003313

To: Rik Visagie

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Subject: Geological observations bearing on geotechnical data for the Grum open pit

INTRODUCTION

For all deposits in the Anvil District one of the major determinants of the stability of excavations in rock is the orientation of the dominant metamorphic clevage or foliation (S_2). At the Grum deposit the orientation of the foliation is locally totally unknown because the bedrock surface is covered by thick overburden. There is however a body of evidence bearing on the orientation available in the underground workings and on surface at the northwest end of the proposed pit. Another line of evidence is found in the structural style of the Anvil District which, though not site specific, provides a general guide to the reasonability of assumptions.

At Grum assumptions must be made in the absence of specific data. It is the impression of the author that the assumptions made, while conceivebly correct, are not consistent with the usual structural style of the district. There are further assumptions made that tend to systematically exaggerate the foliation dip on the order of 5^{o} - 10^{o}.

The purpose of this memo is merely to point out that these troublesome points exist but not to propose a solution. Indeed no solution can presently be provided with the available data because there are simply too many unknowns. Definitive answers to these questions will require more data, this means drilling more holes to retrive oriented core. While the cost of drilling many such holes may seem high it will be small in comparison to the cost of stripping off an unnecessarily large area only to find a more favorable situation than had been predicted or worse, that the overall stripping ratio and mining costs will have to be higher because the situation is less favorable. Additionally the memo presents new data gathered during the 1984 field season and re-examines old surface data in light of new structural interpretations of the Vangorda Plateau. This is a response to and reiteration of section 6.6.1 of the Montreal Engineering Phase Two Geotechnical Report.

REGIONAL FOLIATION DIP

The Vangorda Plateau portion of the Anvil District is characterized by shallow foliation dips that are generally toward the southwest but locally are thrown into gentle warps such that the dip can be shallow in any direction. Near faults and in areas of strong contrasts of ductility steeper dips are found but large domains of steep foliation dip have not been proven to exist. The stereonet of foliation attitudes from the vicinity of Grum presented in the Montreal Engineering phase two geotechnical report (plate c-2 of appendix c) demonstrates this fact. Figure 1 of this memo is a modification of that stereonet which discards all but 58 of the 113 poles ploted on plate c-3 since they are derived from domains that are not relevant to Grum (the mylonitic border of Anvil Batholith and the footwall sequence of the Tie Fault). This modification considerably lessens the prominent peak at 000/20W which is largely due to the schist sequence in the footwall of the Tie Fault. Figure 1 still demonstrates the overall low angle nature of the foliation when only phyllites of the Vangorda Plateau sequence are considered.

FOLIATION IN THE UNDERGROUND WORKINGS

Foliation poles measured underground at Grum were plotted on plate c-3 of the Montreal report. The latter plot is remarkably similar to figure 1 with poles tending to fall on a girdle close to the plane of the Grum cross sections and on a peak corresponding to a strike a little more northwesterly than 000 (160° to 170°). In general the measured dips underground are so low and so variable that it is difficult to think of an average foliation strike for Grum on the basis of a stereonet analysis alone.

A somewhat different analysis of foliation dips underground can be made by attempting to draw highly generalized form lines for foliation dips (note that to do this analysis I have examined the geology of the walls of the cross cuts as portrayed by Kerr Addison and overruled some ploted foliation attitudes as being inconsistent with with the walls or the breast). The results of this analysis (figure2) show that two major domains exist with the domain boundary at about 2N. Southwest of 2N foliation dips are nearly always toward the southwest about 10° to 30° (the average strike is about 140° and dip direction 230°). Northwest of 2N the dips are more variable but there is a strong component dipping gently to the northeast (average strike about 125° and dip direction 035°) and a tendency to reverse back to a southwest dip at about 7N. This gentle warp in the foliation is apparent on all the Grum cross sections and the mapped cross cuts.

<u>1984 WORK ON SURFACE FOLIATIONS</u>

Figure 3 is a map of the area of the proposed Grum pit showing the foliations measured during the 1984 field season. Considerable attention was paid to this area and several new areas of outcrop were found and measured. The results show the foliation defines a fairly smooth arc with a poorly defined change in foliation attitude at about 3N. Southwest of that line dips are to the southwest with an average strike of about 140° (figure 4), this is the surface extension of the domain S.W. of 2N in the subsurface. To the northeast dips are toward the northwest with a slight tendency to dip north (figures 3 and 4), this is presumably the surface expression of the dip reversal in the subsurface. There is a rather remarkable antithetic correlation between foliation dip and the proposed pit walls so that it tends to dip into both the southwest and northwest walls (figure 3). If this situation persists to depth then these walls can be kept steep as presently planned. Indications are that this is the case.

Figure 5 shows the results of measurment of S_2 and L_2 for the area around Grum. It is analogous to Figure 1 but draws data from a smaller area. Note that on this stereonet and the underground map (figure 2) the average foliation strike is close to 000^{o} but that is not a common direction for individual measurements.

STEEP FOLIATION ALONG THE EAST WALLS

The northeast walls are the contentious issue and it is these areas where overburden cover is greatest and data is least. Certainly where the walls are in thick overburden the pit slopes will have to be kept shallow. Dewatering of the overburden must be considered as this will have a substantial effect on stability as the Montreal report points out. In the bedrock it is these areas where the predicted foliation dips look most suspicous to me. Dips of up to 70^{o} are predicted by Montreal Engineering (see plates c-13 to c-15) on the basis of manipulating the foliation angles measured and displayed by Kerr Addison on cross sections.

There are two points to be made here. First the assumption has been made that the foliation angles plotted by Kerr geologists on section were apparent dips. This is not the case. Sirola states on page 11 of the 1977 Mineral Inventory Report that foliation was plotted numerically, while the meaning of this statement is unclear, checking their logs against the sections shows that the measured core angle was simply plotted directly in relation to the apparent drill hole trajectory on section. By assuming a strike of 000^{o} and apparent dips on section one arrives at a dip that is too large. Figure 6 and Table 1 of this memo show that the magnitude of this overestimate 0^{o} to about 10^{o} depending on the local geometry. Consequently the dips plotted on plates c-13 to c-15 should not be accepted uncritically. Of greater importance of course is possibility that the 000^{o} strike is not applicable. Reference to the foliation charts for the northeast and southeast walls shows that this is not necessarally good news since the statement is made that shallower dips will mean less stability (footnote 2 of table V). The extent to which this generalization is valid is uncertain since there must come a point when stability starts to increase as dip decreases. If dips are 20 ^{o} then increased stability may set in especially if there is waviness in the foliation resulting in a lower sheet dip (thus the concern over a small increase to dips thought to be in the 15^{o} to 30^{o} range).

It is at this point where the second issue must be discussed. That is that foliation angles are measured relative to drill holes that are not necessarily vertical nor on section. It is this correction for drill hole deviation that can be most significant at Grum and it is likely that the areas of steep dip predicted in the pit have their origin here. A typical area of suspicious steep dip is at 10 north on section 66W on level plan 1203m (plate c-13). The drill hole that is the source of data here is FAGA139. At the point in question the foliation angle measured is 45^{o}, when ploted on section this translates to a dip of 58^{o} and when "corrected" for apparent dip this becomes the 68^{o} shown on plate c-13. Figure 7 shows the orientation of the drill hole,the cross section and a small circle that represents the cone that is the locus of all possible poles to the foliation. Because this is a special case the small circle also is a close approximation to the locus of all possible dip directions for the foliation. This figure shows that the true dip for the 270^{o} (i.e. the assumed 000^{o} strike) direction is 57^{o}, it also shows that a number of alternate solutions for the foliation dip exist.

