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STRUCTURAL ANALYSIS OF THE VANGORDA OPEN PIT MINE, ANVIL Pb-Zn-Ag DISTRICT, FARO, YUKON.

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FOR: Curragh Resources

117 Industrial Rd.

Whitehorse, Yukon.

Vangorda Pit
LEGEND
Geological Contact
Bedding
Foliation (S1, S2, S3)
Foliation Form-surface Trace
Fold Axis (F2, F3)
Fault
Antiform
4G
4EC
4E (Pyrite Sand)
4A
3G/4L
3GO, 3GO9, 3E
* Note. Rock codes correspond to those used for core logging.
Scale 1 : 500
Overburden Fault
9400.0 N
9500.0 N
9600.0 N
9700.0 N

Oct. 28th
St. John's

RECEIVED
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Lee.

A short field report to outline some of my ideas on what was exposed in the Vangorda pit this past summer. I concentrated on the pit exposure (ignoring drill core) since this was the first opportunity to look at Vangorda rocks in outcrop. The report is, of course, very preliminary. There was little data available by the end of the summer — and severe time constraints now! A copy of the report has been sent to Dave Tenney.

MSc. thesis is going as planned — will be finished on time. Rocks from Vangorda have arrived here and I will cut some of them in the next few days and send blocks to Ken for polished sections. All else is in motion for the move to U.K. in January.

If you're interested in the type of work I have been doing up until now there will be a paper in CJES in January entitled "The kinematic and geometric evolution of the Emma Lake thrust stack, Grenville Front zone, southwestern Labrador" by Brown, van Gool, Calon, and Rivers.

Can I get copies of the new sections sent to RHBNC some time early in the new year.

Regards to all in Whitehorse and Cirque (chuck?)

Dennis.

1.0 Introduction

The Anvil Range lead-zinc-silver district is located in the northern Canadian Cordillera, 200 km northeast of Whitehorse, Yukon (Fig. 1). The Anvil District is underlain by a structurally thick sequence of upper Proterozoic to lower Paleozoic polydeformed, polymetamorphosed, metasedimentary and metavolcanic rocks. These rocks are intruded by Cretaceous granites and granodiorites of the Anvil plutonic suite. Within the district, five stratiform, massive sulphide lead-zinc-silver deposits lie along a northwest-southeast curvilinear trend (Fig. 2), parallel ot the structural grain of the district.

During the 1990 field season a study was undertaken to investigate the structural style of one of the massive sulphide lead-zinc deposits, the Vangorda deposit, during the early stages of its development as an open pit mine. Exposure in the vicinity of the Vangorda deposit is poor, consisting of several small outcrops along Vangorda Creek, which truncates the ore body. Up until the 1990 field season the structural style of the Vangorda deposit was based largely on interpretation of drill core, combined with an understanding of the regional geology. With the opening of the Vangorda pit this summer new outcrop was created that allowed direct structural analysis of the deposit to be carried out. That work forms the basis this report.

2.0 Geological Framework

The Anvil District lies immediately north of the Cretaceous-Tertiary Tintina Fault, a major dextral strike-slip fault in the area. The structural grain of the district, outlined by S_2 form-surface traces and lithologic contacts, is roughly northwest-southeast (Fig. 2). The dominant structural feature in the district is a broad structural arch, the Anvil Arch, that is related to uplift accompanying emplacement of the Anvil Batholith. Numerous, late extensional faults occur in the district and have been interpreted to be related to emplacement and subsequent unroofing of the batholith (eg. Jennings and Jilson 1987).

