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STRUCTURAL PATTERN OF THE CROCKER FORMATION IN SOUTHERN PART OF BEAUFORT AREA, SABAH

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ABSTRACT. *The Crocker Formation is characterised by deep-sea sedimentary rock sequences which is Oligocene to Early Miocene of age. The sedimentary rock sequences of the Crocker Formation deformed by Middle Miocene tectonic event caused faulting and folding. The lineament pattern and the orientation of bedding in a NE-SW direction demonstrate that the compression direction is oriented NW-SE. The analysis of the folds and faults also show a NE-SE direction of the major compression.*

KEYWORDS. Crocker Formation, lineaments, folds, faults, joints and tectonic compression.

INTRODUCTION

The Crocker Formation of Oligocene to Early Miocene age is mostly concentrated in the western part of Sabah. Liechti *et. al.* (1960) subdivided this formation into East and West Crocker Formations. The West Crocker Formation is relatively younger and overlies the East Crocker Formation. Collenette (1958) and Stauffer (1967) mentioned that the Crocker Formation consists mainly of clastic sediments of flysch type, which were deposited in an elongated basin of abyssal depth. According to Wilson and Wong (1964), the Temburong Formation is a facies transition of at least the upper part of the Crocker Formation.

Sabah which is located at the northern part of Borneo island is close to the active tectonic plates of Pacific, Philippine, Eurasia and Indo-Australian plates. The formation of the NW Borneo Accretionary Belt is closely related to the opening episode of the South China Sea (Hamilton, 1979; Taylor & Hayes, 1983). The Crocker Formation forms part of this accretionary belt. This accretionary belt consists of imbricated terrain due to subduction of South China Sea plate toward Sunda shield plate and Borneo crust at SW and SE directions, respectively (Tan & Lamy, 1990). According to Stauffer (1967), the structural pattern of the Crocker Formation is dominantly monoclinal with eastward dip and eastward direction of younging. The major tectonic event of Middle Miocene which generated NW-SE compressional force direction affected the Crocker Formation to be imbricated, folded and faulted (Tongkul, 1987).

BACKGROUND OF THE STUDY AREA

This study was carried out in the southern area of Beaufort, Sabah. Beaufort itself is about 110 km from Kota Kinabalu. This town is linked to the other areas by the Kota Kinabalu-Sipitang main road and railway besides logging roads. The study area covers approximately 100 km^2 that is 4 km from the town of Beaufort (Figure 1). Topographically, the study area can be divided into lowland and moderate hilly areas (Figure 2). The lowland area is dominated by areas below 100 m and largely located at the northwest of the study area. The southern part of the area is dominated by moderate hilly area with elevation range between 500 m to more than 1000 m. There are three main rivers, which run across the study area known as Sungai Padas, Sungai Bukao and Sungai Lumadan. The location of the field stations is shown in the Figure 3. The strike and dip directions of bedding and fault planes were measured including joint and fold structures.

