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Structural analyses of the western part of the Schirmacher hills, east Antarctica

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Abstract

The Western part of the Schirmacher Hills is mapped in detail. The rock types found in the area are interlayered calc-khondalite-phroxene granulite unit, augen gnesis and streaky gneiss. In this area, the early Dl and D2 deformations have been oblitered by dominant D3, deformation which produced isoclinal, inclined to reclined fold with an axial planner foliation striking E-W and dipping towards south, The ductile shear zone with a thrust sense of movement is synchronous with the D3 folding. The later deformations, D4 and D5 produced two sets of open upright folds and two sets of cross cutting shear zones are associated with these two later deformations.

Introduction

The Schirmacher Hills is located between 71° 44' 30" S to 70° 46' 46" S latitudes and 11° 22'4" E to 11° 54'00" E longitudes in the Queen Maud Land of East Antarctica. The hill range occupies an area of 35 km^2. The Schirmacher Hills is characterized by polymetamorphic medium to high grade metamorphics. The area has suffered several phases of deformation and metamorphism (Sengupta 1988, Stackebrandt et al. 1988). The present work mainly dealt with the lithological and structural history of the western part of the Schirmacher Hills.

Lithology

The main lithological units within the western part of the Schirmacher Hills are recognized on the basis of compositional difference. The major units are intercalated calc gneiss-khondalites-mafic granulities-granites, augen gneiss and streaky gneiss (Fig.l).

Intercalated calc gneiss, khondalites and mafic granulites occur as a mappable unit in the western part of the Schirmacher Hills. These different rock types are so closely interlayered that they can be considered as a single unit. However, the thickness of the individual rock types varies form few centimetre to a few metres. These are three thick veins of granite gneiss occurring roughly parallel to the bands of granulites (Fig.2). Isolated bands'of calc gneiss and khondalite also occur in the western part of the study area at the contact between the augen

gneiss and streaky gneiss. The bands of pyroxene granulite behaved as a competent unit within the interlayered calc granulites and khondalites. These bands often show boudingaed structure within the ductile matrix of granite gneiss.
The augen gneiss is well foliated and contains quartz-K-feldspar-plagioclase biotite with some garnet and hornblende. The augen structure is mostly represented by the very coarse elongate grains of K-feldspar. The size of the K-felfspar varies from a few millimetre to about 2.5 centimetres. The K-felfspar augen show marginal grain refinement, which can even be seen by naked eye. However, there are some augen which show porphyroblastic growth. The long axis of the augen is parallel to the foliation indicating that they have grown syntectonically. Streaky gneiss occuring in the extreme western part of the Schirmacher Hills, is fine grained with well developed foliation. Its contact with the augen gneiss is gradational.

Deformation History

The Schimacher Hills have suffered at least five phases of deformations (Sengupta 1993). The earlier deformations Dl and D2 took place under granulite fades condition. Dl is restricted within some mafic and ultramfic enclaves, D2 foliation is traced by pyroxene grain and D2, fold is formed by the folding of Dl foliation within the enclave. The dominant deformation of the study area is D3 deformation. D3 folds are isoclinal, inclined to nearly reclined. The axial plane of D3 folds is striking E-W with a moderate dip towards south. D3 folds are mostly found in mesoscopic scale. D3 foliation within the study area have a general strike of 80° with a southerly dip of 30°. The hinge parallel lineations show an orientation of 32° towards 239° (Fig.3).

D3 foliations is marked by biotite and hornblende in amphibolites and quarz and feldspar in granites which indicate that it took place under amphibolite fa---es condition . Thick bands of garnetiferous granite gneiss that invadee tha interlayered calc granulites khondalites-pyroxene granulite unit in the western part of the study area is syntectonic with D3, The foliations within the granite gneiss is subparallel to the axial plane of mesoscopic D3 fold.

The axial plane of D3 fold has been refolded by later deformation. The mesoscopic D4 fold is found within the cla-khondalite unit. D4 Deformaiton produced open upright fold with steep northeasterly trending axial surface. D4 fold is coaxially superimposed on D3 fold forming hook-shaped outcrop (Fig.4). The dominant D3 foliations dip towards south along the southern margin of the oasis and dip towards north towards the northern margin of the Schirmacher Hills. Along the central zone of the Schirmacher Hills in the western part, the foliations are nearly horizontal. The variation in the amount and directions of the D3 foliations is likely to be due to D5 deformation, D5 folds are also open and upright, but the axial plane of D5 fold is striking E-W with steep axial surface.

