The trend and distribution of these rocks, as shown on Map No. 2, indicate that the formations generally have an east-west strike direction (N 78°E), with a complex outcrop pattern produced by folding and topography (see Map 2). In local detail, the strike changes considerably and is entirely due to folding. This is especially noticeable in the hinge areas of the folds.

The dip of the beds varies considerably and is usually directed to the south or north, depending on which flank of the folds it happens to be. In the eastern and north eastern corner of the area, overfolding is present to some extent (refer to Section B-B' (Map 7) in the Eureka Section (Map 2) and Figures P, Q, T, and V on Map 5). In this area the axial planes of the folds dip steeply to the south, with both limbs of the folds dipping steeply south.

Although, locally, the bedding planes of the banded ironstone have variable dips and strikes, poles of the bedding planes plotted on a pye diagram, for each of the sub area, tends to lie on a great circle (Refer to figures A-B, H, K, O and S on Map 5). Apart from this there also seem to be no noticeable change in the general behaviour of the bedding from one sub area to the next.

The behaviour of the bedding planes over the entire area are depicted on two synoptic diagrams covering the eastern- and western section of the area (see Fig. 11). The eastern section includes sub areas M, N, O, P, Q, R, S, T, U, V and S and the western section includes sub areas A and B, C, D, E, F, G, H, I, J, K and L indicated on Map 5.

The poles of the bedding planes in both synoptic diagrams clearly defines a great circle, this would indicate regular folding about parallel axes. The azimuth and amount of plunge of the axes can readily be determined from the above mentioned diagrams as being 255° and 8° respectively.

3. Major Folding

(a.) General

The major folding of the area follows two main trends; an earlier north-south and a later east-west trend. The two fold systems can be referred to as a double system of folding (see Map 1).

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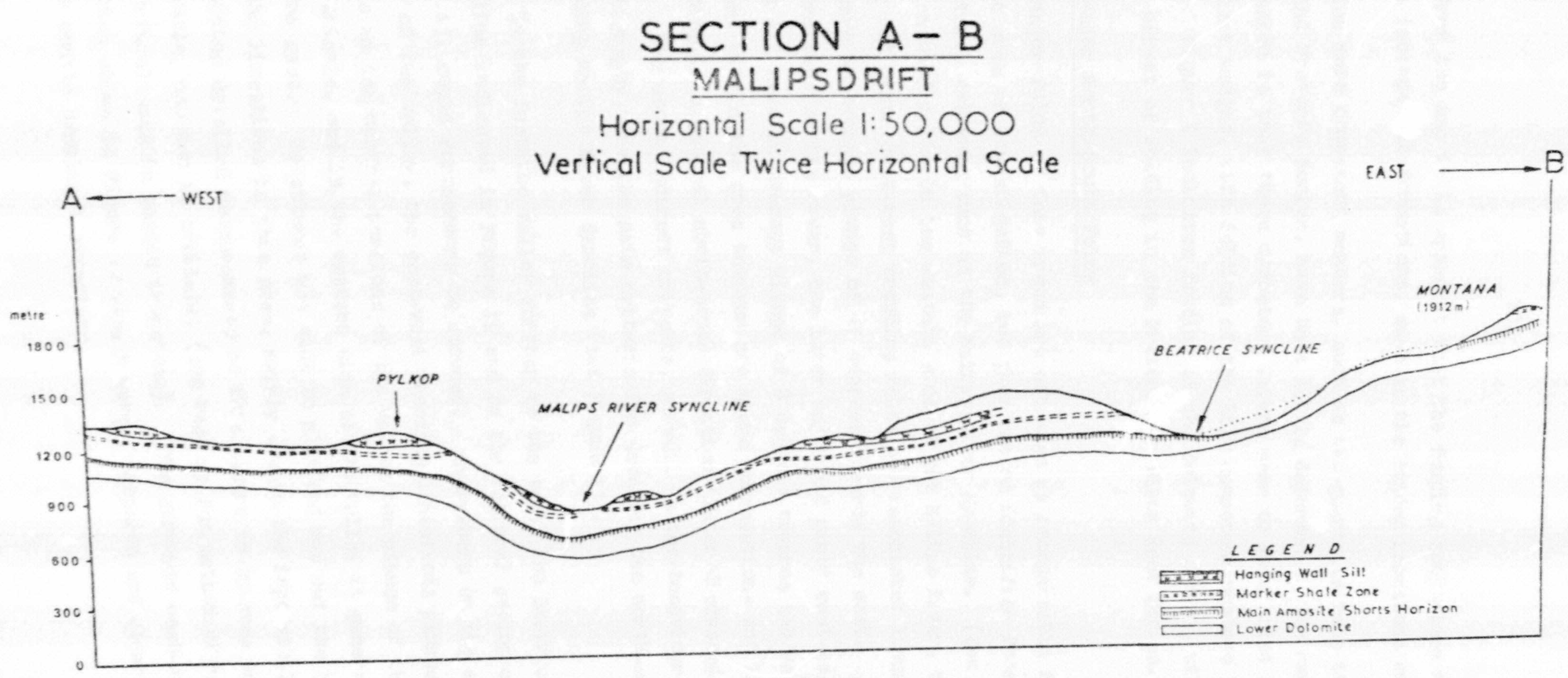