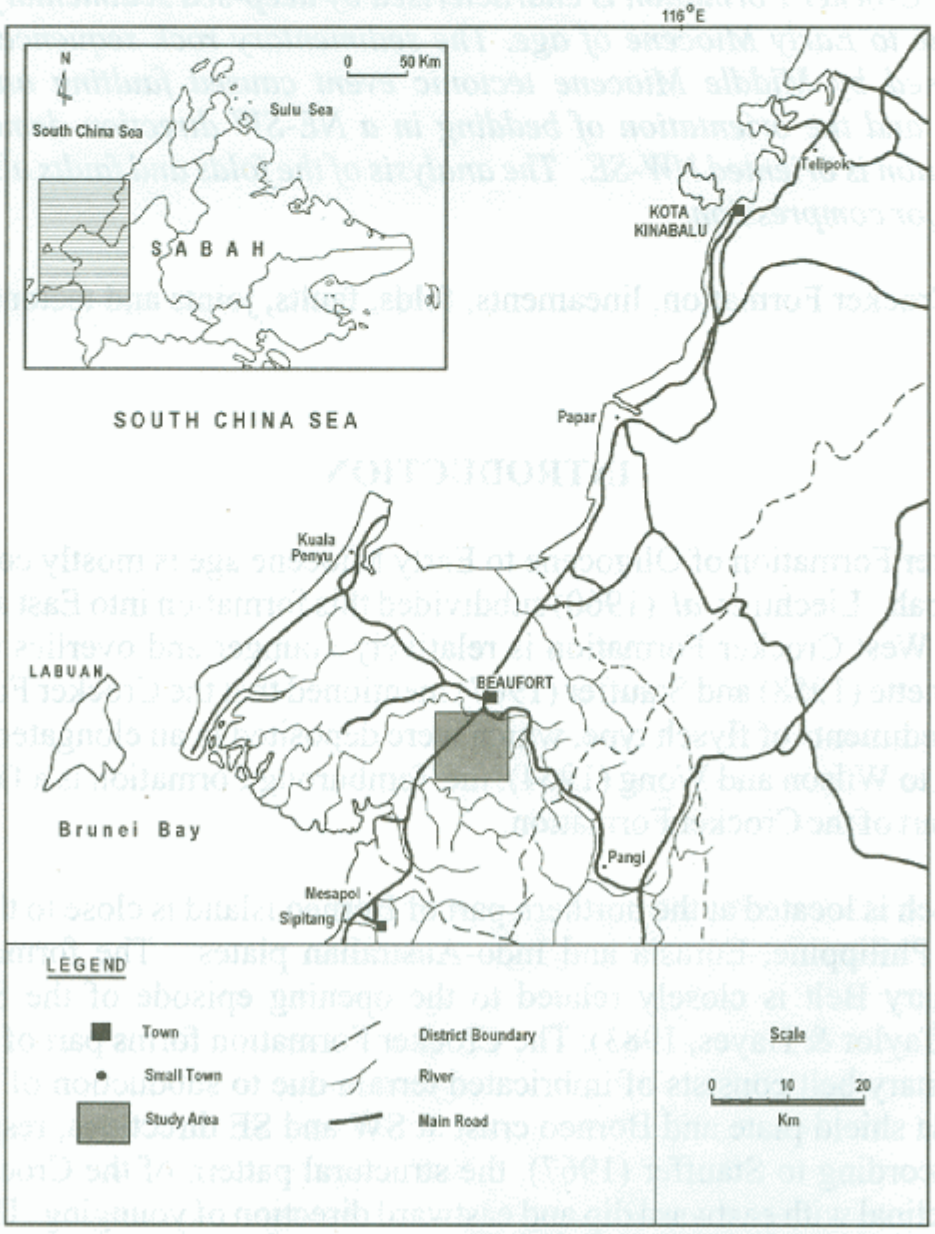

Figure 1. Location of the study area

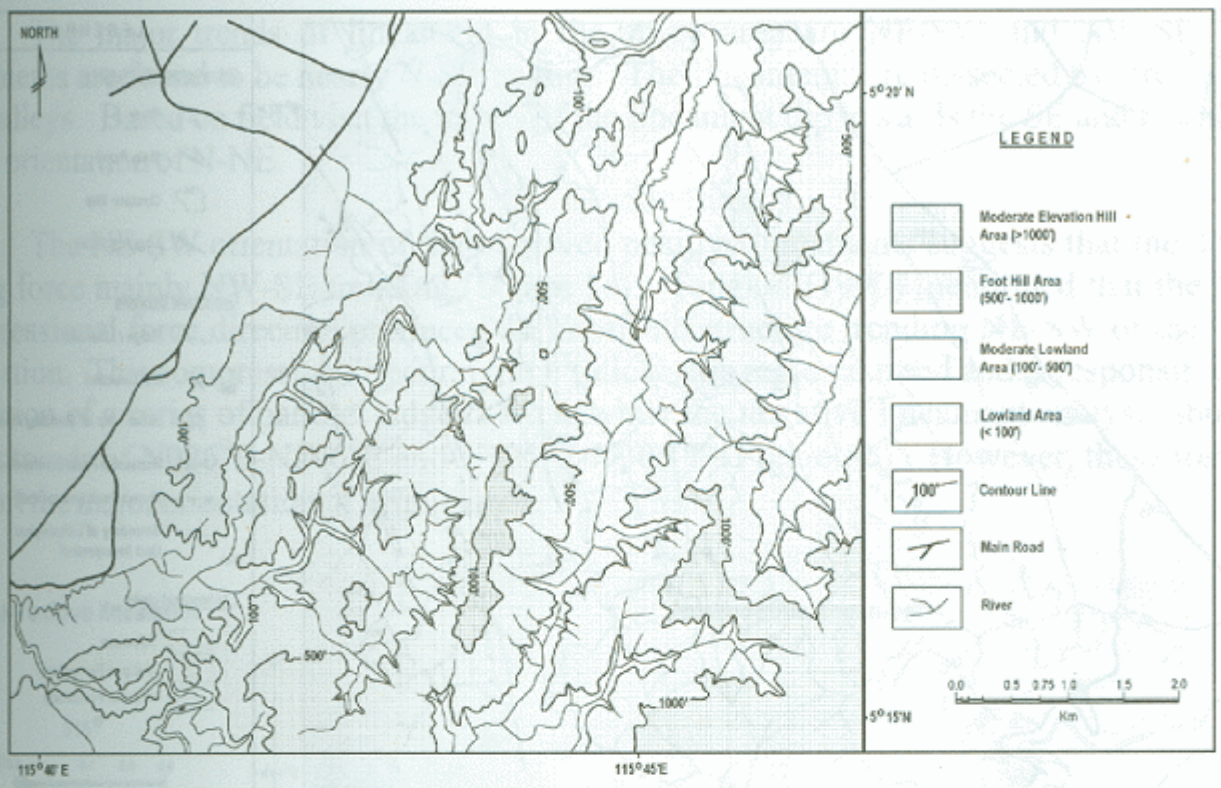

Figure 2. Topography of the area

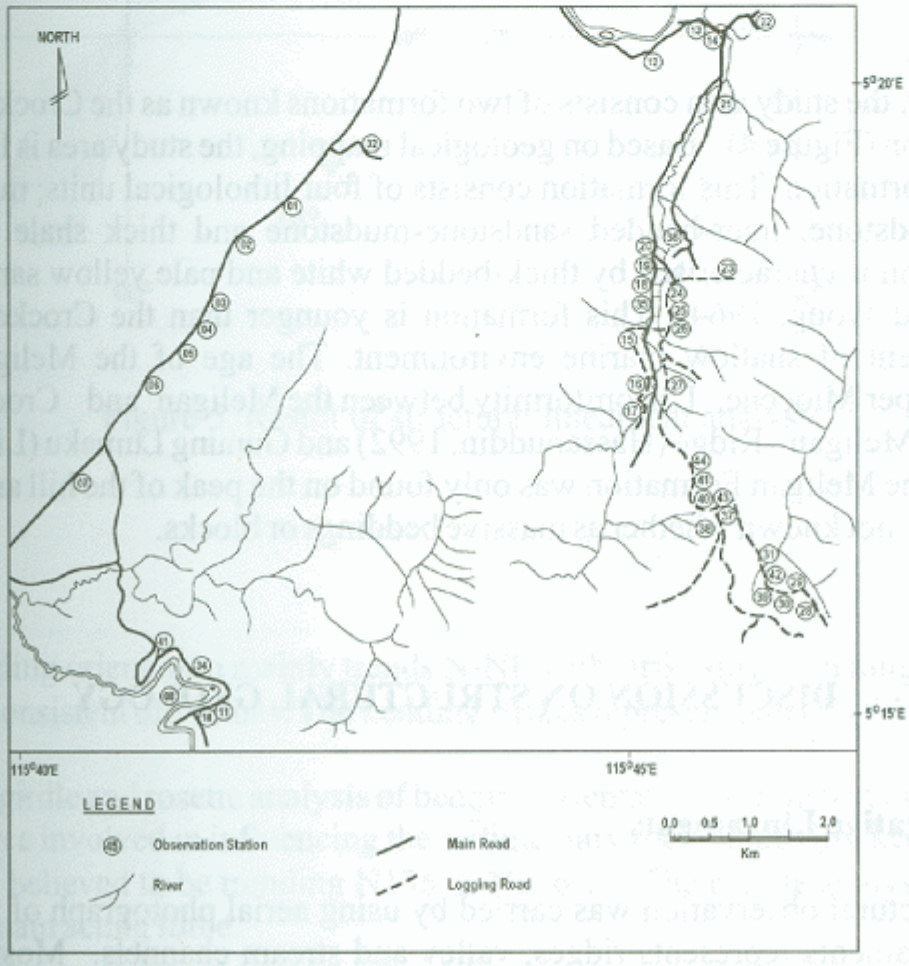

Figure 3. Location of field observation

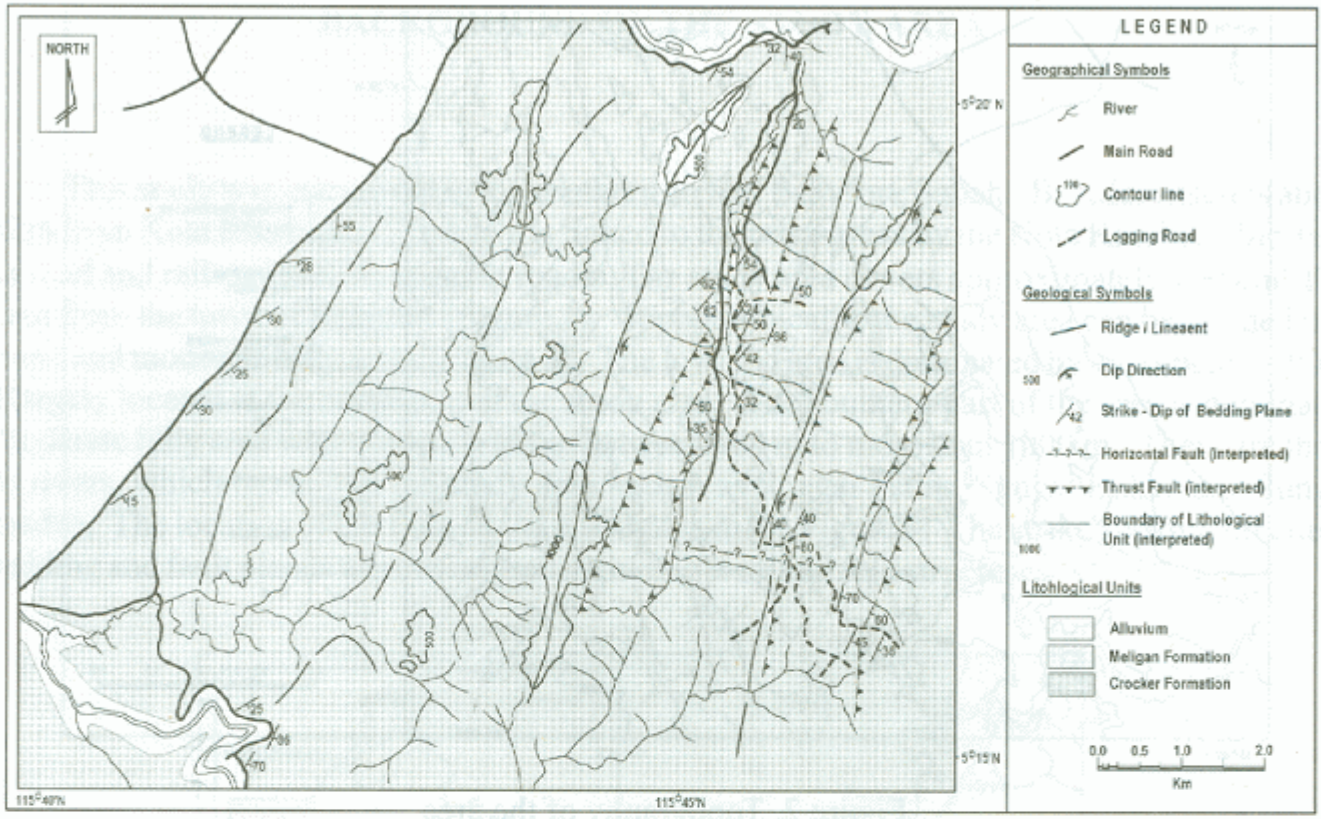

Figure 4. Geology of the area

Generally, the study area consists of two formations known as the Crocker Formation and Meligan Formation (Figure 4). Based on geological mapping, the study area is largely dominated by the Crocker Formation. This formation consists of four lithological units; massive sandstone, thick-bedded sandstone, inter-bedded sandstone-mudstone and thick shale unit units. The Meligan Formation is characterised by thick-bedded white and pale yellow sandstone with grey shale (Wilson and Wong, 1964). This formation is younger than