranges. It can also be found in the eastern parts of Yetkanzin and Thabyaw ranges

and western part of Bodawgyi Taung. Graphite bearing C.S.R can be found at the southeastern flank of Yetkanzin range (Loc. LA 589123). Black spinel chondrodite diopside marble occurs at the eastern part of Nagamauk range (Loc. LA 618181) (Htar Htar Aung *et. al.*, and Sandar Win *et. al.*, 1995).

The type area of gn is the western flank of Bodawgyi Taung. It is also closed to the hornblende granite gneiss. They are also found at the Thedinthone Taung (Loc. LA 622146) (Mya Thidar *et. al.*, 1995).

The Leucogranite (G_l) can be found in the western part of Bodawgyi range and western part of Thedinthone Taung and sometimes shows graphic texture (Loc. LA 599155 and LA 621145) (Pwint Phue Lwin *et. al.*, 1995)

The exposures of G_b can be found at the eastern part of Bodawgyi Taung and eastern part of Thabyaw range (Myat Thandar *et. al.*, 1995). The best exposure of G_b can be observed at the western part of Bodawgyi Taung (Loc. LA 592103) (Myat Thandar *et. al.*, 1995).

Biotite microgranite (mG_b) occurred at the Bodawgyi peak and eastern part of Thabyaw range (Loc. LA 604165) (Sandar Win *et. al.*, 1995). Pegmatite with Leucogranite dykes and aplite dykes can be found in Thabyaw range, Bodawgyi and Nagamauk ranges. They are also found at the Thedinthone Taung (Htar Htar Aung *et. al.*, 1995).

The sequence of igneous rocks evidence can be found along the Yetkanzin car road (Loc. LA 606158) (Pint Phue Lwin *et. al.*, 1995). Igneous intrusions occurred in the eastern and southern parts as the isolated hills and patches in metasedimentary rocks.

Model formation of ruby, sapphire, spinel and emerald green diopside are present in this area (Searle and Haq, 1964).

Structural geology of the study area

This region is situated between Sagaing fault in the west and Shan-Scarp fault in the east. There are some minor folds of calc-silicate rocks in the study area. As in previous works, all of the metamorphic rocks in the study area are dipping toward east and forming homoclinal limbs. But in some places, the dip direction of the metasedimentary rocks may vary because of granitic intrusion and faulting.

The several S-bands and sausage (the term after Khin Maung Latt, 1991) are defined as the structures prominently observed in calc-silicate rock. Axial traces of fold axes and stretched lineation of the sausages are also no exception to the general trend (Khin Maung Latt, 1991).

Folds

Many types of minor folds such as overturned, recumbent, asymmetrical and complicated folds, drag folds flow folds and parasitic folds are exhibited very dominantly in the calc-silicate rocks (Fig.4). Minor overturned folds are common. They can be observed at the Nagamauk range and Shwemyintin range. They range from minor folds with amplitudes of a few centimeters to larger ones. Such minor folds in calc-silicate rocks can be indicated a major structure of the area, as bedded calc-silicate rocks are comparatively very incompetent to stress.

Faults

This area is faulted against the Irrawaddy Formation by the right lateral strike-slip movement of Sagaing fault and sitting at the eastern portion. Faults are the distinct structural features of this area. They are associated with the Sagaing Fault system and occur as cross-faults. There are five major faults in this area.

The first is between Bodawgyi and Yetkanzin ranges. It is running nearly ENE and WSW. It is a right lateral strike-slip fault, i.e., evident in discontinuous offset quartzofeldspathic vein in diopside marble with calc-silicate bands (Loc. LA 590107). The northern portion is to the east and southern portion is to the west (Myat Thadar *et. al.*, 1995; Mya Thidar *et. al.*, 1995).

The second is along the eastern flank of Yetkanzin range, running NNW-SSE direction and calc-silicate (southern portion) and white marble (northern portion) units are met at the same elevations along this fault. It is also right lateral strike-slip fault (Mya Thida *et. al.*, 1995; Pwint Phue Lwin *et. al.*, 1995).