SECTION A – B
MALIPSDRIFT
Horizontal Scale 1:50,000
Vertical Scale Twice Horizontal Scale
A
WEST
EAST
B
metre
1800
1500
1200
900
600
300
0
PYLKOP
MALIPS RIVER SYNCLINE
BEATRICE SYNCLINE
MONTANA
(1912 m)
LEGEND
Hanging Wall Sill
Marker Shale Zone
Main Amosite Shorts Horizon
Lower Dolomite

FIG. 12

From the map it is apparent that the folding took place mainly in the incompetent formations, such as the banded ironstone and dolomite.

The more competent members, such as the quartzite beds of the Black Reef and Pretoria Series, have been little deformed. The overall impression is that these competent layers seem to have acted as a resistant wedges, with folding of the less competent members in between them. Figure 3 indicates folding of the Dolomite Series, with little or no effect of folding in the Pretoria or Black Reef Series.

(b) Major North-South Folds

Major folds of this trend are not seen as recognisable folds, in the area of investigation, but they can be identified from indirect structural evidence such as the Malips River Syncline. (See Map 1 and section in Fig.12). On the western side of the Malips River, the later major and minor east-west trending folds and associated lineations all have an average plunge of 12 degrees towards the east. On the eastern side of the river, the later major and minor east-west folds again all have an average plunge of 8 degrees towards the west. Present within the area however are micro corrugations and lineations trending in a general north-south direction (later discussed on page 39). The above indirect criteria, as well as the behaviour of the stratigraphy, are the main criteria for deducing the north-south trending Malips River Syncline (see Figure 12).

In the Beatrice Valley further to the east, the Beatrice syncline indicated in Figure 12 and on the regional geological plan (Map 1), could furthermore be deduced. Everywhere on the eastern side of the valley, the east-west trending lineations plunge westward, while in the central portions of the valley the plunge of the lineations is variable, and in the western side of the valley it generally plunges to the east. No attempt was made to plot and map out the behaviour of the lineations in this area, mainly due to the impossibility of recording detailed measurements of this nature in an area where no suitable base map is available (see Page 15 for method of recording structural data in banded ironstone). The surveyed east-west geological section shown in Figure 12 was, however, prepared and clearly indicates this gentle synclinal structure.

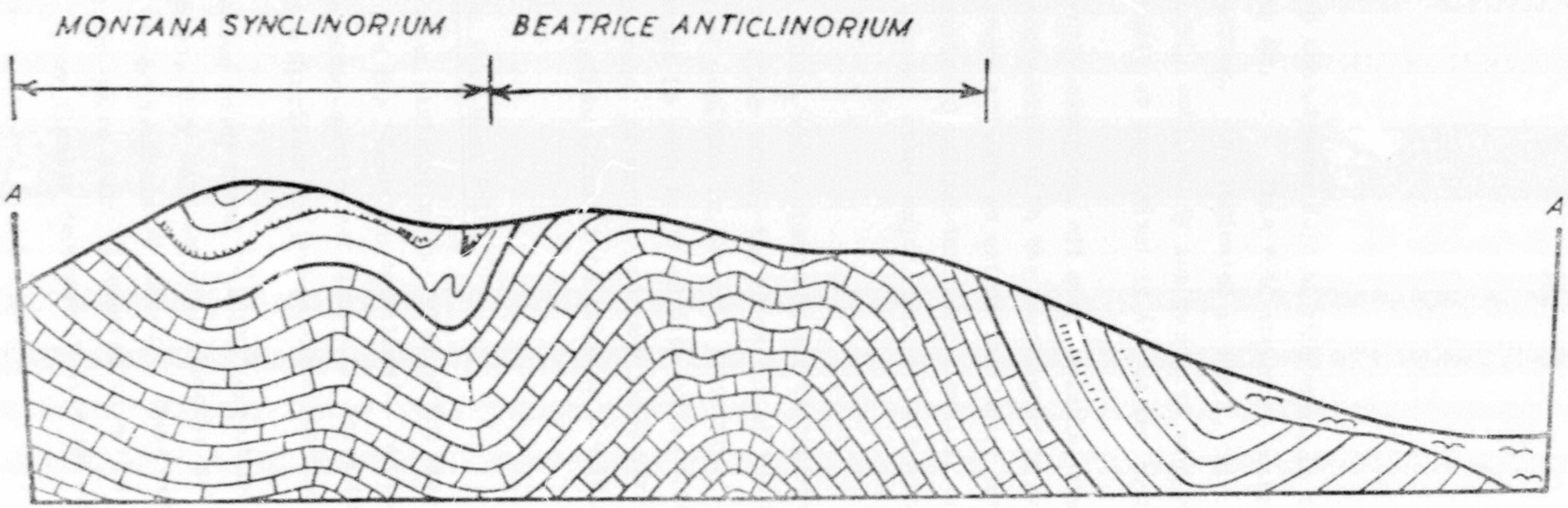


FIG 13 NORTH – SOUTH SECTION SHOWING BEHAVIOUR OF THE DOLOMITE SERIES IN THE BEATRICE VALLEY AREA.