the Crocker Formation and represents sediment of shallow marine environment. The age of the Meligan Formation is believed to be Upper Miocene. Uncomformity between the Meligan and Crocker Formations was found at Meligan Ridge (Hassanuddin, 1992) and Gunung Lumaku (Liecthi *et al*, 1960). The outcrops of the Meligan Formation was only found on the peak of the hill and the occurrence of its outcrops was not known whether as massive beddings or blocks.

DISCUSSION ON STRUCTURAL GEOLOGY

Positive and Negative Lineaments

The regional structural observation was carried by using aerial photograph of the area. Positive and negative lineaments represents ridges, valley and stream channels. Most of the observed lineaments are concentrated on the eastern part of the study area.

The major trends of lineament in the study area are NE-SW and NW-SE. Some lineaments are found to be nearly N-S trending. The lineaments are dissected by stream system and valleys. Based on field visit the trends of the lineament dip towards the SE and E with major strike orientation of N-NE.

The NE-SW orientation of the observed positive lineaments suggests that the dominant acting force mainly NW-SE trending (Figure 5a). Tongkul (1990) mentioned that the NW-SE compressional force direction produced an imbricate structure trending NE-SW of the Crocker Formation. This compressive direction force follows the regional trend and is responsible for the formation of a series of parallel ridges. Meanwhile the negative lineament analysis shows two major trends of N026°E-N206°E and N125°E-N305°E (Figure 5b). However, these trends still support the major orientation of acting force.