Underground mapping shows that northeast dips do occur thus this possibility should be considered, if the generalized dip direction for the domain north of 2N is used here the resultant dip is 32^{o} to the northeast. If this is to cause of the several very speep foliation dips predicted for the northeast and southeast walls then it is possible that there is a fairly well developed component of northeast dips there. Once the slight exaggeration of southwest dip is removed and the possibility of a slight waviness to the northeast is added in the situation could be somewhat more hopeful than we are anticipating.

A FIELD APPROACH TO ORIENTING UNORIENTED DRILL CORE

There are exercises that could be undertaken in the field to attempt to solve the problem of foliation orientation but the likelyhood of success is not great. Phyllites of the Vangorda Plateau contain several linear and planar features in addition to S_2 (figure 8) that can be used to orient the core in an ideal and simple situation. This technique can be powerful provided there is an adequate background of well established information on the usual orientation of the features near Grum and that the problem is not rendered insoluble by ambiguous relationships. Some orientation work has already been done during 1984 at Grum aimed at this possibility, several problems were encountered not the least of which was poor outcrop. This problem can be partly eliminated by trenching to improve the outcrop. About $2500 worth of backhoe time could significantly improve the outcrop situation and about a month of field time would be required to gather data from outcrop and drill core. The problem then is whether there will be a sufficiently distinctive array of structures available to work with and whether observations made in hangingwall Vangorda formation phyllites can be extrapolated to footwall Mt. Mye formation phyllites. Neither of these questions can be satisfactorally answered now but more field work could provide a sufficiently compelling statistical background for further interpretation. The basic problem is that with the additional data provided by the trend of a fine crenulation lineation on the main foliation the dip direction can be narrowed down to two choices (plus or minus about 25^{o}), with the addition of the dip of the crenulation clevage related to the lineation (which acts as the reference fabric element in terms of the field logging manual) the choice is narrowed down to one possibility. The drawback with this approach is that one can never be quite sure that there is one fine crenulation lineation or, more importantly, that the related clevage dips in the assumed direction. During the 1984 field season 31 measurements of the fine crenulation lineation were made near Grum, all are within a azimuthal range of 45^{o} averaging 155^{o} - 335^{o}. Ten related foliations were measured, 8 dipped steeply southwest as expected, one was vertical and one dipped northeast (figure 9). Attempts to use this method to date have proved to be frustrating and ambiguous because evidence was found that there were reference foliations dipping in both directions. Should this method give statistically convincing results it still cannot provide information about areas that have not been drilled yet (it should not be considered a substitute for oriented core) and much of the potential northeast wall has no holes at all. There is a slightly better that even chance that this approach would work.

MODERATE ANGLE FAULTS

Faults with moderate dips are an important component of the overal structural style of the Vangorda Plateau and the Grum deposit. Preliminary indications are that a major gouge marked fault zone will be found in the northeast wall. The fault is expected to be striking north - south and dipping 40^{o} to the west. If the foliation is dipping to the southwest there may be a major problem with 3-D wedge failure. As the structural interpretation of Grum progresses more data on this structure will become available. A larger fault of similar nature (the Doal Lake Fault) and orientation truncates the Grum deposit at its east end. Current pits do not include this area but a large pit intended to take the upright panel will probably encounter stability problems due to this structure. Similarly oriented faults were pointed out to be present in the Montreal report (p. C-6).

Figure 10 shows the results of measurment of close spaced joints to wide spaced fracture clevage in phyllites around the Grum deposit (1984 data). These poles fit well with those measured underground and show that the joints measured in ore do apply to rocks outside the ore. This direction is very widely developed throughout the Vangorda Plateau. Other joint directions occur but they are more local; nonetheless they can be the significant controls on rock breakage.

OVERBURDEN EAST OF THE GRUM DEPOSIT

Figure 3 shows overburden thickness isopachs. As is apparent from that map there is a buried valley to the east of the Grum deposit. The valley runs north - south and appears to be controlled by the soft highly gouged phyllites of the Doal Lake Fault Zone. The east side of this valley, from the available evidence, is quite steep and slopes toward Grum at an angle of 25^{0} . Figure 11 shows this valley in relation to the approximate Olk Pit limit. Incrementally larger pits designed to mine the upright panel and other sulphide horizons will encounter increasing thicknesses of overburden. It does not appear likely that the west sloping sub-overburden surface will ever daylight in the pit but sufficiently large proposed pits may have problems with failure on this plane.

RECOMMENDATIONS

It is recommended that drilling of oriented cores be undertaken to define foliation dips along the northeast portion of the pit. The number of holes required will probably be at least 25 if foliation dip proves to be variable. Since this will represent a large expenditure the possibility that these holes could also be part of a dewatering network should be explored.

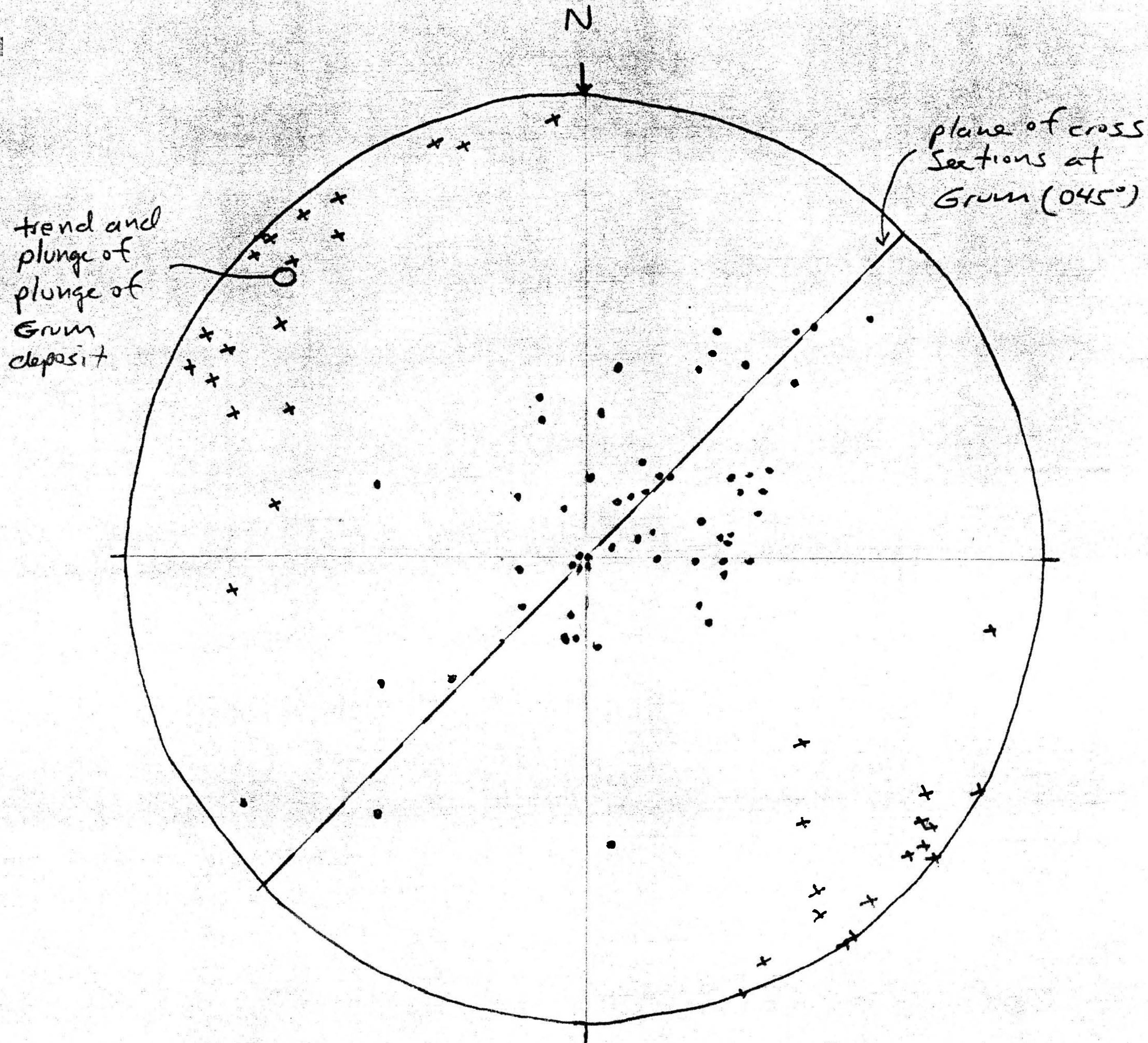
On a shorter term the sorts of analysis of foliation dip undertaken here should be extended. Since shallower dips may be expected than the 34^{o} minimum currently studied, foliation charts for lower dips should be derived for the northeast and southeast walls. Since foliation waviness may occur along these walls, Q-sums analysis of the foliation should be undertaken.