HORIZONTAL SCALE 1:50,000
VERTICAL SCALE APPROX. 1:50,000

A third conspicuous fold of this trend is the Wonderkop Anticline shown on Map No. 1. This fold structure occurs outside of the area of investigation. As indicated in Map 1, this broad structure, which is very clearly outlined by the quartzite members of the Pretoria Series, plunges steeply at approximately 60° to the south.

The gently plunging, although variable, tightly folded east-west folds, in conjunction with the mountainous terrain, complicates the outcrop pattern to such an extent that apart from the Malips River - and the Beatrice Syncline described above, it was impossible to determine whether other major folds of this nature exist in the area investigated.

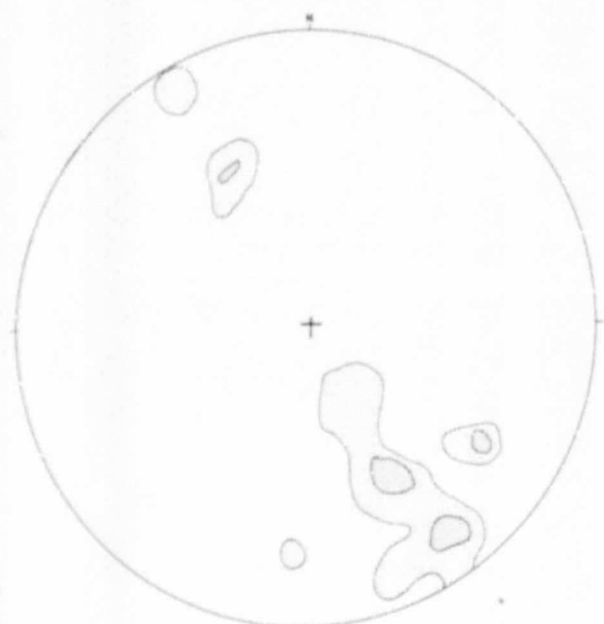
These folds, where observed, are concentric in nature (De Sitter, 1956). In other words, the thickness of the bands stays the same regardless of position in the fold structure. Generally, folding of this nature is seen as broad open folds, with small amplitudes measured in tens of metres and very large wavelengths measured in hundreds of metres (clearly revealed in the longitudinal section in Figure 12).

(c.) <u>Major East-West Folds</u>

The most striking major folds of the area are the "Montana Syncline" and the "Beatrice Anticline". As indicated on Map 1 and in the cross-section in Figure 13, these two folds could also be defined as a Synclinorium and an Anticlinorium.

These two folds trend in a 255° direction and as the cross-section shows, they have large wavelengths and amplitudes measured in the order of hundreds of metres. These two major structures can be traced for quite a few kilometres on either side of the Beatrice Valley. They finally decrease in size and appear to die out on both sides.

Western Section Pye diagram indicating plots of north-south trending lineations at 1% and 2% intervals.



Eastern Section pye diagram indicating plots of north-south trending lineations at 1% and 2% intervals.

Figure 14.

The areas north and south of these two structures appear to have been folded in a similar fashion. It is, however, difficult to follow and trace out any of these structures for any considerable distance, mainly as a result of scree cover.

Throughout the area a large proportion of the folds are of the concentric type (see Figure 13). The folds normally plunge gently to the east and west (see Map 1). Although the axial planes of these major folds could not be accurately measured, they appear to be vertical. This would indicate a near horizontal compressional direction.