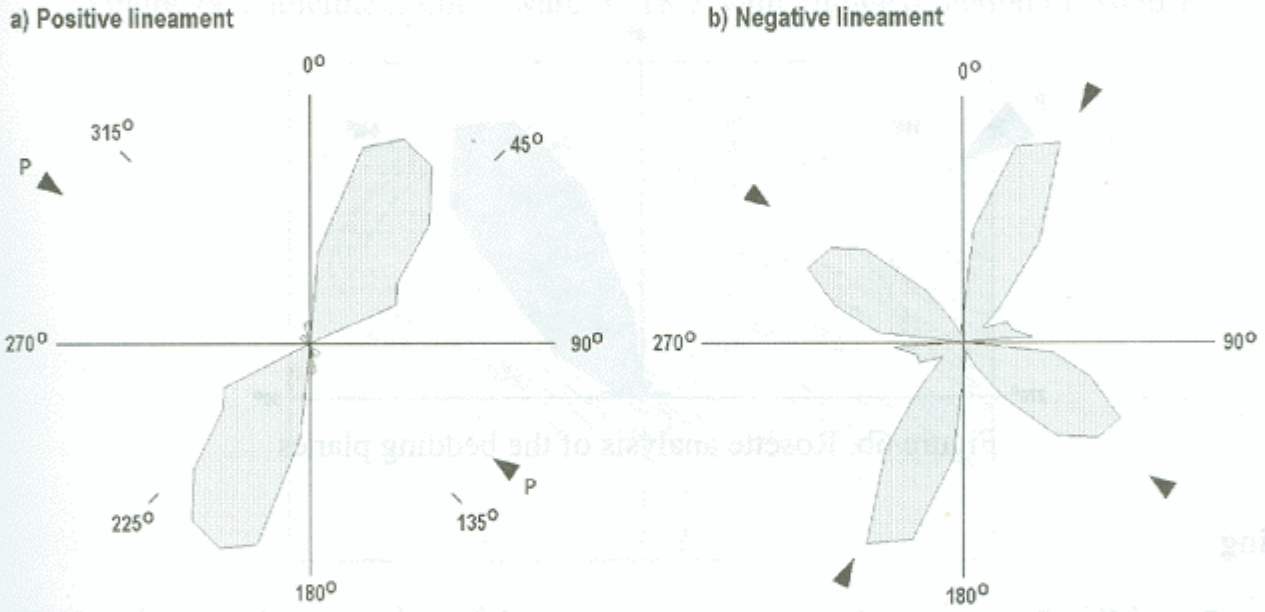

Figure 5. Result of structural lineament analysis.

Bedding Plane

The bedding orientation mainly trends N-NE with strike direction ranging from N000°E-N080°E with inconsistent dip values. The bedding strikes represent part of a fold.

The pie-girdle and rosette analysis of bedding orientation is shown in Figure 6a and Figure 6b. The main force involved in influencing the sedimentary rock of the Crocker Formation within the study area is believed to be trending N136°E-N316°E. The rosette analysis shows the same direction of the main acting force.

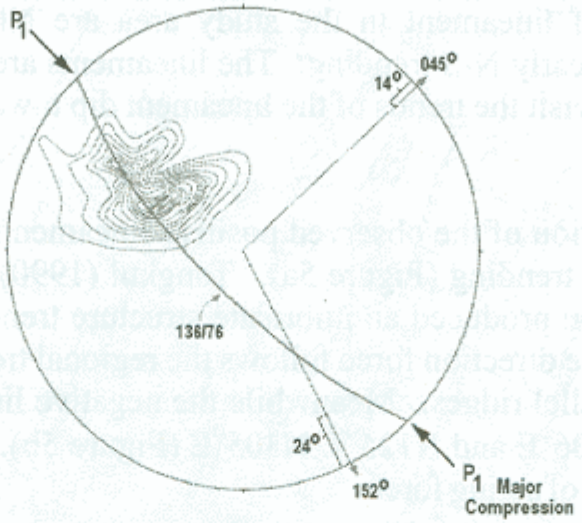

Figure 6a. Pie-girdle analysis of bedding planes.