Five ductile deformation events have been documented in the Anvil District (Jennings and Jilson 1987), the first two of which are of primary importance. The first deformation, D_1, is related to northeast-directed folding and thrusting during pre-to mid-Cretaceous docking of outboard terranes (Hansen 1990) which resulted in the development of a penetrative regional foliation development (S_1), and regional metamorphism. The second deformation event (D_2) is related to emplacement of the Anvil Plutonic Suite during the Cretaceous, and resulted in southwest- directed folding, development of a penetrative foliation (S_2), contact metamorphism (Pigage and Anderson 1985; Smith and Erdmer 1990). Emplacement of the batholith was accompanied by extensional faulting. D_3 to D_5 produced minor folding and steeply dipping crenulation foliations that overprint D_1 and D_2 structures.

3.0 The Anvil Cycle

The regional stratigraphic sequence for the Anvil District is outlined in figure 3. Two units are of significance in this study; the non-calcareous, carbonaceous, phyllitic Mt. Mye Formation, and the overlying calcareous, carbonaceous, phyllitic Vangorda Formation. The contact between the two is marked by a quartz-bearing carbonaceous unit at the base of the Vangorda Formation. The Anvil District lead-zinc-silver deposits straddle the boundary between the Mt. Mye and Vangorda formations.

The ore bodies themselves are SEDEX type (Carne and Cathro 1982) deposits. Despite the polydeformed and polymetamorphosed nature of the district, a generalized stratigraphic model that reflects the original geometry of the ore deposits has been developed (cf. Jennings and Jilson 1987). In this model, individual ore bodies have an overall lensoid shape that can range up to 4000 m across and 150 m thick. These bodies may occur as a single lens with little or no interbanded sedimentary rocks or as stacked, multilayered bodies with a substantial amount of interbanded metasediments.

Individual ore lenses typically consist of a number of lithofacies that, from top to bottom, include; a baritic massive sulphide horizon, a pyritic massive sulphide horizon, a pyritic quartzite horizon, and ribbon banded graphitic quartzite horizon (Fig. 4). This geometry is more or less constant throughout the district and has been termed the Anvil Cycle (Jennings et al. 1980). Anvil Cycles occur on a number of scales and in varying degrees of completeness throughout the district. It is important to note that all ore types in the Anvil District are metamorphic tectonites containing well-developed S1 and S_2 foliations (Pigage 1990).

Both the host rocks and certain ore facies of the Anvil deposits are overprinted by a muscovite ± chlorite alteration zone. The alteration zone may have formed as reaction between ore fluids and host rock, D_1 and/or D_2 metamorphism, or as a combination of both.

4.0 The Vangorda Deposit

The Vangorda deposit is a shallow, relatively small (5.4 million tons) ore body structurally located 50 to 120 meters below the base of the Vangorda Formation, within the Mt. Mye Formation. The deposit is elongate in a northwest-southeast orientation and plunges shallowly northwest, parallel to the regional F_2 fold axis orientation.

The structure of the Vangorda pit is dominated by east-west-plunging, meso- to macroscopic F_2 folds with a penetrative S_2 axial planar foliation, and by roughly northeast-striking high angle faults (see attached status map). Locally, in the hinge zones of F_2 folds, a S_1 foliation is preserved as a steeply dipping lithon texture. A number of minor, and several major faults truncate D_2 folds and foliations. As well, at least one fault (Main Zone Fault) appears to be parallel to S_2, cutting through the limb of a F_2 fold.

The deposit is truncated at its northwest end by a high angle fault, the Northwest Fault. An interpreted high angle fault, the Cross Fault, cuts the deposit nearly in half. The southwestern half of the deposit occurs in the hinge zone of a macroscopic F_2 fold, and has an overall M asymmetry that appears to be structurally upright (Figure 5a). The northeastern part occurs as two horizons, a 5-10 meter thick lower horizon and a 10-15 meter thick upper, or main horizon, separated by a low angle southwest-dipping, S_2 parallel fault (Main Zone Fault, Fig.5b). This report is concerned only with the northeast end of the deposit, which was exposed during the past field season.

Based on structural fabric orientations, the exposed Vangorda pit has been divided into three domains that are separated by high angle faults (Fig. 6). These domains are discussed in detail below.