4. Minor Folding

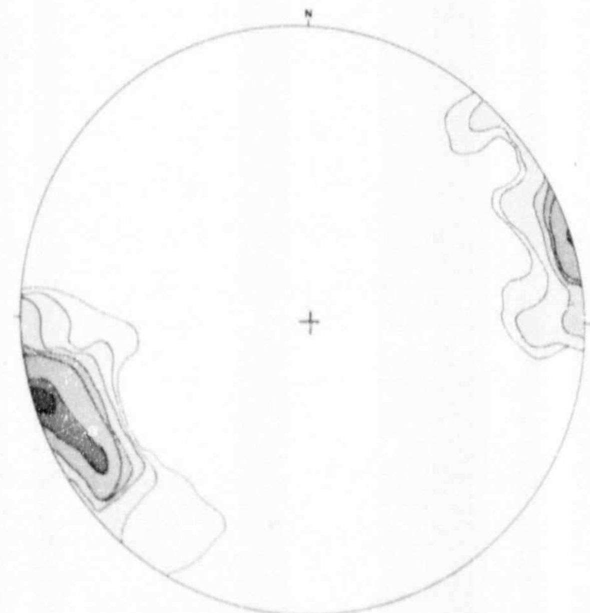
Situated in the crests of major similar folds and on the flanks of major concentric folds are minor folds, which vary in size from a few millimetres to tens of metres. Using the relevant data obtained from these minor structures, an attempt is made to analyse of the tectonic history of the area.

(a.) North-South Folding

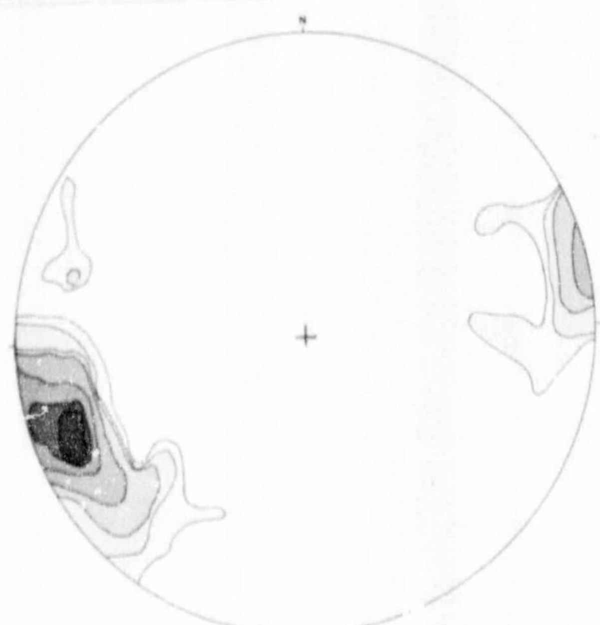
In the area investigated minor folds of this nature are not common. These folds are usually seen in the form of micro corrugations, the folds rarely exceeding a few centi metres in amplitude.

These minor north-south trending folds shows a considerable variation both in the amount and direction of plunge. The two synoptic diagrams for the eastern and western section of the area in fig. 14 summarizes the results of the folds in the area under discussion. Generally, depending in which part of an east-west fold it happens to be (crest, north or sout' dipping limb), the plunge is horizontal, north or south dipping.

Apart from these minor folds showing a considerable scatter in direction and amount of plunge, direct field observation suggests the effects of later superimposed east-west folding such as indicated in figure 17. This figure indicates micro folds folded about an east-west fold axis. From the above observations, as well as the fact that no earlier structural features appear to be present in the area, the author has concluded that this set of minor folds, together with the major north-south folds discussed on page 35 to which the above set appears to be related (trend and behaviour), are the earliest folded structures to have developed in this area.



Western Section Synoptic pye diagram of east west lineations. Total 166 measurements contoured at 1%, 2%, 4%, 6%, 10%, 14% and 18% intervals.



Eastern Section Synoptic pye diagram of east-west lineations. Total 195 measurements contoured at 1%, 2%, 4%, 6%, 10%, 14% and 18% intervals.

Fig 15.

In the following section it will also clearly be seen that the prominant east-west folds have suffered no detectable later superimposed deformation.

(b.) Folds of the East West Trend

In virtually every outcrop minor folds of this system can be observed. The bedding planes, influenced by the intensity of the folds, range from micro folds to those of tens of metres in wavelength and amplitude. In Map 4 cross-sections drawn at regular intervals across the area indicate the behaviour of the larger and conspicious folds.

Although the folds are so variable in size, the overall general plunge is regular and gentle. For instance, the "Tet Syncline" indicated (in plan on maps 2 and 3 and in six regularly spaced cross-sections) on Map 4 shows this as a very regular and gently plunging syncline. The folds on either side of this structure behave in a similar fashion as can be observed on Map 4. As a result of these gently plunging minor folds and with the topography having a high relief, the outcrop pattern is extremely complicated (see Map 2).

The general tendency of these minor folds is to culminate at a specific point to a certain maximum, in both the cross-sectional and longitudinal section and from there to gradually diminish in size and eventually to die out completely. In all cases it is characteristic for these folds to steepen their plunge just before the final pinch out. The net result is a series of elongated cigar shaped, basin and domelike structures. In Map 3 these structures have schematically been indicated, Map 4 however shows the exact behaviour of each fold along strike. The "Tet Syncline" indicated on this map is a typical example of this. (Refer also to Map 2). Another very conspicuous fold, which also shows this characteristic very clearly is the "Krans Anticline". In this case, the fold is an anticline which pinches out towards the east (see Map 2, Map 4 and detailed Cross-sections C-C and D-D drawn across this structure in Map 7). To the west and on the west side of the Malips River, this fold appears to die out. The geological Maps 2 and 3 and the cross-sections shown on Map 4 clearly outline numerous other lenticular shaped synclinal and anticlinal structures.