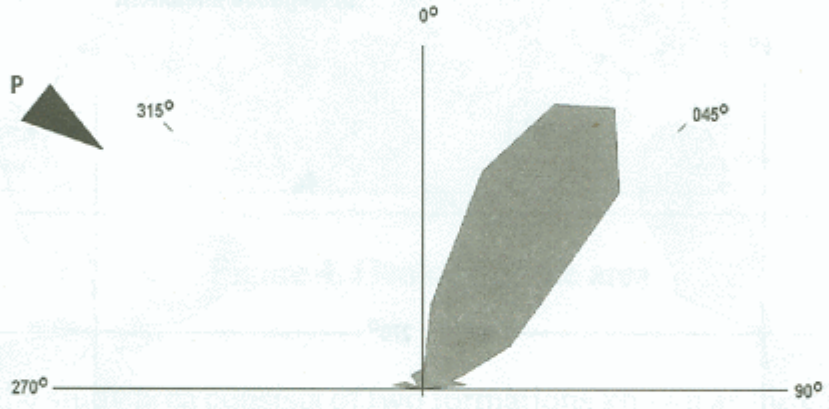

Figure 6b. Rosette analysis of the bedding planes

Folding

Generally, three types of fold structures were found--tilted (S11), recumbent (S39), and synform (S23) folding (Figure 7ac). The fold wings readings were analysed using beta method (Figure 8). The result of the fold analysis is shown in the Table 1. The major orientations of force still trends NW-SE and E-W.

Table 1. Fold structure analysis

Station No.	ANALYSIS OF FOLD STRUCTURES		
	Plunge direction	Plunge angle	Compression Force
S11	N036°E	6°	N126°E – N306°E
S17	N027°E	18°	N117°E – N297°E
S23	N223°E	8°	N113°E – N313°E
S23a	N013°	5°	N103°E –N283°E
S39	N178°	22°	N088°E – N268°E