Ductile Shear zones

There are different generations of shear zones found within the study area.

Primarily, the shear zones in the study area can be grouped under two groups based on the mineralogy of the sheared rock. They are- (1) Granulite Facies Shear Zone and (2) Amphibolite Facies Shear Zone (Sengupta and Bose. 1997). However, in this area most of the shear zone belong to the second group. Amphibolite facies shear zones produce protomylonite, mylinite and ultramy'lonite with varying intensity of deformaiton. Map scale amphibolite facies shear zone can grouped into two classes.

(i) Ductile shear zone parallel to D3 foliation
(ii) Ductile shear zone at high angle to D3 foliation.

Ductile shear zones parallel to D3 foliation

These shear zones occur in all parts of the present area. The width of the shear zone varies from a few centimetres to a few metres; it continues for a few metre to a few kilometres in length. These shear zones occur at low angle to the D3 folds, with their mylonitic foliation have a general strike of E-W with a moderate dip towards south. The mylonitic lineration plunges moderately towards southwest.

The layer parallel shear zone is best developed at the contact of augen gneiss and interlayered calc-khondalitic unit. Within these shear sone the mylonitic foliation itself deformed to tight or isoclinal fold both in mesoscopic scale. A new mylonitic foliation is parallel to the D3 foliation that occurs outside the shear zones. The hinges of the shear zone fold are strongly curved resulting in the formations of sheath folds (Sengupta and Bose, 1997). The mylonitic lineations are greatly deformed over the hinges of the shear zone fold and show is unrolled (Ghosh and Sengupta, 1987). In some places the shear zone fold in calc gneiss, show closed outcrop with diverging axial surface of the smaller folds (fig.5). The asymmetry of shear zone folds, along with other shear sense indicators (and types porphyroclasts, offset of passive makers) in the mylonite, show a north-easterly oriented thrust type of movement along this shear zone. Although all the rock types within the shear zone are somewhat sheared, calc unit shows intense mylonitization. This may be because of calc unit, being more incompetent, has taken up the strain.

Layer parallel shear zones are also well developed in the augen gneiss. This shear zone produced mylonite with progressive increase in the intensity of deformation. With increasing deformation, there was progressive reduction in grain size resulting in the formation of mylonite to ultramylonite.. Increase in the intensity of deformation is also marked by the increase in the bands of ferromagnesian menerals and quartzofeldspathic minerals. Figure 6 a and b show such shear zone where mylonitic foliation is parallel to the D3 foliations of the host augen gneiss. The augen gneiss along with a band of pyroxene granulite shows tight D3 folds. The shear zone foliation is parallel to the axial surface of these folds. Along the shear zone the early foliation is obliterated by the mylonitic foliation (Fig. 6c) Syntectonic pegmatite has been emplaced along the shear zones. The pegmatite shows folds with axial surface and hinges sub-parallel to the fold in the enveloping gneisses (central part of Figs. 6a and b). The pegmatite shows pinch and swell or boudinage structure that the emplaced parallel to the mylonitic foliation. All these features suggest that ductile shearing and emplacement of pegmatite were syntectonic with D3 folding, Both D4 and D5 folds deform this shear zone.

Ductile shear zones at high angle to D3 foliation

These shear zones occur at high angle to the D3 foliation thereby indicating that the high angle shear zones are later than D3 deformation. Among them two groups can be distinguished. The early corss-cutting shear zone foliations have moderate to steep dips with easterly strike.

(a) Northeasterly trending cross cutting shear zones

In the western part of the Schirmacher Hills, there is a set of northeasterly trending cross cutting shear zones. These shear zones occur within the augen gneiss near Lake 55 (Fig. 1). The sheared rocks produced excellent mylonite. The mylonitic foliations strike northeasterly with steep dip towards southwest. The pitch of the mylonitic lineation ranges from 30° to 35° from SW (Fig. 7). These northeasterly trending shear zones occur at the limbs of tight D4 folds, where the limbs of fold rotated to a subvertical attitude. Figure 8 shows such a situation in augen gneiss, where subvertical shear zones have developed at the limbs of D4 fold. Shear zones indicators suggest the right normal sense of the movement of shearing.