Domain 1

Domain 1 rocks exposed in the pit consist of buff to dull grey non-calcareous phyllites, typically with a light grey foliation surface and thin, discontinuous interbands of carbonaceous phyllite. This unit is overlain by a dark grey, commonly quartz-bearing phyllite. Rare, thin bands of beige with light green flecks, commonly powdery metabasite are also found. Domain 1 is bound to the northeast by the pit limit and to the southwest by the Sump Fault.

Rocks in Domain 1 are tightly to isoclinally folded by shallowly east-west-plunging F_2 folds (Fig. 6). Asymmetric folds are rare, but where observed verge towards the south. Paucity of asymmetric folds and lack of stratigraphic markers make it difficult if not impossible, to determine the geometry of the large scale fold structure.

A penetrative S_2 foliation is everywhere axial planar to F_2 folds. S_2 typically dips shallowly towards the south-southwest, with a marked swing of dip-directions towards the west (Fig. 6).

There are relatively few faults in Domain 1 and those that do occur are minor, having up to one meter or less offset. The Sump Fault outcrops in the pit wall and the pit floor as a narrow (0.5 - 1 m wide) gouge zone across which there is a change in lithology from a massive pyritic quartzite in the footwall to a noncalcareous phyllite in the hangingwall (Fig. 7). The Sump Fault dips moderately to steeply southeast. However, no kinematic indicators were found to confirm an actual movement direction. The Sump Fault marks the boundary between Domains 1 and 2.

Domain 2

Rocks in the pit wall of Domain 2 consist of strongly weathered, leached massive pyritic quartzite and pyritic quartzite interpreted to be from the footwall of the ore body. Lesser, locally oxidized, baritic and pyrrothitic ore, overlain by alteration zone phyllites, occur in the floor of the pit (see attached status map). The contact between the ore units and the alteration zone phyllites appears to be stratigraphic, and strikes roughly northwest and dips shallowly southwest.

Folding in Domain 2 consists of a single sub-cylindrical, close to tight, and shallowly east-west-plunging (Fig. 6) F_2 antiform. The antiform consists of a structurally quiet long limb to the northwest and a hinge zone to the southeast. Mesoscopic fold asymmetries near the hinge zone indicate the antiform verges towards the south to southwest. In an outcrop in the pit floor, the hinge zone of this antiform was found to be truncated by the Sump Fault.

The dominant fabric in Domain 2 appears to be S_2, which is a coarsely spaced fracture cleavage that dips shallowly towards the northeast (Fig. 6) and is everywhere axial planar to F_2 folds. However, in the hinge zone of the F_2 antiform a S_1 fabric is preserved as a lithon texture, and is folded by the F_2 fold. It is not clear if S_2 is the fabric found in the limb zone of the antiform, or if it is S_1 transposed into parallelism with the axial surface of the F_2 fold. For instance, in handsamples collected from blasts in Domain 2, a well-developed banding in the ore rocks is isoclinally folded in a style similar to F_2 folds observed in outcrop, suggesting transposition of S_1 into S_2 may be common.

As in Domain 1, only minor faults with very little offset were mapped in Domain 2.

The criteria for placing a fault between Domains 2 and 3 is somewhat tentative and purely interpretative. The evidence for a fault are as follows. In the pit wall, the overburden contact drops very sharply, and tightly folded phyllites of Domain 3 to the north strike into the structurally quiet footwall massive pyritic and pyritic quartzite of Domain 2. Also, in cross-section there is a marked change in both structural style and lithology between sections 25+00E and 24+00E. In long section the change is less obvious, but it is difficult to correlated lithologies across this area (9610 local grid). Further, bench plans and blast hole assay maps indicate a distinct break in the ore lenses across this zone. Based on the above, a fault is interpreted to occur between cross-sections 24+00E and 25+00E, in the area where the overburden contact drops. This fault has been named the Overburden Fault (see attached map).