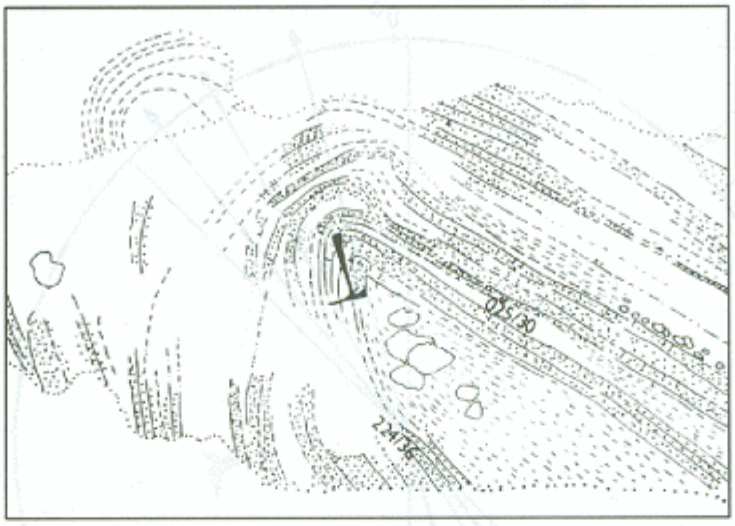

Figure 7a. Anticline tilting toward N318°E with plunge direction of N036°E

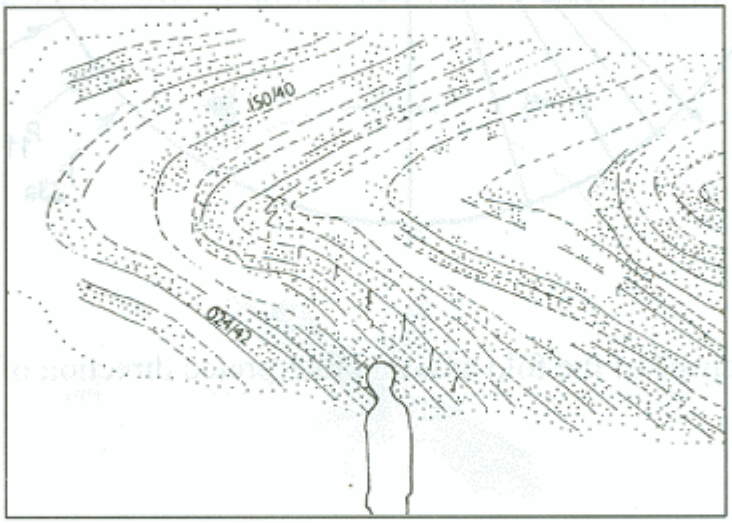

Figure 7b. Recumbent fold with plunge angle of 22° towards N178°E

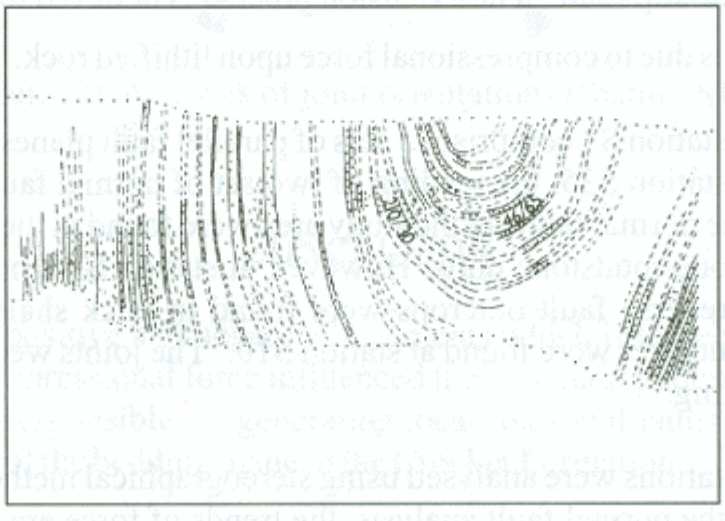

Figure 7c. Syncline plunging towards N223°E

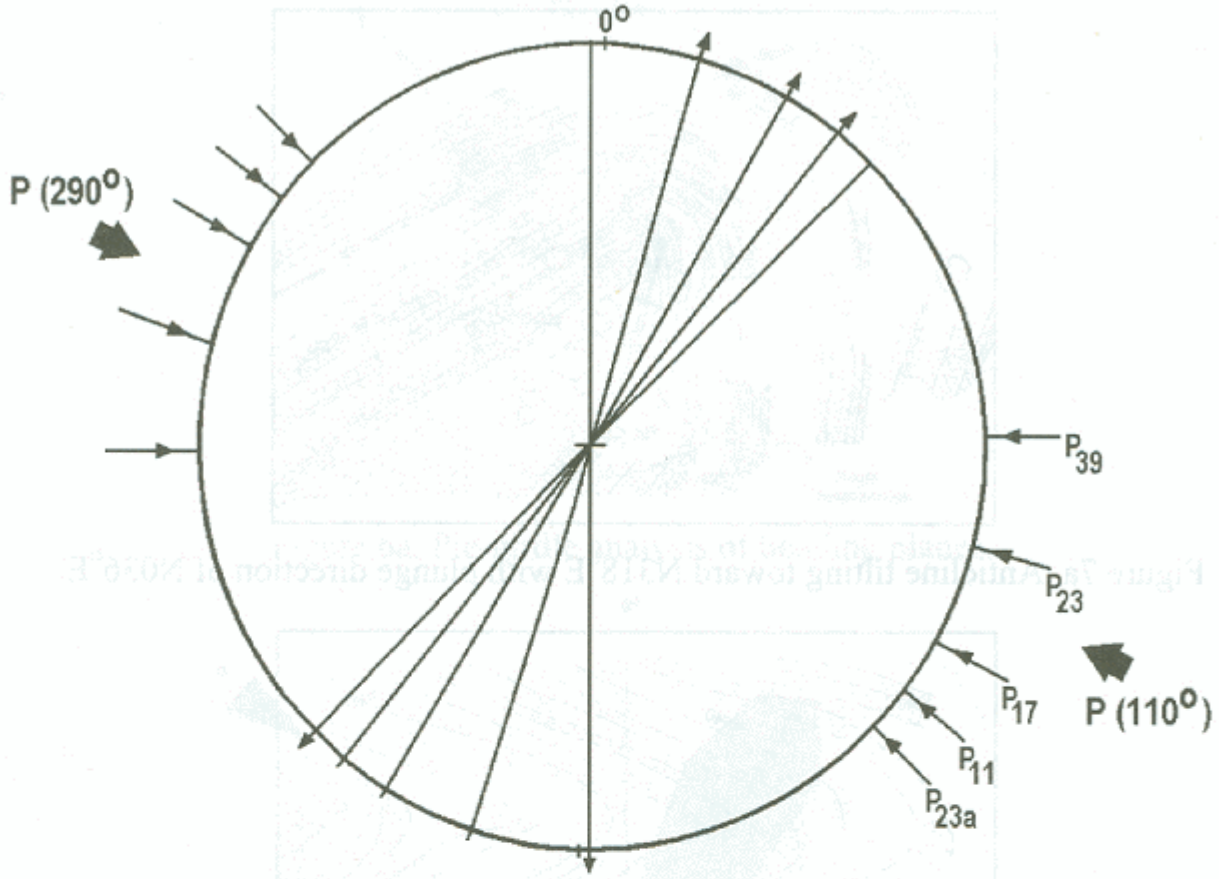

Figure 8. Analysis of the fold axis and interpreted direction of acting forces

Faulting and Jointing

Only normal and reverse faults were found in the study area. Aerial photo-interpretation showed no signs of strike-slip fault. The extension process is believed to have caused the normal fault while reverse fault is due to compressional force upon lithified rock.