The third and fourth are left lateral strike-slip faults. The third is running NW-SE direction along the northeastern portion of the Thabyaw range, indicated by alignment of igneous intrusion being isolated hills and structural evidence is shown in discontinuous offset quartzofeldspathic vein in biotite-granite gneiss body (Fig.4, E & F) (Pwint Phue Lwin *et. al.*, 1995; Sandar Win *et. al.*, 1995)

The fourth is running nearly in E-W direction along the southern flank of Nagamouk range, indicated by topographically changes and imbricate structure in diopside marble (Loc. LA 605181).

The last fault is located at the northern part of the Shwemyintin range. It is also right lateral movement and running nearly NE-SW direction, evident by the discontinuous offset quartzofeldspathic vein (Loc. LA 599204).

Results and Discussion

Pinle-in area is structurally divided into five zones. The first is the western part of Nagamauk range and Shwemyintin range, the second is the eastern part of Nagamauk range, the third is Thabyaw range, the fourth is Yetkanzin range and the last zone is Bodawgyi range (Fig.5).

For zone one, four directions are occupied in NNW quadrant and when one is in WNW. The location of major fold may be at SSE quadrant.

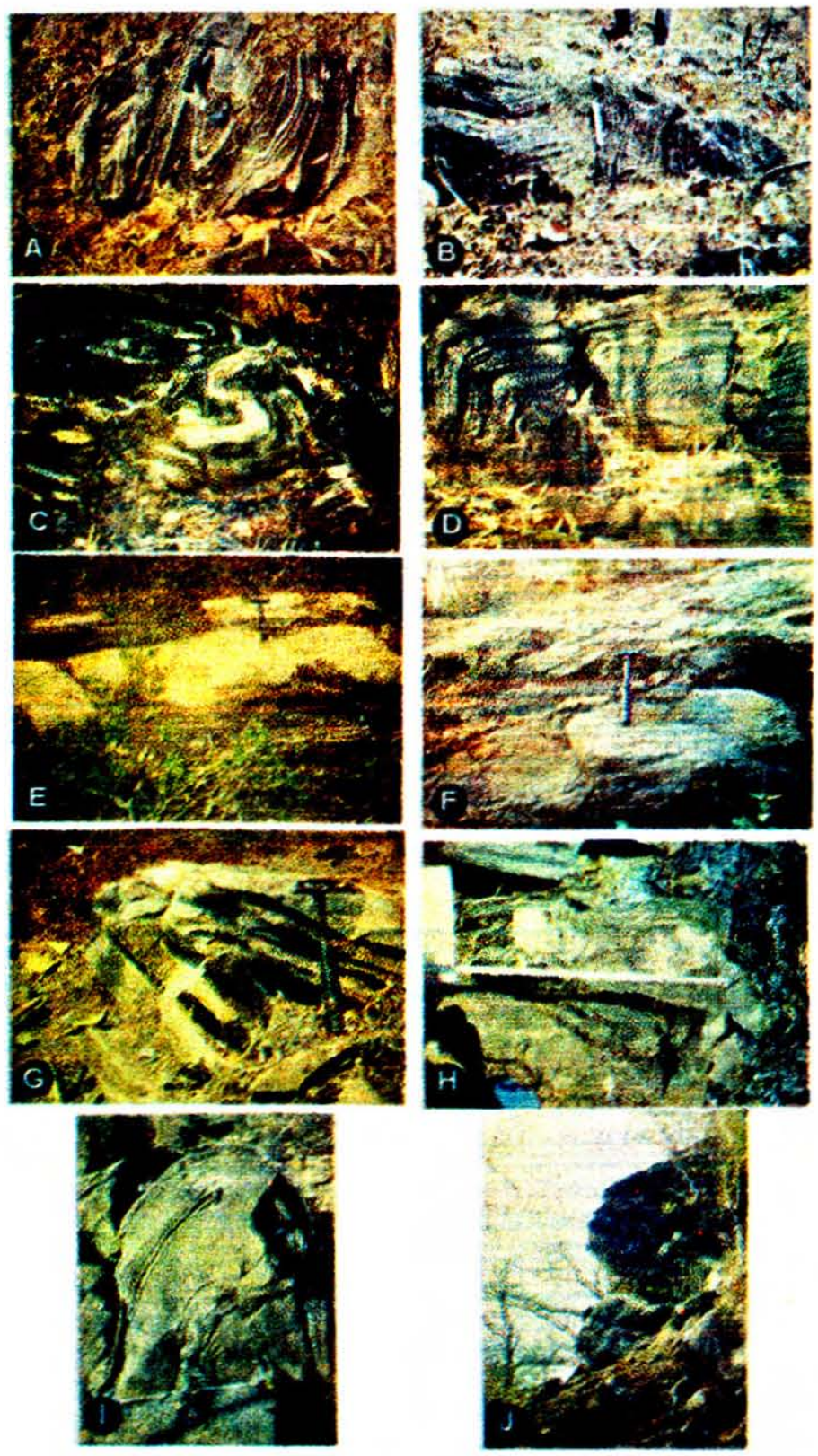

Figure 4. Minor structures from the Pinle-in Area. **A,** Drag fold, plunging towards 310° azimuth in bedded diopside marble and calc-silicate rock. Loc. LA 594201. Looking NW **B,** Isoclinal fold, plunging towards E, Loc. LA 588183. Looking E **C,** S-shaped band and recumbent fold in calc-silicate rocks Note, sausage structure is also occurred. Loc. LA 622165. Looking N **D,** Recumbent fold in calc-silicate rock Note minor parasitic fold is occurred left side of the hummer Loc. LA 587135 Looking N. **E,** Sausage structure occurred along the Yetkanzin road in Biotite-granite-gneiss