A geotechnical engineer should examine the data for Grum in close co-operation with a project geologist. Most of what is said here was previously mentioned in the recommendations of the phase two geotechnical report. The other recommendations of the Montreal Engineering report should also thus be enacted or examined at the earliest practical date.

In light of the uncertain results of the field approach to orienting core this method is not strongly recommended but should be considered as a possibility. On going structural reinterpretation of the Grum deposit should attempt to isolate areas of known foliation dip or areas where the overall geology can help define the most likely foliation dip.

TABLE 1. Amount of exaggeration of dip that results from the asśaumption that the dips on section are apparent dips and the the strike is north - south

apparent dip on a section at 045 degrees	true dip if plane strikes 000 and dips west	exaggeration of dip that results
0	0	0
10	13	3
20	27	7
30	38	8
40	49	9
50	59	9
60	68	8
70	75	5
80	83	3
90	90	0



• S_2 pole
× L_2 lineation

FIGURE 1

D_2 structural elements
from northwest Vangorda
Plateau portion of sheet F6
(1979 data)

Limits on data are :
a) Vangorda Ck on SE
b) Batholith contact on N & NE
c) Tie Fault on NW
d) a line parallel to and 2000' SW of the

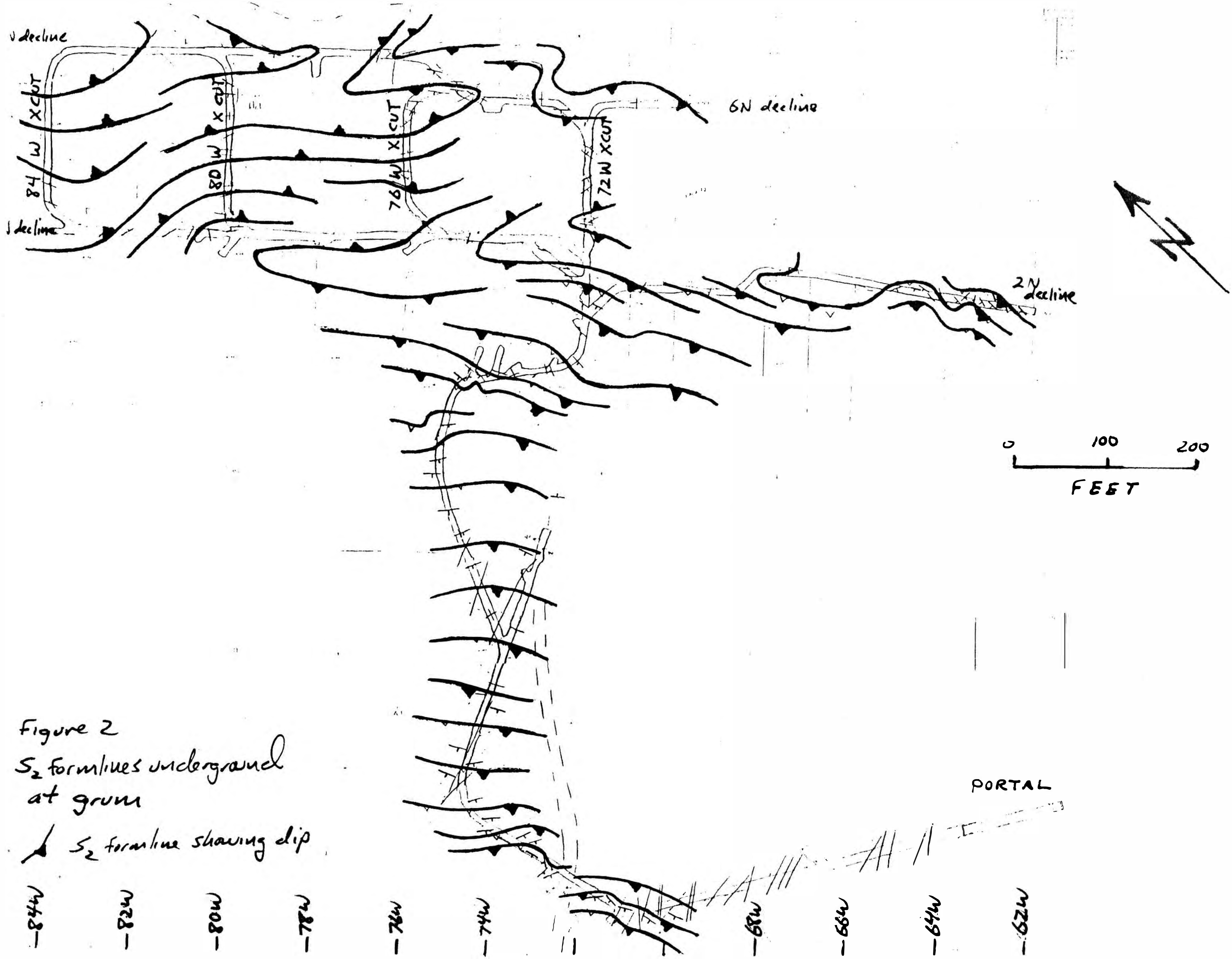


Figure 2
S_2 formlines underground at grum

S_2 formline showing dip

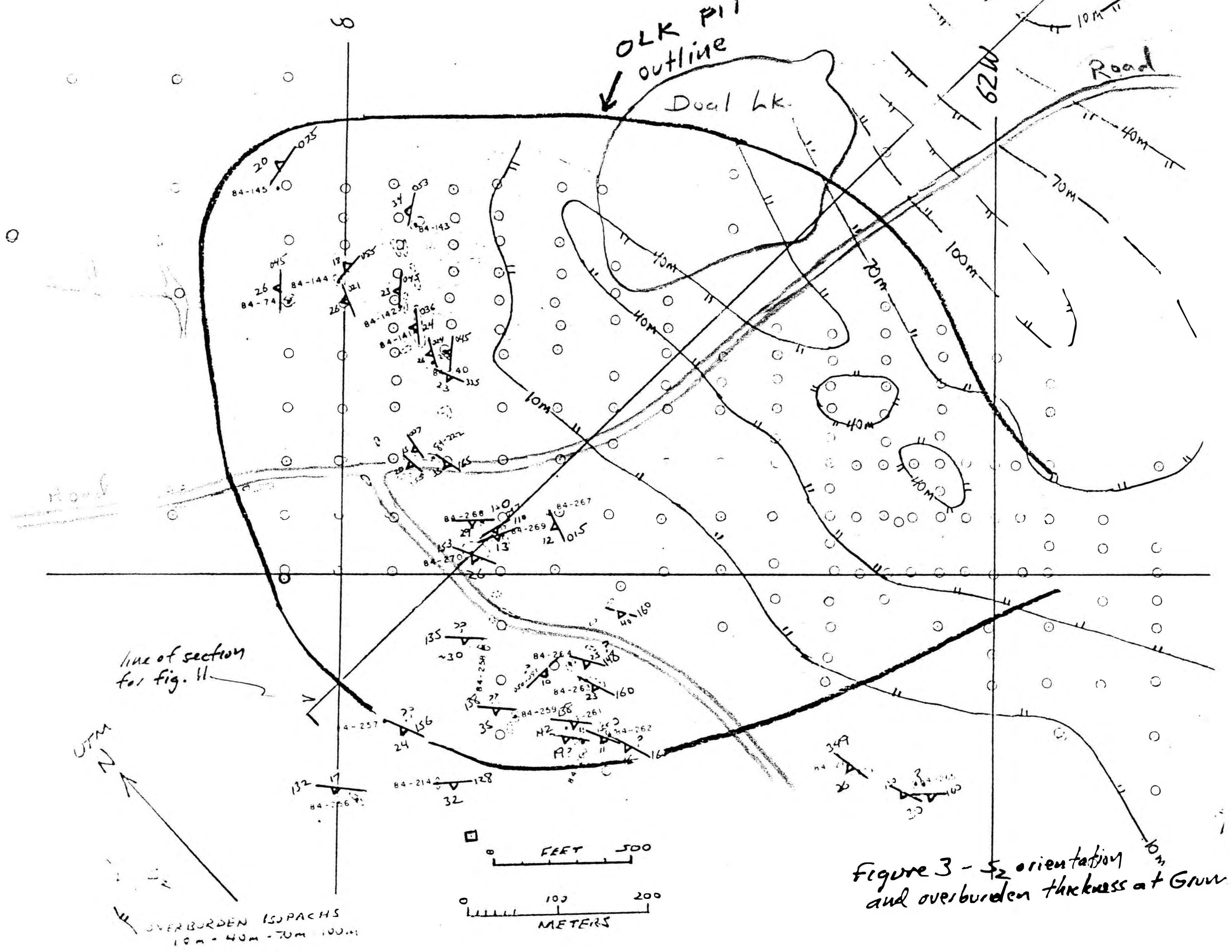
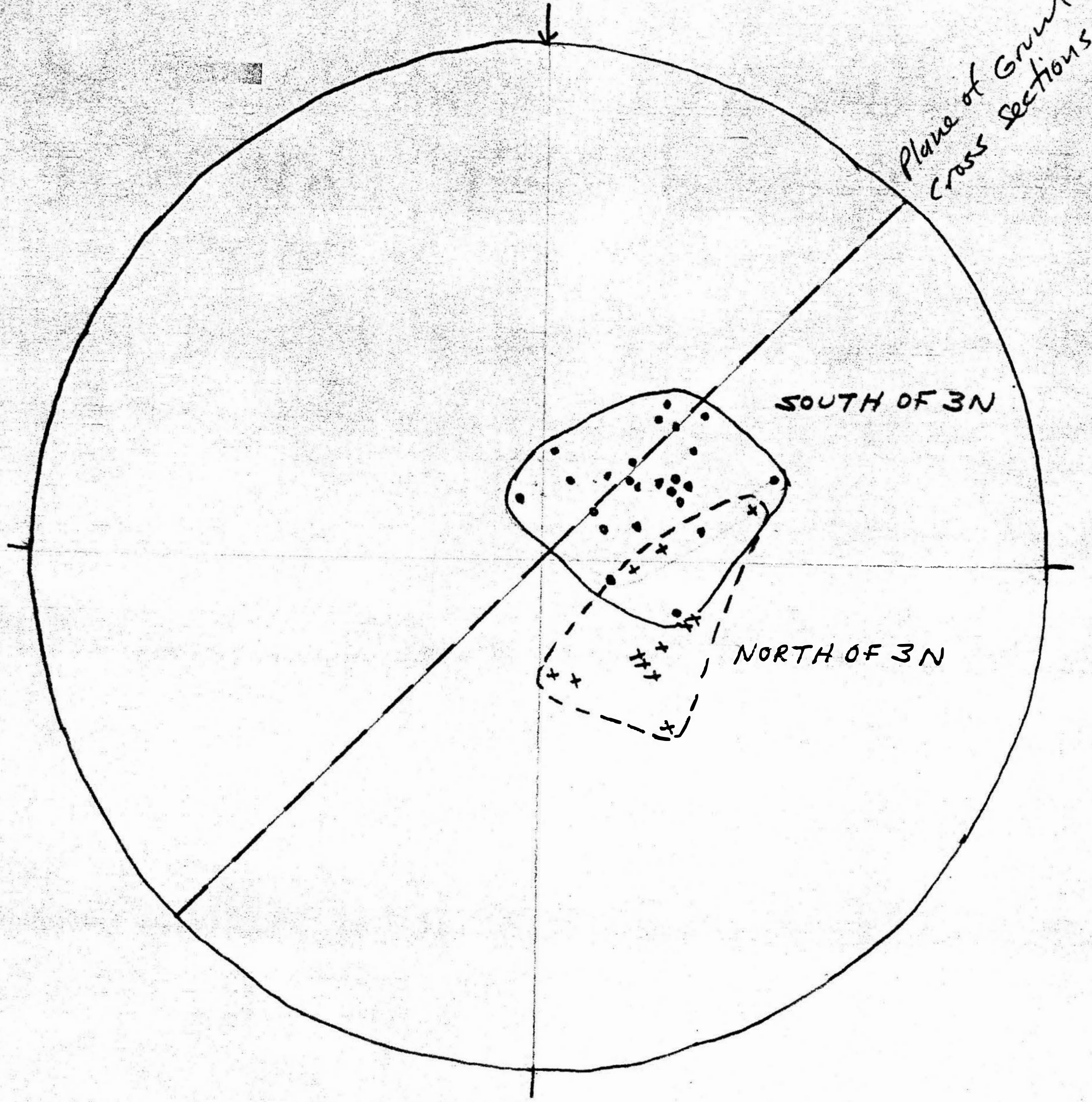