The abovementioned characteristic of the folds to pinch and swell, used in conjunction with the information on a more regional scale (see previous Major East-West folding on page 37), is seen as to be the result

Fig. 16. Synoptic diagram of Axial Planes for entire area; 88 poles contoured at 1%, 2%, 3%, 4%, 6%, 8%, 10% and 12% intervals.

of superimposed folding on an unequal north-south buckled surface. A certain amount of differential stress might possibly have contributed to this effect.

Associated with and located within the Eureka Syncline small parasitic folds (generally a few centimetres in amplitude and wavelength) are occasionally encountered, which plunge much more steeply (up to 30 degrees) than the larger structure in which they occur (see Map 6). To the author this would indicate either differential compression which would result in a variation of movement in the "a" direction, or possibly superimposed folding. These anamolous occurrences however are very rare and were found in one small area only along this fold.

Generally the folds of this trend plunge gently to the west and east at angles seldom exceeding 10 degrees manifested in the cross-sections indicated on Map 4. In figure 15 the Pye diagram plots for the east and west section of the area indicate the folds to plunge gently west and east in a 250° direction.

The plots of the axial planes related to the east-west folds as summarized in the synoptic diagram in fig 16 fall on the Pye circle of the bedding planes (for bedding plane plots refer to the synoptic diagrams in fig. 11). The axial planes as indicated in the synoptic diagram are vertical or very steep dipping indicating a near horizontal stress field for these folds.

Most of the east-west folds in the area are of a symmetrical nature and are relatively tightly folded in a similar or concentric fashion.

(i.) Cleavage Folds

Almost 60% of the folds are of the cleavage or similar type, i.e. the distance between the bedding planes parallel to the axial plane remains constant, while the distances measured at right angles to the same lithological unit are variable (Fig. 18).

The cleavage, normally developed parallel to the axial planes of these folds is only found in the softer, shaly sections of the banded ironstone. A typical manifestation of these folds can be seen in the "White Cappy" blue fibre horizon in the main blue workings throughout the property (see Fig. 18).

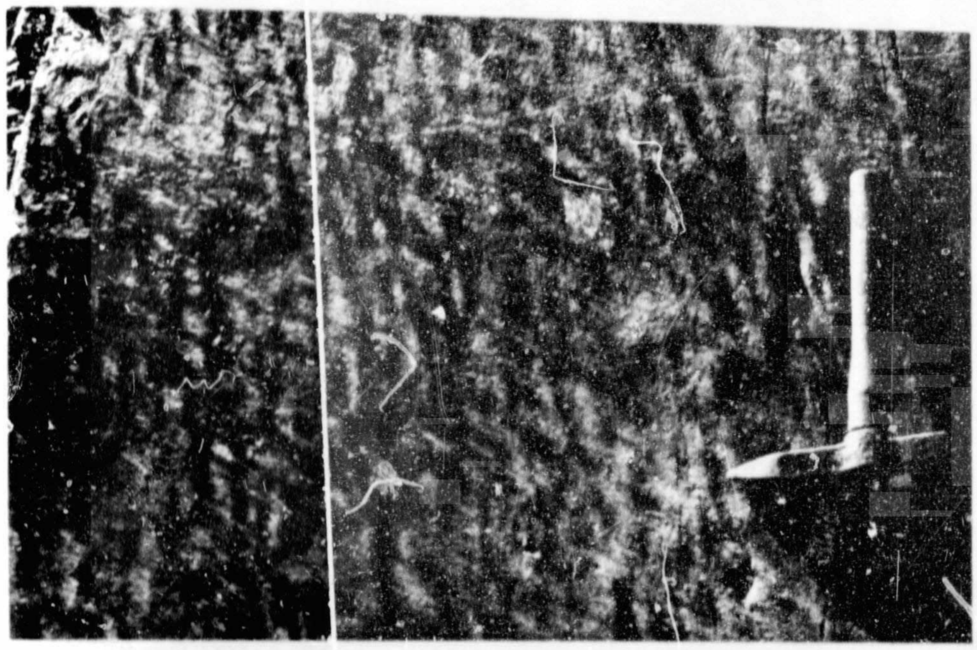


FIGURE 17

EXAMPLE OF MICRO-FOLDS CROSSING AT HIGH ANGLES. THE TWO SETS OF LINEATIONS CORRESPOND INTIMATELY WITH THE DIRECTIONS OF THE MAJOR EAST-WEST AND NORTH-SOUTH TRENDING FOLDS.