In the vicinity of Lake 55, an early cross cutting pyroxene grains. The foliation within the dyke is parallel to the axial plane of relict early folds trending 20°.

The shifting of early dyke is well exposed on the out crop and it has been mapped in detail. Horizontal displacement of the dyke has been directly measured on the field (Fig. 1 and 9). The mylonitic foliations contain slicklines, which indicate the direction of movement within the shear zone. The orientation of the Slickenline lineation has been used to determine the direction and amount of net slip.

Geometrical determination of the amount of net slip has been described by Ghosh, 1993. The method for determining the net slip is as follows. Figure 10 shows the shear zone, SZ, striking 78° with a dip of 75° towards South. A dyke running along AB and CD shows dextral strike separation of 100m . In either side the shear zone, the dykestrikes 20° and dipping 45° towards Southeast. The lineations on the mylonitic foliation have a trend of 246°.

To determine the net slip we have to find from stereographic projection the trend of the line of intersection of the shear zone and the dyke. The lines BE and DF are drawn parallel to this trend. The intercept LM drawn parallel to the net slip gives the trend of the horizontal component of the net slip. The angle MLN is equal to the plunge of the stretching lineation, with NM perpendicular rot LM. LN gives us the magnitude of net slip with downward movement of the hanging wall (Fig. 10).

Following this method we have calculated the net slips of five consecutive cross cutting shear zones which have displaced the mafic dyke. The dyke has been shifted dextrally with horizontal separation 100 metres, 50 metres, 30 metres, 20 metres and 12.5 metres respectively from north to south. The horizontal separation increase from south to north. The shear sense indicators shows right normal sense of the movement of shearing. Graphical solution of the field date also indicates normal sense of movement with hanging wall moving downward. From south to north the calculated net slip of the shear zones are 6.8 metres, 14.2 metres, 31.4 metres, 45 metres and 85 metres.

(b) Easterly trending cross cutting shear zones

Easterly trending cross-cutting shear zones extend from extreme west of the Schirmacher Hills in the southern border of the oasis to the northern border of the Hill in the central part of the study area (Fig. 1). This shear zone occurs in the region of augen gneiss and produced typical mylonite. The Mylonitic foliations have a moderate to steep clips towards south with a low to moderate plunge of mylonitic lineation towards southwest. The width of this shear zone is 5 metres and il continues for more than two kilometres in length. The foliation of the shear zones shows gentle warping. This is possible due to the fact that it has been folded by later folds. This shear zone thus must be post D3 deformation as it cut across th eD3 foliations.

Along the shear zone the sheared rocks show excellent development of mylonite. The mylonitic foliation is deformed to mesoscopic noncylindrical tight to isoclinal folds of variable pitch of fold axis. Along the shear zone large blocks of layered rock have been rotated to high angle to the foliaiton (Fig.l 1). Within the block the foliation is at right angle to the surrounding foliation. The shear zone foliation swerves around the rotated block. The asymmetry of the clast and the foliation around it indicates a right normal sense of movement of shearing. The general strike of the mylonitic foliation is 100° with a dip 60° towards south. The mymonitic lineation has a plunge of 36° towards 234° (Fig.12).

Brittle Shear Zones

The rocks of the central part of the Schirmacher Hills are dissected by number of brittle and brittle-ductile shear zone (Ramsay 1980). The most of these shear zones are subvertical ir gave steeo dips with easterly of northerly strike. Discrete veins of pegmatite have sometimes emplaced along these shear zones. The map scale brittle deformation is indicated by N-S fault across the easterly trending cross cutting shear zone. This fault lies in the extreme west of the study area across augen gneiss and streaky gneiss. The presence of brittle fault has been indicated by absence of augen gneiss and other lithjological unit along strike. The sense of movement along the fault is sinistral.