Figure 3 - S_2 orientation and overburden thickness at Grum



• poles to S_2 south of 3N

× poles to S_2 North of 3N

Figure 4
S_2 poles measured in the immediate vicinity of Grum during 1984

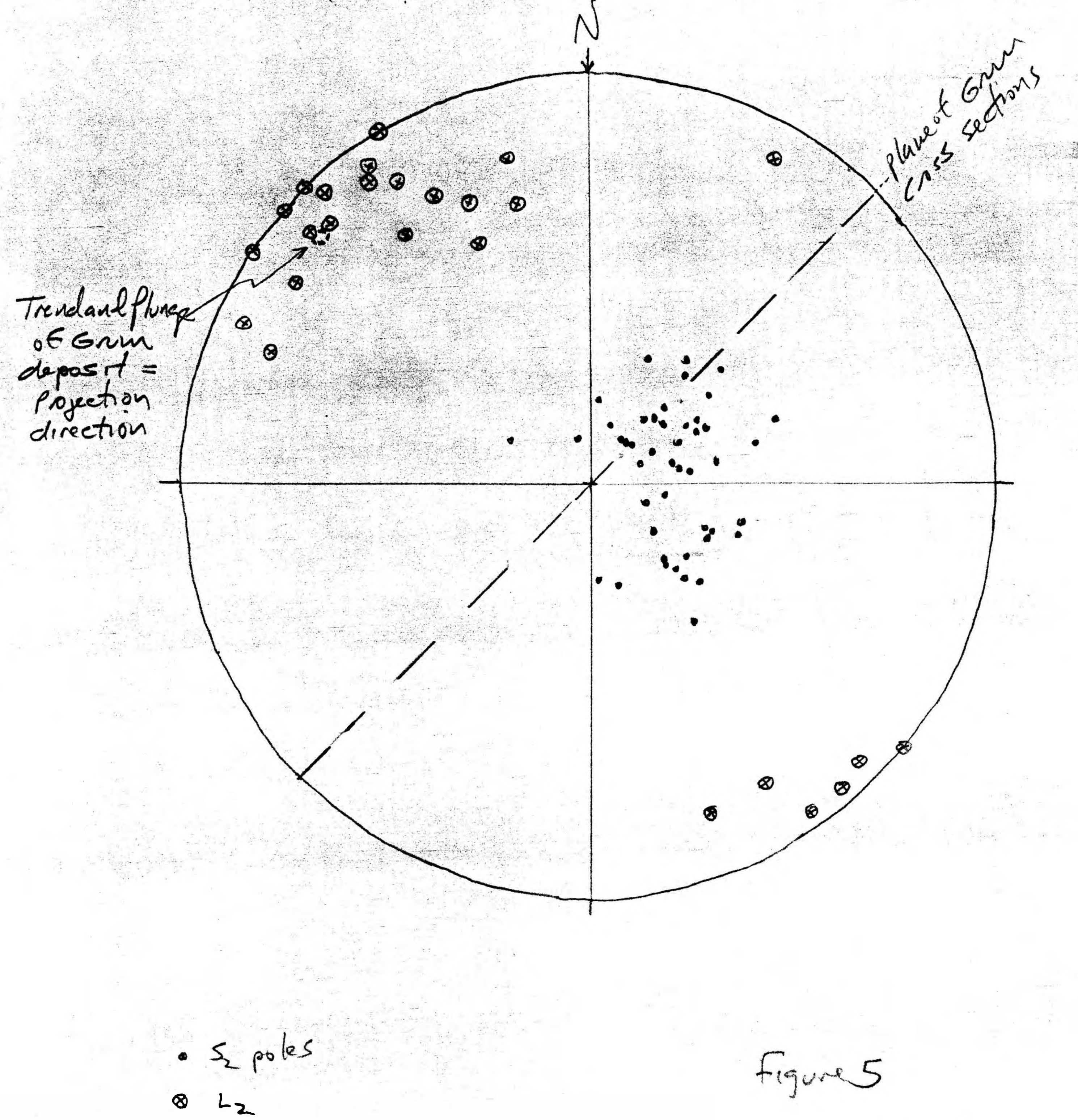


figure 5

Poles to S_2
& L_2 lineations

all domains Near the Grum Deposit

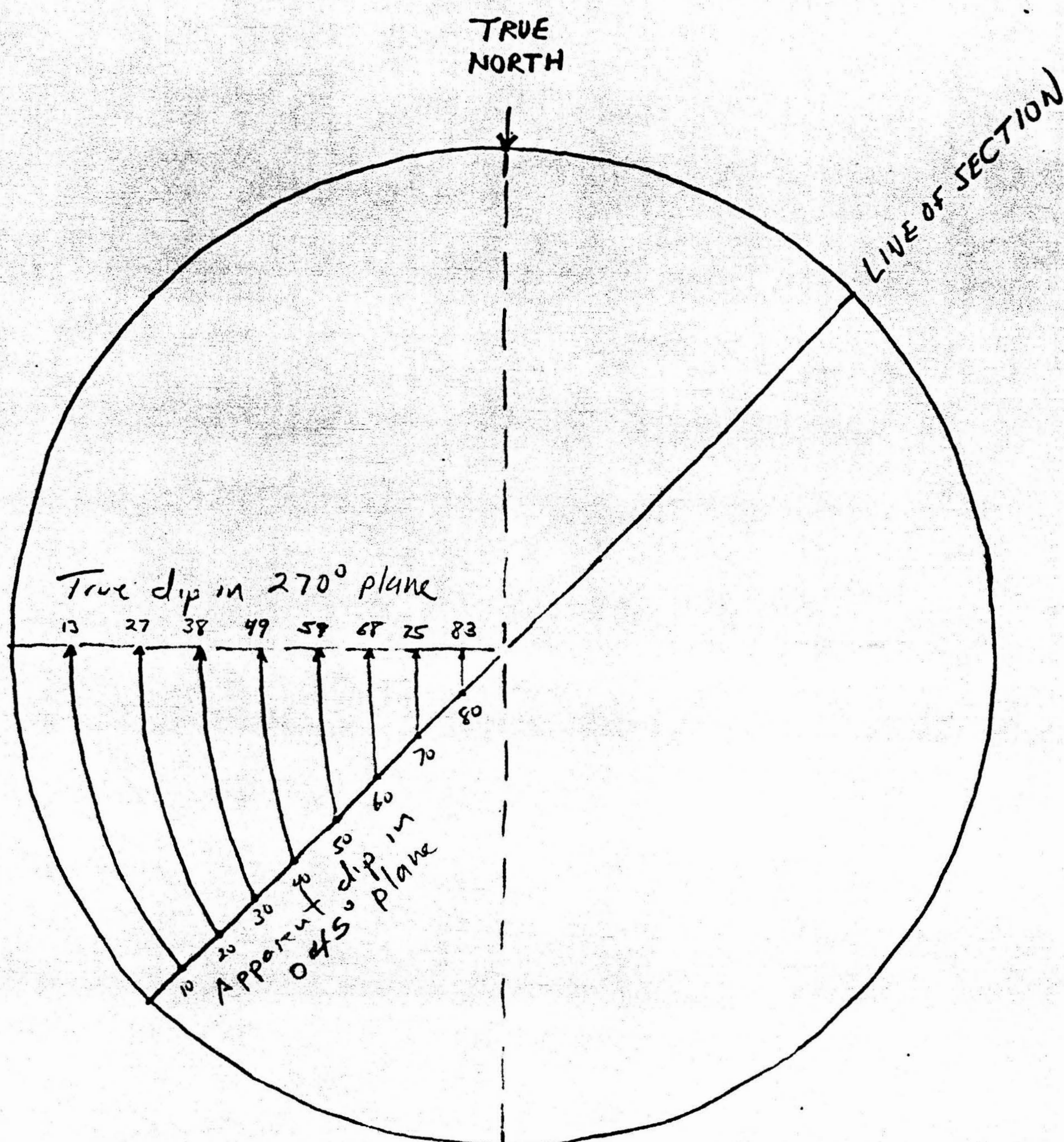
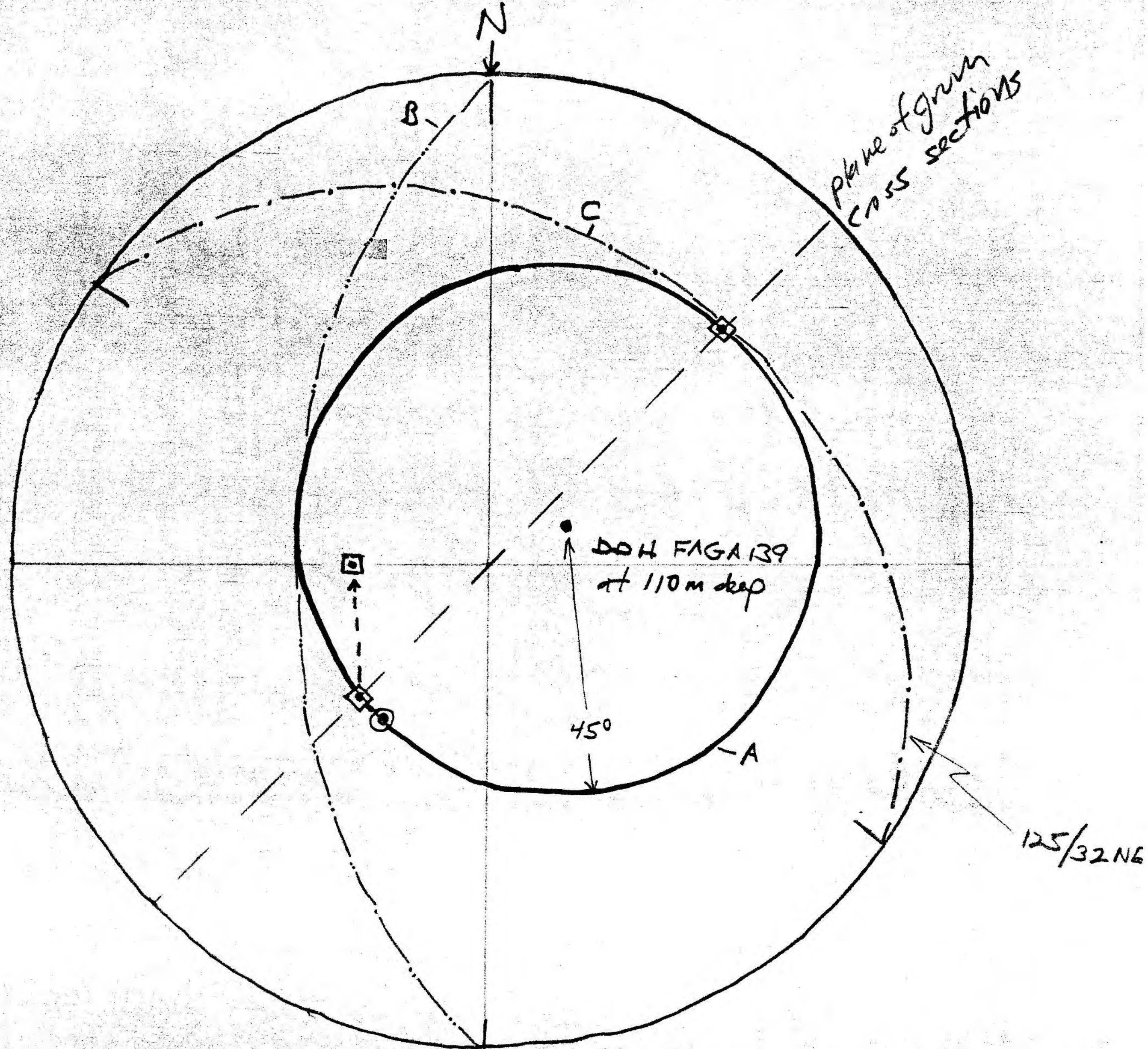


figure 6.