Normal fault at station S2 comprises 3 sets of parallel fault planes, which cut across thick-bedded sandstone. At station S35, the reading of two set of normal fault is 305/52 and 110/74, respectively. Most of the normal faults in the study area were found in the thick-bedded sandstone and interbedded sandstone-mudstone units. However, at station S24, normal faults cut through thick shale unit. The reverse fault outcrops were found in thick shale unit and thick-bedded sandstone unit. Joint structures were found at station S10. The joints were filled up by iron oxide due to chemical weathering.

The fault and joint orientations were analysed using stereographical method (Figure 9) and rosette (Figure 10). Based on the normal fault analysis, the trends of force are N-S and nearly NE-SW while the reverse fault is NW-SE direction. Meanwhile, the joint analysis gives a NW-SE and NE-SW trending force direction.

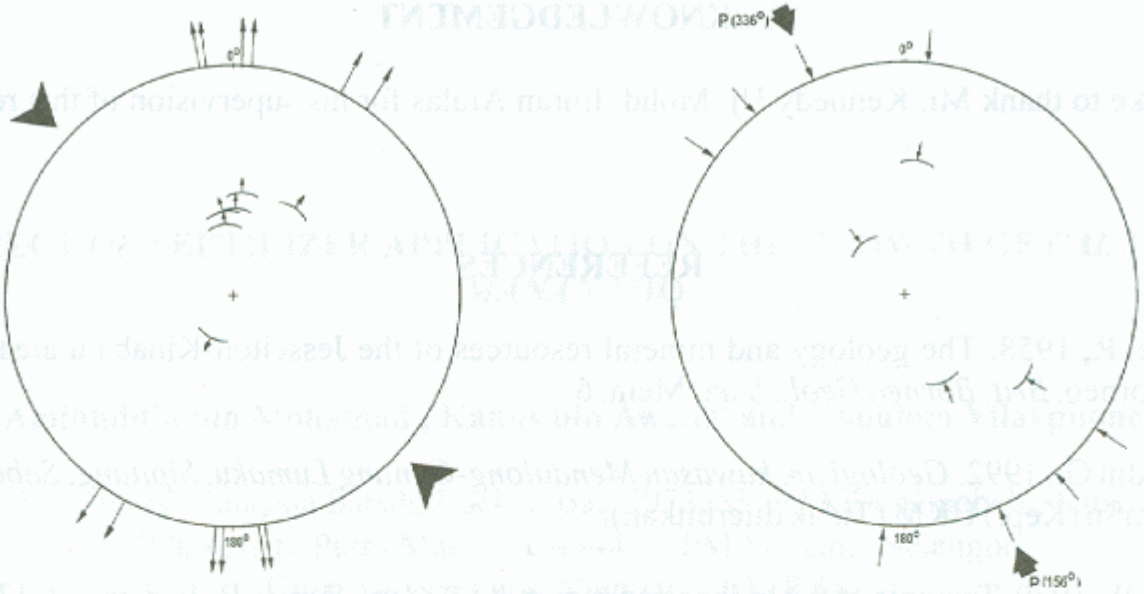

Figure 9. Analysis of normal (left) and reverse (right) faults.

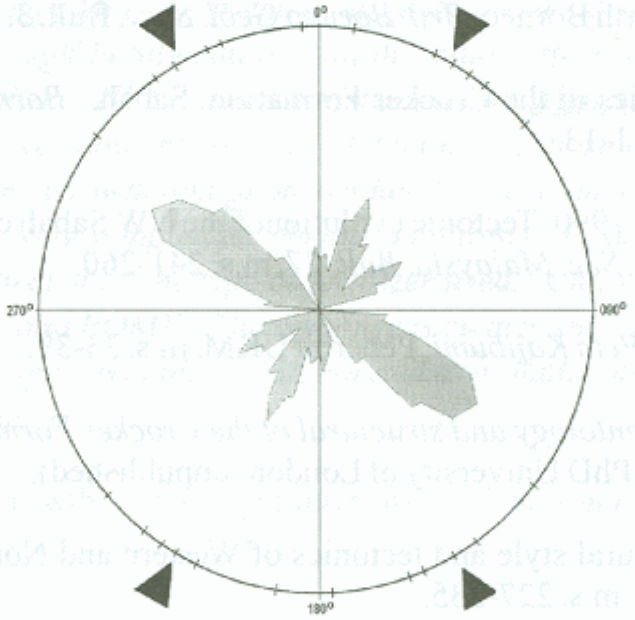

Figure 10. Analysis of joint orientations (Station S10).

CONCLUSION

The regional pattern of positive and negative lineaments which is largely NE-SW trend, suggest that a major NW-SE compressional force influenced the structural pattern of the study area. This compressive force was responsible for generating local folds and faults and controlling the N-S and NE-SW orientation of the bedding plane of the Crocker Formation.

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