Summary

The western part of the Schirmacher Hills is characterized by different lithounits. The compositions of the western part of the study area is of amphibolite facies and calc-khondalite unit in the east is of granulitic composition. From the field studies and structural analyses of different structural elements it could be said that eastern granulite has been thrusted over the western amphibolitic rocks along a thrust zone that occur at the contact of augen gneiss and interlayered calc-khondalite unit. The sense of thrusting is towards northeast. The presence of strain concentration along narrow zone is mostly acocaited will all major deformation delineated in the study area. Northeast trending shear zones are broadly syntectonic with D4. The latest groups of deformation, which is manifested by the cross cut N-S fault in theextreme west of the Schirmacher Hill.

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Figure Caption:

Fig. 1. Lithological map of western part of the Schirmacher Hills, East Antarctica.

Fig.2. Granite bands parallel to the D3 foliation within the interlayered calc-khondalite pyroxene granulite unit.

Fig.3 (a) Contours of 233 foliation (D3) poles in the western part of the Schirmacher Hills with 0.43-2. 2-4.3-8. 6-12. 9-15 percent (b) Contours of a total of 32 D3 stretching lineation in the western part of the Schirmacher Hills with 28.12-15. 62-3.1 percent.

Fig. 4. Deformation of layer parallel shear zone by open D4 fold. Early isoclinal fold within the shear zone (below the marker pen) has been refolded by open upright fold (D4) giving hook-shaped outcrop pattern.

Fig 5 Shear zone fold in calc gneiss.

Fig 6 (a) and (b) Emplacement of syntectonic pegmatite along ductile shear zone s developed parallel to the axial planes of a folded pyroxene granulite (pxg) and augen gneiss (Ag) unit. The pegmatite (Pg) shows folds with hinge and axial plane parallel to the D3 folds of the enveloping gneiss. It also shows development of pinch-and-swell structure parallel to the mylonitic foliation. Details of the inset is shown in gigure (c). (c) Details of the area showing truncation of the early foliation by the mylonitic foliation.

Fig.7. Contour of 24 mylonitic foliation (S) poles with 33.33-25-16. 66-8. 33-4. 16 percent and total number of 19 mylonitic lineation with 26.31-15.78-10.52-5.26 percent of northeasterly trending shear zone near Lake-55 of the Schirmacher Hills.

Fig 8. Northeasterly striking subvertical shear zone at the limbs of a D4 fold in the western part of the Schirmacher Hills.

Fig.9. Displacement of mafic dyke by a set of subvertical shear zones striking northeasterly. On the right side, a foliation parallel shear zone is deformed by D4 and D5 folds.

Fig. 10. Geomatrical construction of structural features of a shear zone for the determination of net slip.