Stereonet showing the result of assuming plotted S_2 in plane of section is an apparent dip



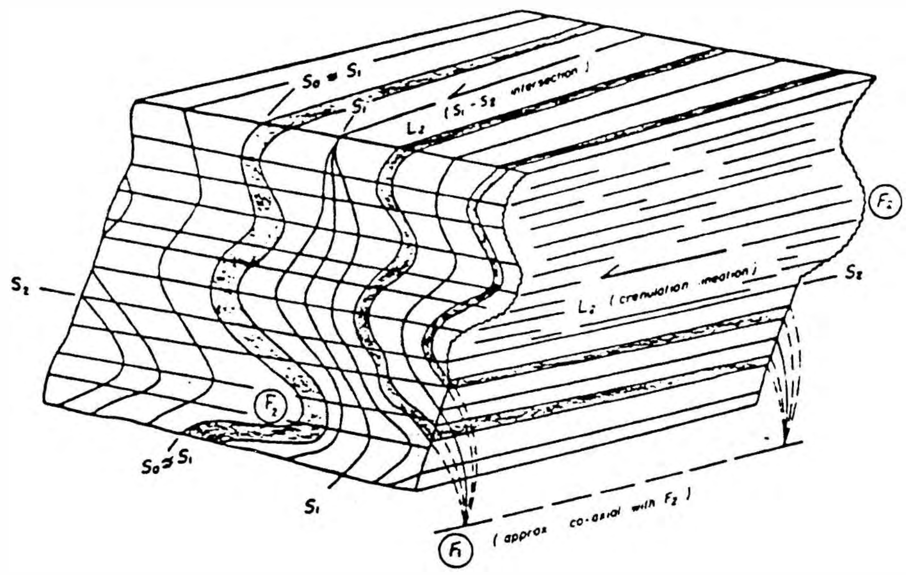
A — small circle representing the cone of all possible poles to S_2 and approximately all possible dip directions

⊡ Two possible solutions for S_2 dip direction if dipping in plane of sections - Korr plotted the one with southwest dip - the dotted line shows the exaggeration of the dip if an apparent dip is assumed.