Loc. LA 606158. Looking S. **F,** Discontinuous and offset quartzofeldspathic vein in Biotite-granite-gneiss body. Loc. LA 605154 Looking S **G,** Overturned fold in calc-silicate rock Loc LA 586154 Looking N **H,** Sausage structure in calc-silicate rocks. Loc LA 586138 Looking E **I,** Symmetrical anticline fold, plunging 25/350° Loc LA 586138 Looking N **J,** Sheeting in calc-silicate rocks, near Nagamauk Taung (1110′) Loc LA 600181 Looking W

Zone two is at SE of zone one and at the same range but plunging directions are different. Nine are towards NE, four towards SE and three towards NW. To be easy, line of N-S direction, is used and combined nine and four are placed at eastern part and three at western part. Therefore, thirteen are similar and three dissimilar. For zone two; similar directions show that major fold may be at the W of this zone.

Zone three is separated from zone one and two by a NW-SE trending fault. Intrusive bodies are emplaced along this fault. Zone three is special among other zones, which is situated between two parallel oblique faults. Each fold has different direction. Starting from the west, one directs towards W while another towards E; one NW while another SE; and one NE while another SE. Four of them are overturned anticline, one is overturned syncline and the last is normal anticline. At the northern portion of this zone one overturned anticline towards SE which is situated between two faults. Double plunging overturned anticline and syncline may be existed in this zone.

Zone four is simpler than above. Most of the plunge are directing to the NNW-NNE except one directs towards SE which is situated near the fault. Normal anticline may be situated at S of this zone.

Zone five shows one minor fold which is overturned anticline towards W. In this zone calc-silicate rocks are observed as a roof-pendent.