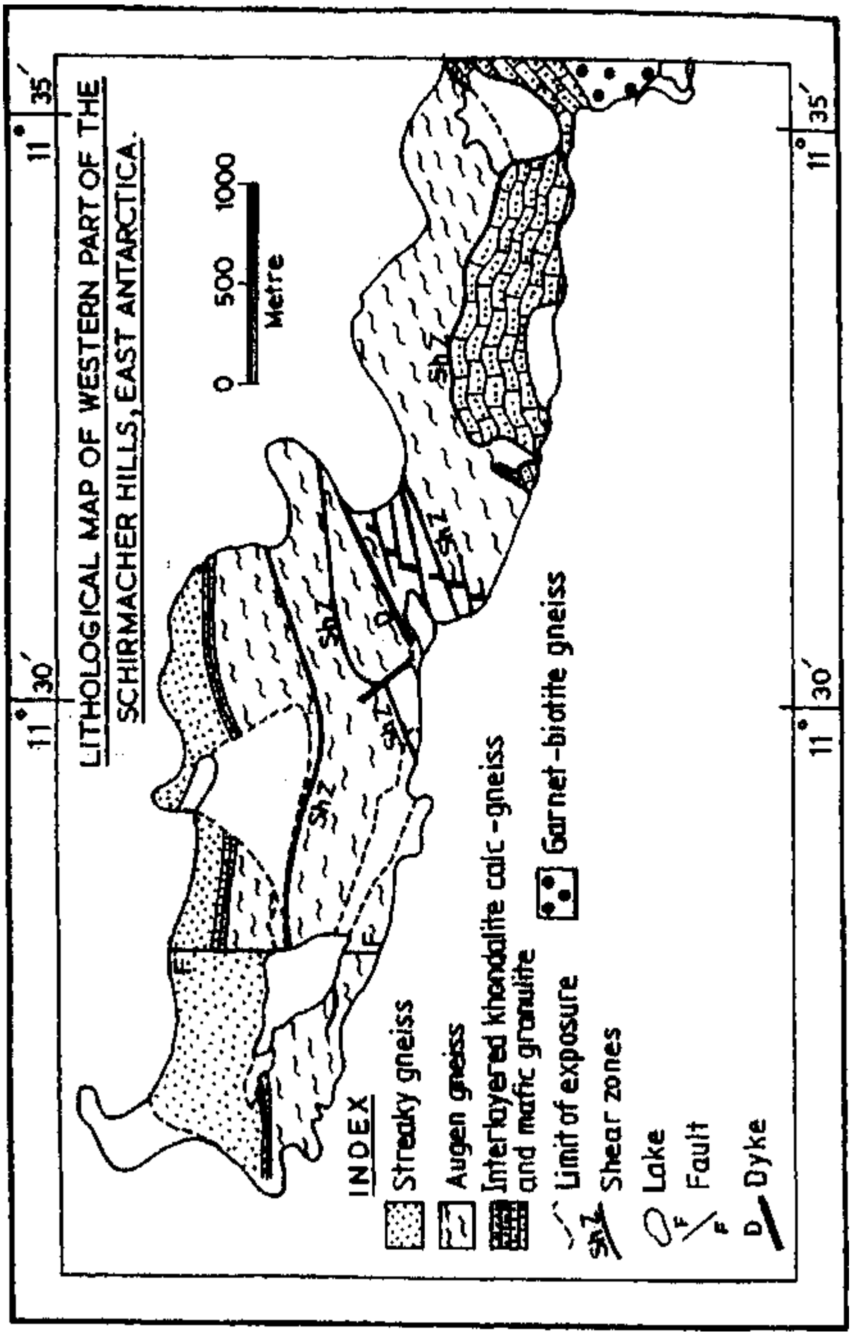


Fig. 1 Lithological map of western part of the Schirmacher Hills, East Antarctica.

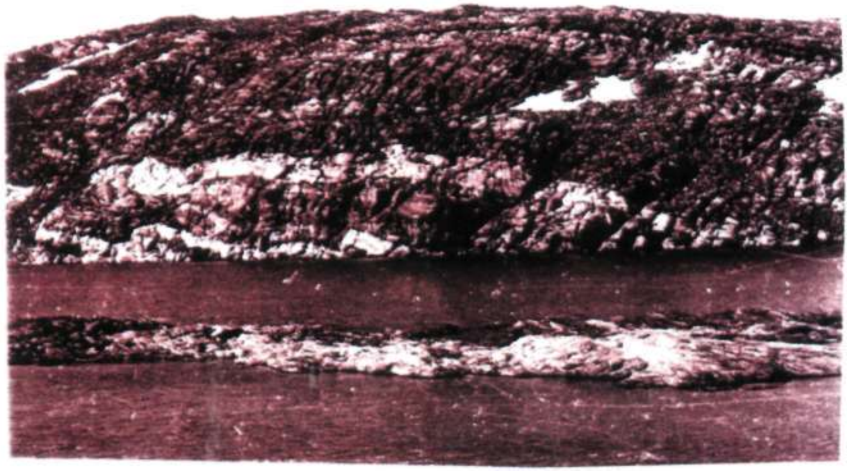
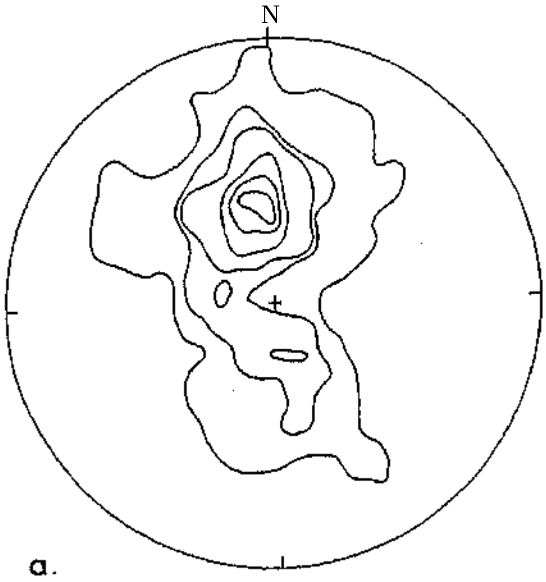