Figure 7

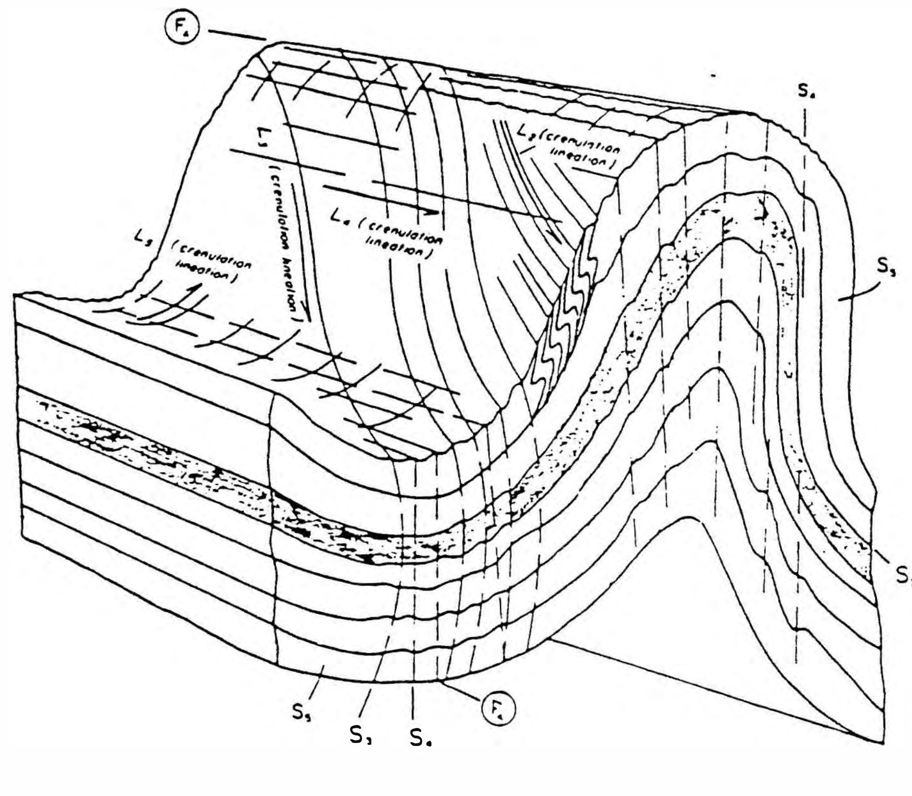
B — great circle showing actual S_2 plane if strike is 000° and dip is to west

C — great circle showing S_2 if average dip direction for S_2 in underground [illegible]



A

Schematic Post-D_2 Geometry



B

Schematic Post D_5 Geometry (F_3 and F_5 omitted)

Figure 8. Summary diagrams showing the fabric elements in rocks of the Anvil District.

D_{1-5} refers to deformations 1-5.

S_{1-5} refers to foliations (surfaces) formed during D_1 through D_5. S_0 is bedding.

L_{1-5} refers to lineations formed during D_1 through D_5.

F_{1-5} refers to folds and fold axes formed during D_1 through D_5.

[A] summarizes the post D_2 geometry and is an idealization of the greenschist facies phyllites. [B] shows the post D_2 deformations superimposed on near pervasive S_2 where parallel to compositional layering and is an idealization of the amphibolite facies schists.

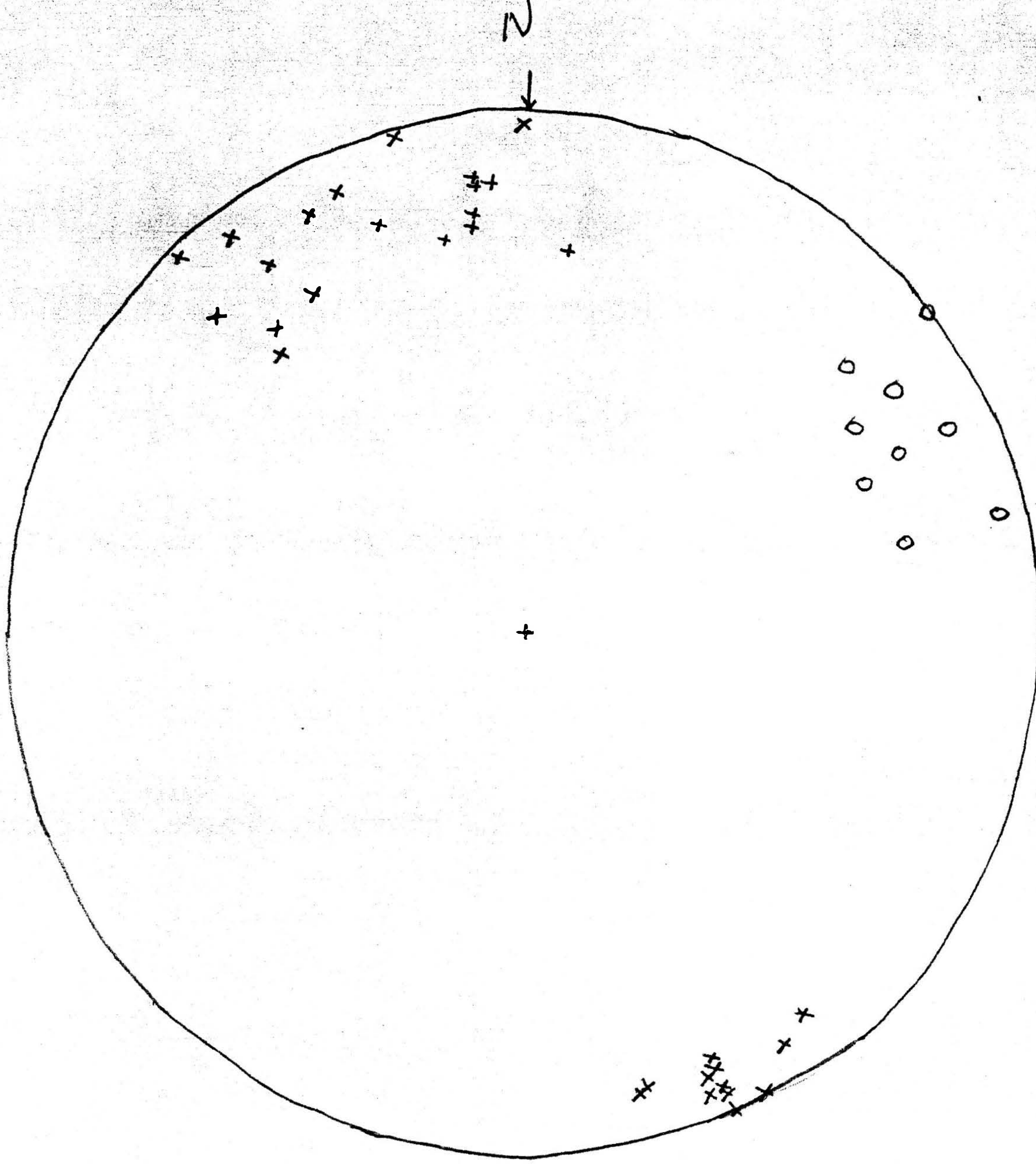


Figure 9

x fine crenulation lineation = L_3 ?
o poles to cleavage related to above = S_3 ?

FINE CRENULATION LINEATION
& poles to foliation causing it.