The existence of major fold is at the S of zone one and W of zone two. It will be situated at SW or W of Nagamauk hill. Type of fold may be more or less anticline preferably overturned nature. This interpretation is accorded with the results of zone three. The axis of overturned anticline, likely to be double plunging, may be located along the Thabyaw range with the direction of NNW-SSE. Lying between two parallel oblique faults makes suffering the beds deformed, distorted and displaced successively. Random distributions of the direction of minor fold axis are systematically indicating; that the major fold is situated at this Thabyaw Range. Zone four may be the continuation of zone three, but due to the formation of double plunging overturned fold it may also be the same major fold.

Conclusion

This paper is quite a very preliminary study of the minor fold structures in calc-silicate rock. Bedded calc-silicate rocks are very incompetent to stress. And, various types of minor folded structures are well observed in calc-silicate rocks. It can be solved to the regional structure of folding. In this area, type of major fold may be more or less anticline preferably overturned nature. The axis of overturned anticline, likely to be double plunging, may be located along the Thabyaw Range with the direction of NNW-SSE. It lies between two parallel oblique faults. The Yetkanzin Range may be the continuation of Thabyaw range. It may also be the same major fold.

Finally, further consideration of the relationships among minor structures and major geologic structures, should improve our predictive capabilities for problems of regional geologic structure. Careful investigations in small minor folds will lead to the site of major fold. So, we should more extensively study regional structures at the calc-silicate rocks unit.

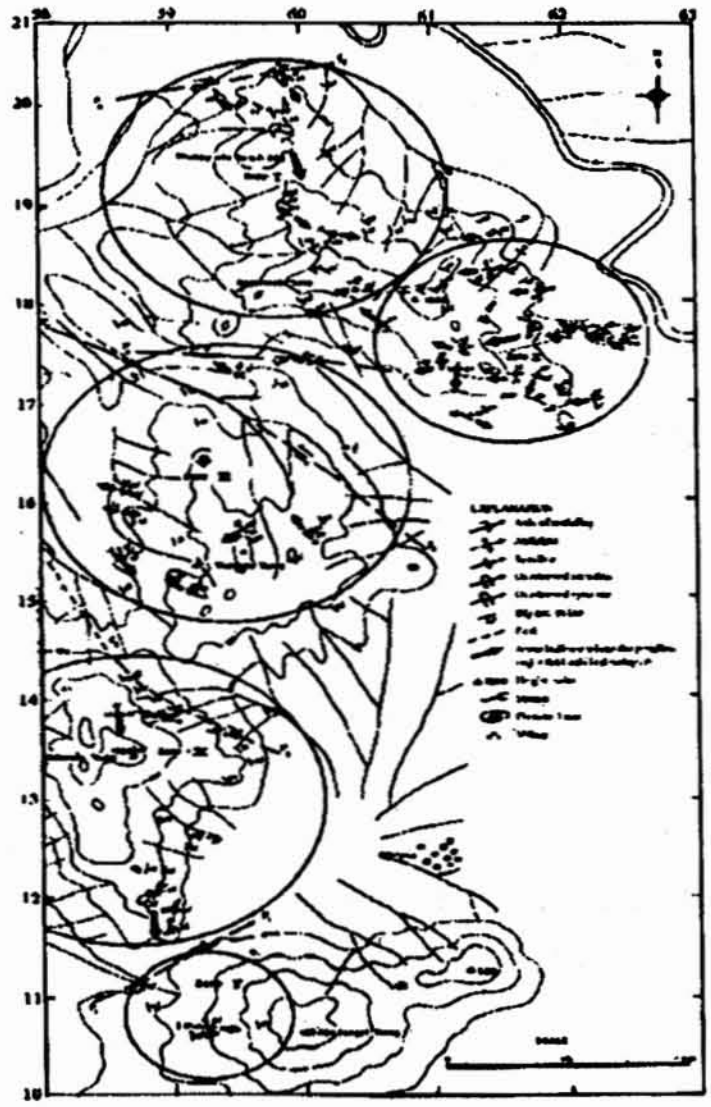

Figure 5. Map showing the distribution of minor folds in respective zones, in calc-silicate rocks, Pinle-in area, Madaya Township, Mandalay Division.

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