Fig. 2



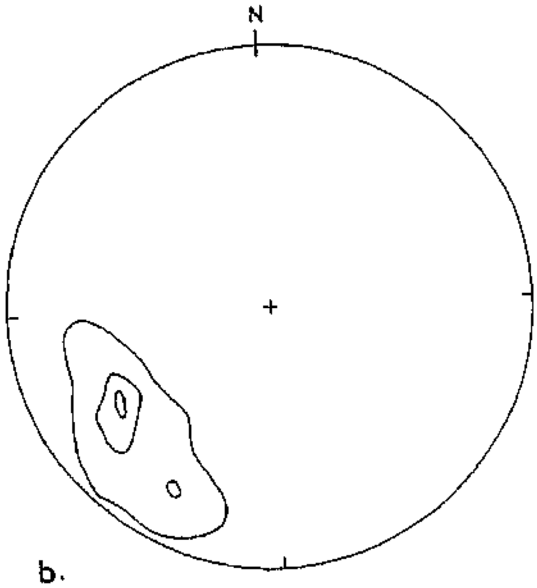


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Fig. 4

Fig. 5

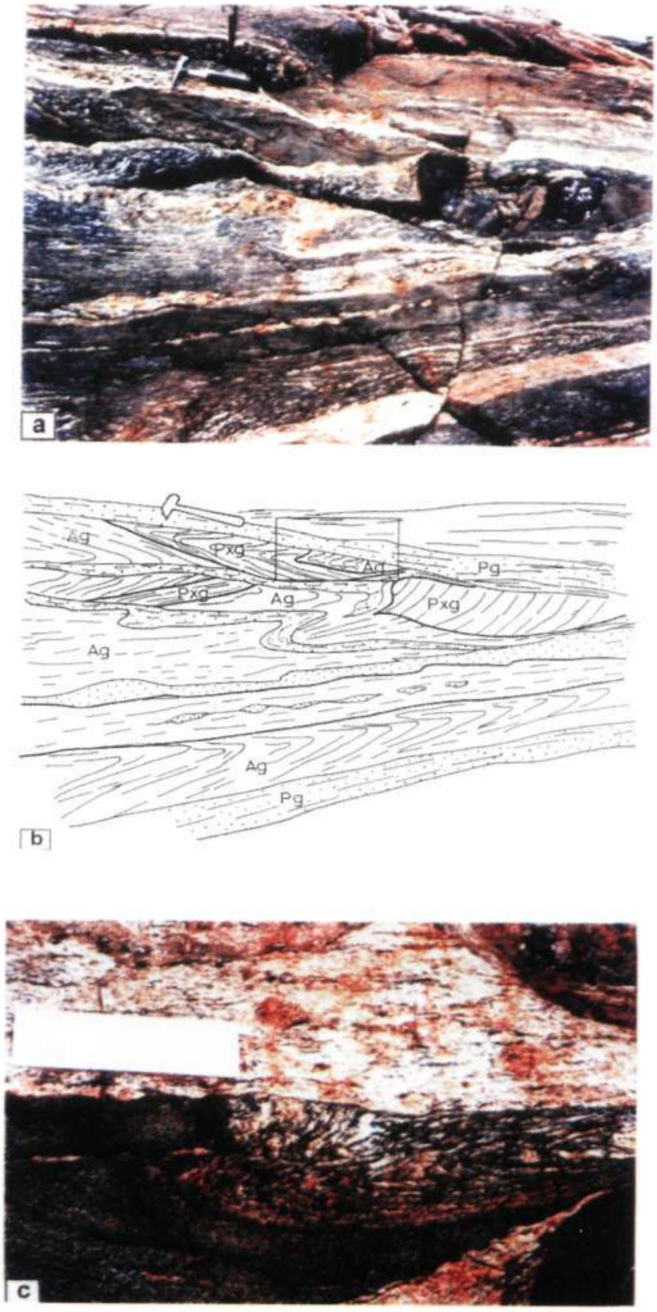


Fig. 6

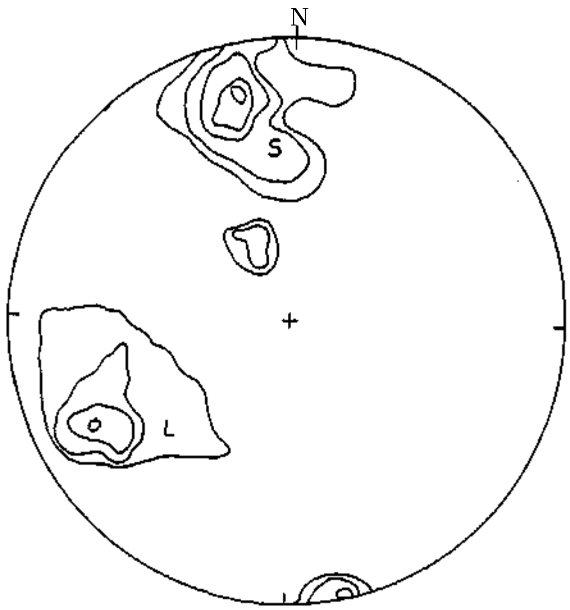


Fig. 7 Contour of 24 mylonitic foliation (S) poles with 33.33-25-16. 