GROOM AREA all
domains

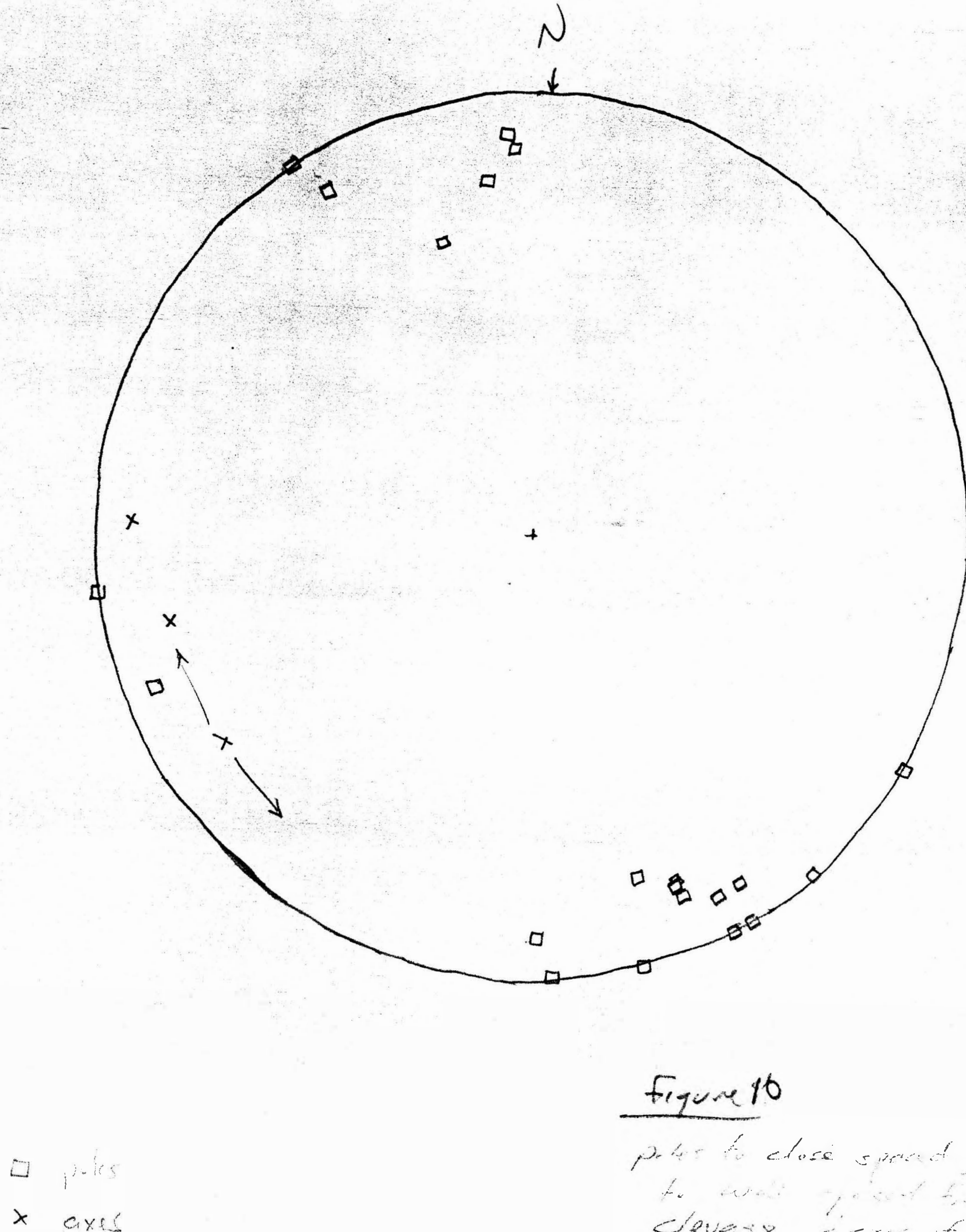


Figure 10

poles to close spaced joints to small spaced fractures cleavage & axes of kinks related to them

GRONM - all domains

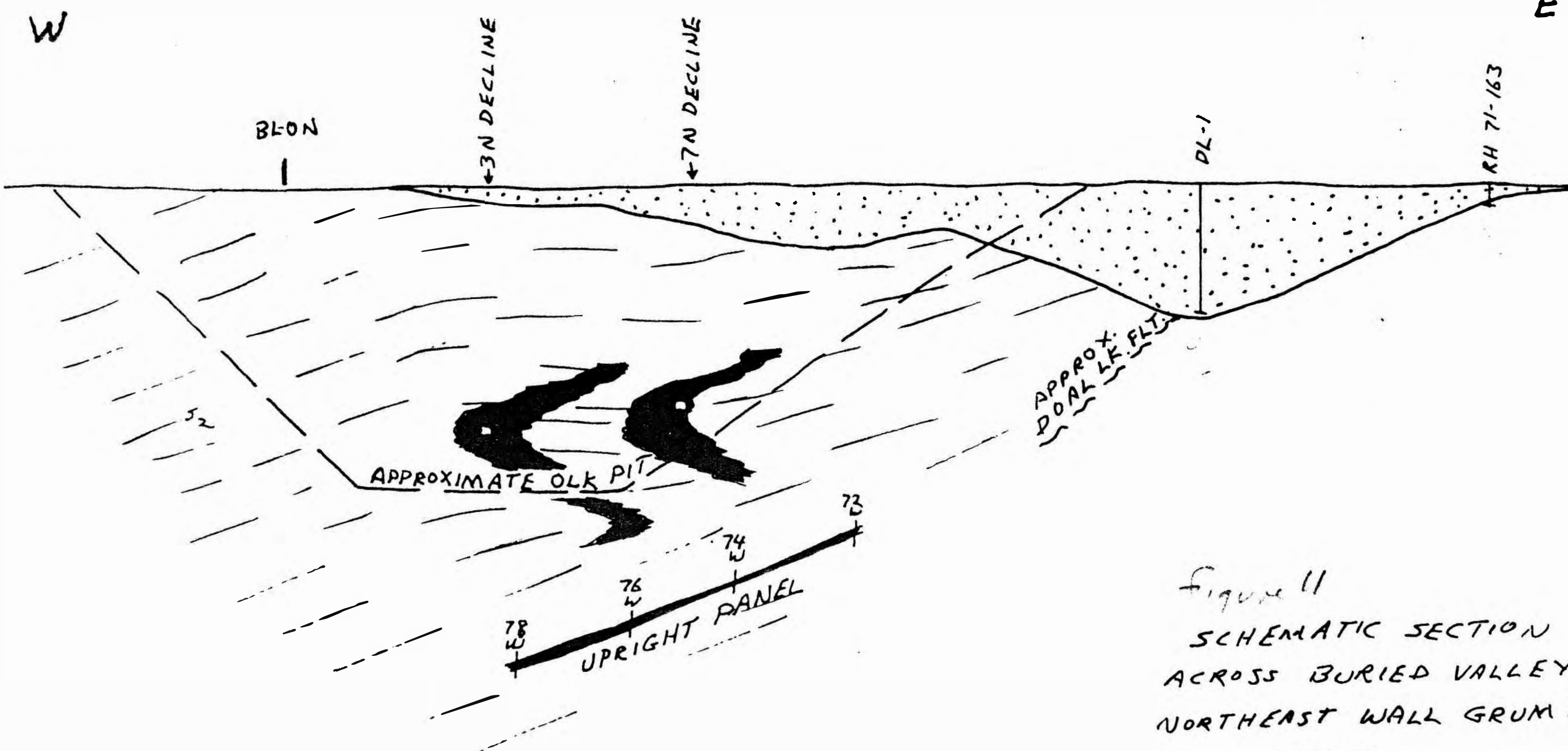


figure 11
SCHEMATIC SECTION
ACROSS BURIED VALLEY
NORTHEAST WALL GRUM PIT
1:5000

Note: BEDROCK GEOLOGY IS HIGHLY SCHEMATIC