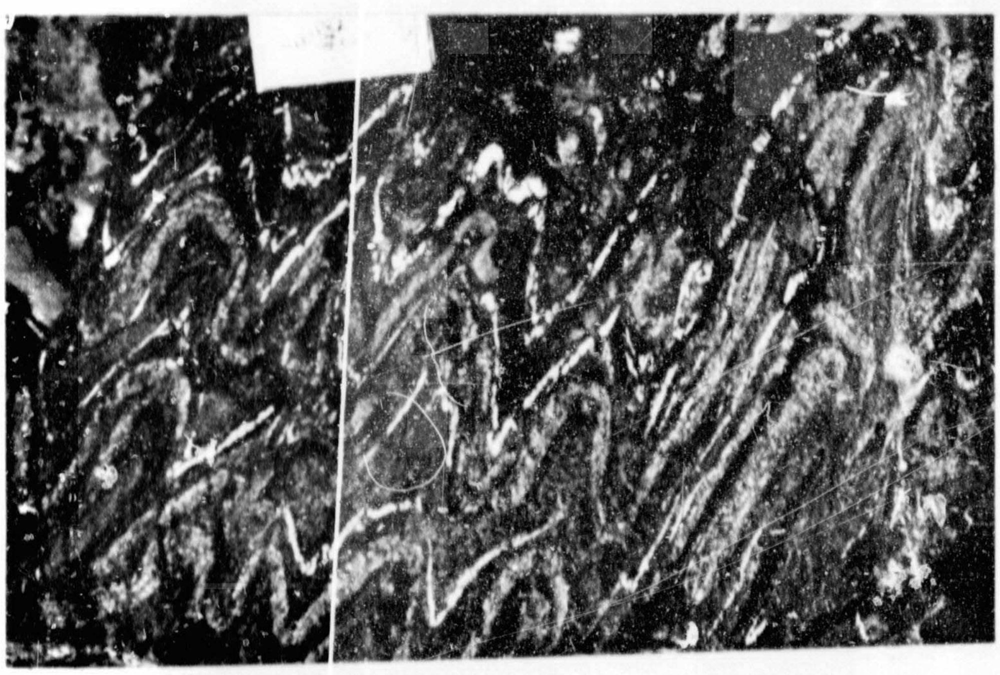


FIGURE 18

CLEAVAGE FOLDING IN THE BANDED IRONSTONE. NOTE DISTANCE BETWEEN THE BEDDING PLANES PARALLEL TO THE AXIAL PLANES REMAINS CONSTANT.

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(ii.) Concentric Folds

Throughout the area a large proportion of the folds the wavelenght is comparable to the amplitude. Both features in question can be measured in tens of metres.

The thickness of any concentrically folded bed remains unchanged. All movement of these folds is confined along the bedding planes. As a result of this, their radius of curvature decreases towards the core of the fold (see Cross-section E-E on Map 7). In the figure, the "Knee-bend" anticline shows the distance between the marker shale bed and individual fibre horizons to remain constant when traced around the hinge of the fold (see Map 2), while the radius of curvature decreases towards the core of this fold.

(iii.) Trends

The folds trend mainly in a 250° direction. Occassionally a second minor fold trend making an angle of 10-15° with the above main trend is developed. This minor set trends almost due east-west for its specific fold axes and axial planes.

From the Eye diagram it is impossible to separate the two sets because of the small angular difference between the two. However, they are easily recognisable and separable in the field, especially where minor folds of both sets occur in the same outcrop. This second minor east-west trending fold set is only occassionally developed. In general this set is found in the Magazine - Eureka Syncline area only (refer Map 6). This map was prepared to show the detailed structural trends in the Magazine Section, where both fold trends occur alongside each other. It is, furthermore, noticeable that in this section, the minor east-west trending folds and associated lineations plunge east, whereas the main fold set trending ENE-WSW plunges gently towards the west. On the minor scale, especially where micro-folds of both trends are found on the same bedding plane, an apparent en echelon fold pattern is produced. This is, however, not true en echelon folding as two distinct axial plane trends are observed. The pattern is thus an interference pattern, unless it is accepted that en echelon folds may also be produced by the intersection of two separate fold trends (De Sitter, 1964).