66-8. 33-4. 16 percent and total number of 19 mylonitic lineation with 26.31-15.78-10.52-5.26 percent of northeasterly trending shear zone near Lake-55 of the Schirmacher Hills.

Fig. 8

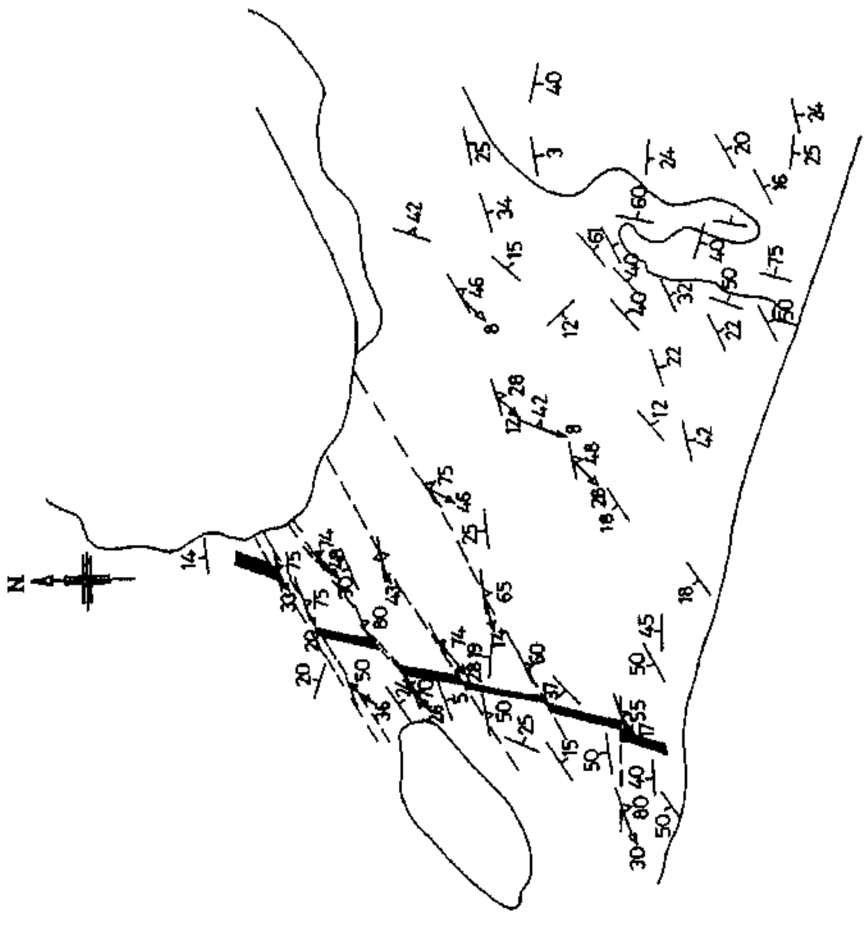
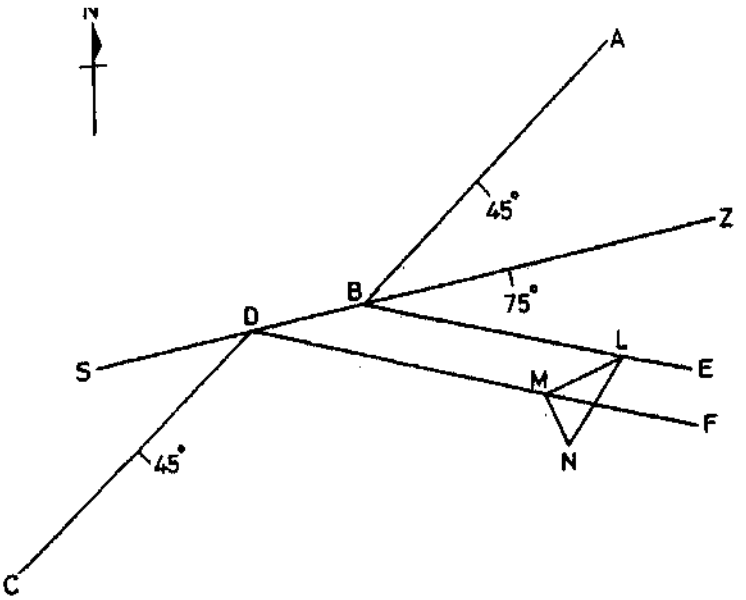