Most of the east-west trending folds have amplitudes of only a few centimetres. The largest fold of this trend is a minor fold with one metre amplitude in the Magazine Section. The other structures associated with this set

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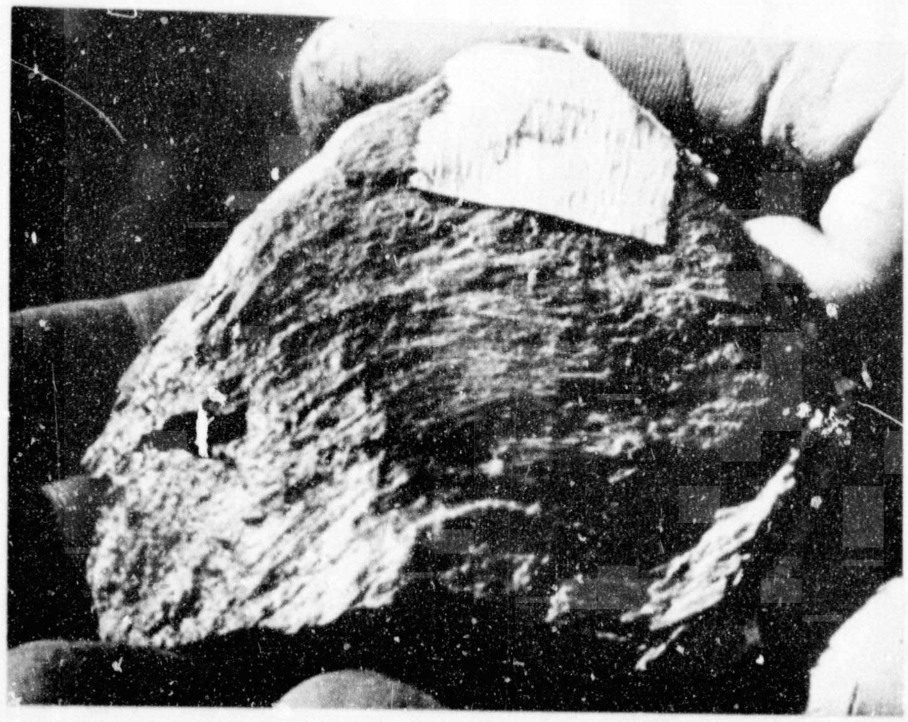


FIGURE 19

EXAMPLE OF HOW THE NORTH-SOUTH TRENDING LINEATIONS HAVE BEEN DEFORMED AND BEEN FOLDED ABOUT LATER EAST-WEST TRENDING FOLDS.

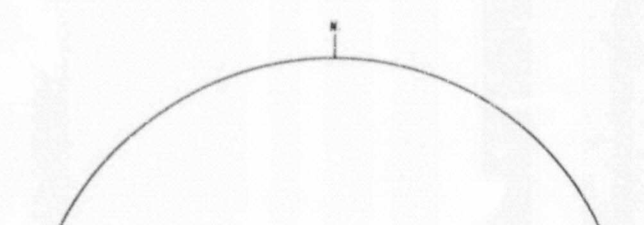


FIGURE 20

PLOT INDICATES AZIMUTH AND AMOUNT OF PLUNGE OF THE MAJOR FOLDS IN THE AREA.

are only ripplings and lineations (micro folds).

The general characteristics of these minor concentric and similar folds under discussion, such as axial planes and plunge direction and amount, correspond intimately with the larger structures. The above is clearly borne out on the detailed structural map (Map 2), where the close relationship is very clearly seen. By also plotting the structural data of the major structures in the area on a Pye diagram (see Fig. 20), the intimate relationship with the minor structures is observed. (See Pyeplots of minor structures on Map 5 and the synoptic Pye diagrams previously discussed). Furthermore, it has also been found that where the larger structures start "fading", these minor drag folds under discussion increase in amplitude and sometimes even take the place of the larger fold (see Cross-sections C-C and D-D on Map 7). Note the pinching out of the Krans Anticline to the east and that the synclines on either side increase in size towards the west (Map 1). This phenomena can be described as en echelon folding as described by Campbell (1958, P.448-453) so that the intimate relationship between minor and major structures are clearly established.

5. Lineations

The most prominent set of lineations found in almost every outcrop of rock (see Maps 2 and 4 for distribution) are those produced by minor folding of individual layers. Another type of lineation reveals itself as very faint lines on the bedding (lineations produced by bedding cleavage intersections and are generally found in the softer, more shaly horizons). The lineations produced generally plunge to the west, at angles seldom greater than 12^{o} (see Map 2 and Pye plots on Map 5).

In the figure 15 two synoptic diagrams summarize the results of the generally east-west trending lineations. From both diagrams it is seen that for each area, the major portion of the lineation poles are clustered in a distinct and concentrated maxima. The maxima for both areas coincide, are normal to the great circle containing bedding plane poles and coincide with the fold axis (refer to Fig's. 11 and 16 as well as to the Pyeplots of the individual sub areas presented on Map 5).