Fig.9 Displacement of mafic dyke by a set of subvertical shear zones striking northeasterly. On the right side, a foliation parallel shear zone is deformed by D4 and D5 folds.



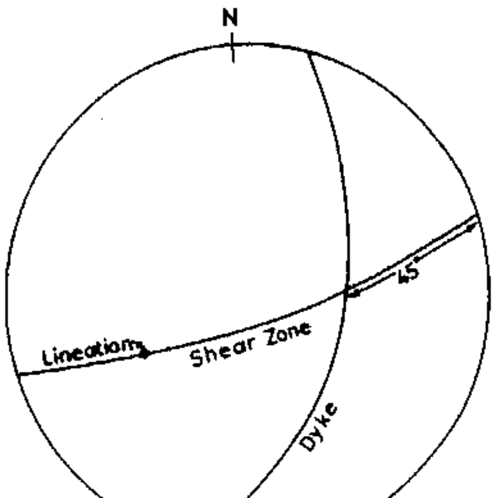


Fig.10 Geomatrical construction of structural features of a shear zone for the determination of net slip.

Fig. 11

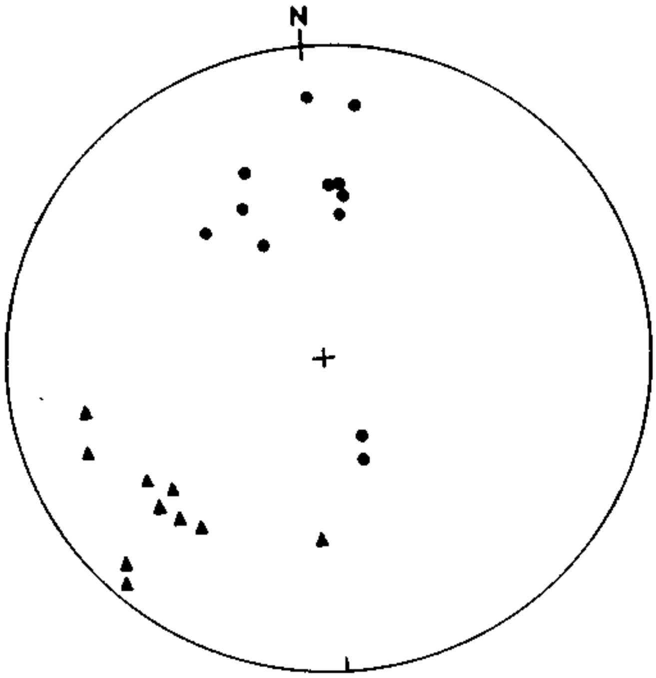


Fig. 12