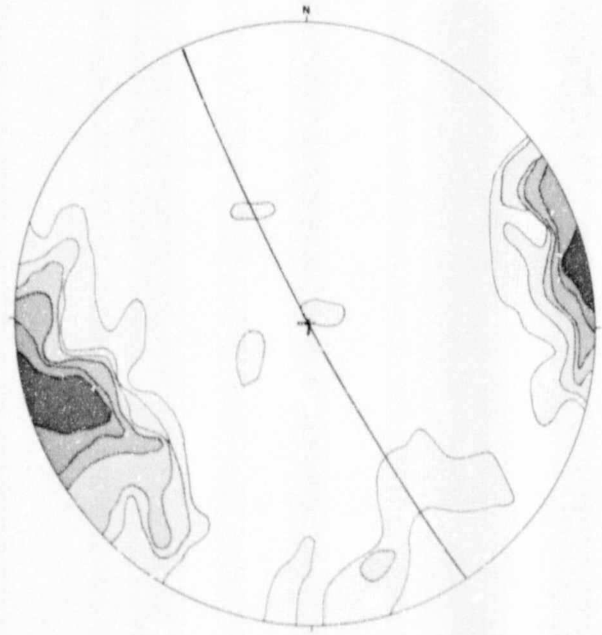
From the above diagrams it is observed that a small percentage (generally less than 10%) of these east-west trending lineations shows some scatter. This could be due to the fact that during the end stages of this main east-west folding, a subsequent very mild minor fold set developed as the result of a slight change in the stress field causing a second set of ripplings and interference on the main set of lineations. (Reference should be made to page 45 where this very mild second trend is discussed).

Apart from the two sets described above, a third set of lineations, with a general north-south trend, were recorded. The considerable scatter in amount and direction of these lineations (refer to Figure 14 and figures on Map 5), as well as the fact that these lineations have been folded about the main east-west fold axis indicates effects of superimposed folding (refer to previous discussion on page 39 where the N-S folds are discussed).

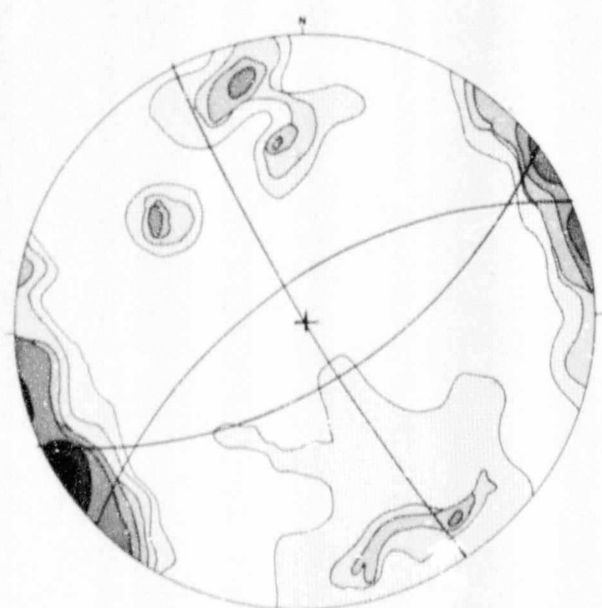
The conclusion drawn from the above discussion is that the plots of the lineations and general display of folds in the field seem to indicate two main periods of deformation, viz. an earlier N-S trend, and the main ENE-WSW trend with which is associated a third possible very mild set trending East West.

6. Faulting

There are only a few faults, of which the major one are present in the brittle members of the Pretoria and Black Reef Series. It will be noted that the major faults present in the area have the tendency to curve into the strike of the formations when intersecting the less competent dolomite (see Map 1, Wonderkop Tear Fault).



Western Section Synoptic Pye diagram of joints; 162 measurements contoured at 1%, 2%, 3%, 4% , 5% and 6% intervals.



Eastern Section Synoptic Pye diagram of joints; 130 measurements contoured at 1%, 2%, 3%, 4%, 6%, 8% and 10% intervals.

50/......

Fig. 21

In the Banded Ironstone and Dolomite, the faults are inconspicuous and small. The few faults encountered in the ironstone formation have a few common features which are listed below :-

(i.) They are normal faults, with small displacements seldom exceeding 5 metres.

(ii.) They are vertical and generally strike NNE-SSW.

(iii.) They are of short strike length.

(iv.) They are clear-cut, but with fault filling.

(v.) They appear to conform with the main shear joint direction which, although not distinctly developed, trends NNE-SSW.

(vi.) They displace the asbestos horizons and all the folds present in the area and can, therefore, not be contemporaneous with the folding.

7. Jointing

Within the area two sets of distinct joints are present. One set trends in a general N. N. W. direction and the joints are at right angles to the fold axes of the E. N. E. fold system. This set is prominently developed in the western portion of the area (see synoptic diagram in Fig. 21 and also Figs. H, N and S on Map 5). As the stereo graphic plots indicated, these joints are perpendicular or sub-perpendicular to the lineations associated with the east-west folding. This may correspond to the A-C joints of Cloos (1947).

The other very prominent set of joints has a trend parallel to the E. N. E. fold axis (see the synoptic diagrams in Fig. 21 and Figs. A-B, H, K, S and T on Map 5). These joints also dip very steeply and appear to lie on the circle (S-plane) defined by the bedding planes.