Domain 3

Domain 3 consists of complexly folded and faulted Mt. Mye phyllites, alteration zone phyllites, ribbon banded quartzite, baritic and footwall ore units, and, locally, metabasite.

Folds in Domain 3 are tight to isoclinal, sub-cylindrical west-northwest to east-southeast plunging F_2 folds (Fig. 6). Local fold asymmetries in the pit wall indicate that here rocks are structurally in the overturned limb of a macroscopic southwest-verging F_2 fold (Fig. 8).

Locally, post-F_2 mesoscopic folds fold the S_2 foliation. To date, not enough of these folds were found to get a consistent orientation or fold style, and no overprinting relationships were found between post-F_2

In phyllites in Domain 3, S_2 is a penetrative southeast-dipping foliation that is everywhere parallel to the axial plane of F_2 folds. S_2 is not well developed in the more ductile ore units. There, S_1 is typically folded and transposed into parallelism with the F_2 axial plane. Well preserved S_1 lithon textures are common throughout the pit wall in Domain 3.

Numerous faults were mapped in Domain 3. Most where minor breccia and gouge zones (Fig. 9) with very little movement. However, one fault was mapped in an active shovel face that corresponds with the Main Zone Fault (Fig 10), which is interpreted to occur from cross section construction. Where observed in outcrop the Main Zone Fault is a 1 - 1.5 meter-wide gouge zone in alteration zone phyllites. Ductile flow breccias in the underlying ore units may also be related to the Main Zone Fault. Rocks mapped in the pit wall, and described above, lie in the footwall of the Main Zone Fault, in what is locally known as the lower horizon (Fig. 5b). Very little of the main zone, in the hangingwall of the fault, was mapped.

5.0 Discussion

On the basis of structural style and orientation of fabric elements (i.e. F_2 and S_2) the exposed Vangorda deposit can be subdivided into three structural domains separated by high angle faults. The variation in fabric orientations between domains is not great, but is clear. These variations are likely due to rotation of fault blocks during movement of bounding faults. The change in lithologies across the domain bounding faults suggest significant movement may have occurred along these faults.

Because of limited exposure during this past field season, not enough data was collected to make any definitive statements about the overall structural style of the Vangorda deposit. However, it is apparent that both high angle faulting and F_2 folding play a very important part in determining the present geometry of the ore body. Most faults appear to be relatively minor and will not significantly affect mining, but their analysis will help to understand the nature of the larger and more significant domain bounding faults. F_2 folds appear to be developed on a scale of 10,s to several 10's of meters. They are roughly sub-cylindrical east-west plunging (somewhat more west-plunging than previously thought), tight to isoclinal, and south- to southwest-verging. Cylindricity of folding can only be established for folds in phyllites and may change significantly in the more ductile ore rocks where flow of material into fold hinges could play an important role.

In phyllites, S_2 is everywhere axial planar to F_2 folds, but in the ore rocks the dominant fabric may in fact be S_1, which has been transposed in parallelism with the F_2 axial surface (more data will be required to comfirm this). It is also reasonable to assume that there is slip along the S_2 surface as indicated by the presence of the Main Zone Fault. Understanding the kinematics of these S_2 parallel faults may be of importance for future exploration targets (for example, finding the rest of the main zone).

Another important point with regard to exploration is the nature of the quartz-bearing, carbonaceous phyllite (shown as unit 4A in the attached status map) that overlies the buff, non-calcareous phyllite. Domain 1 drops down along the Sump Fault from a higher structural level, juxtaposing phyllites in the hangingwall against ore rocks in the footwall. The carbonaceous unit has been interpreted to belong to the ribbon banded quartzite of the Anvil Cycle, but it may in fact be the carbonaceous unit at the base of the Vangorda Formation. If this can be shown to be the case then deeper drilling may be warranted in this end of the pit to determine if the ore body is continuous at depth. The present drill holes show only minor intersections of pyritic quartzite.

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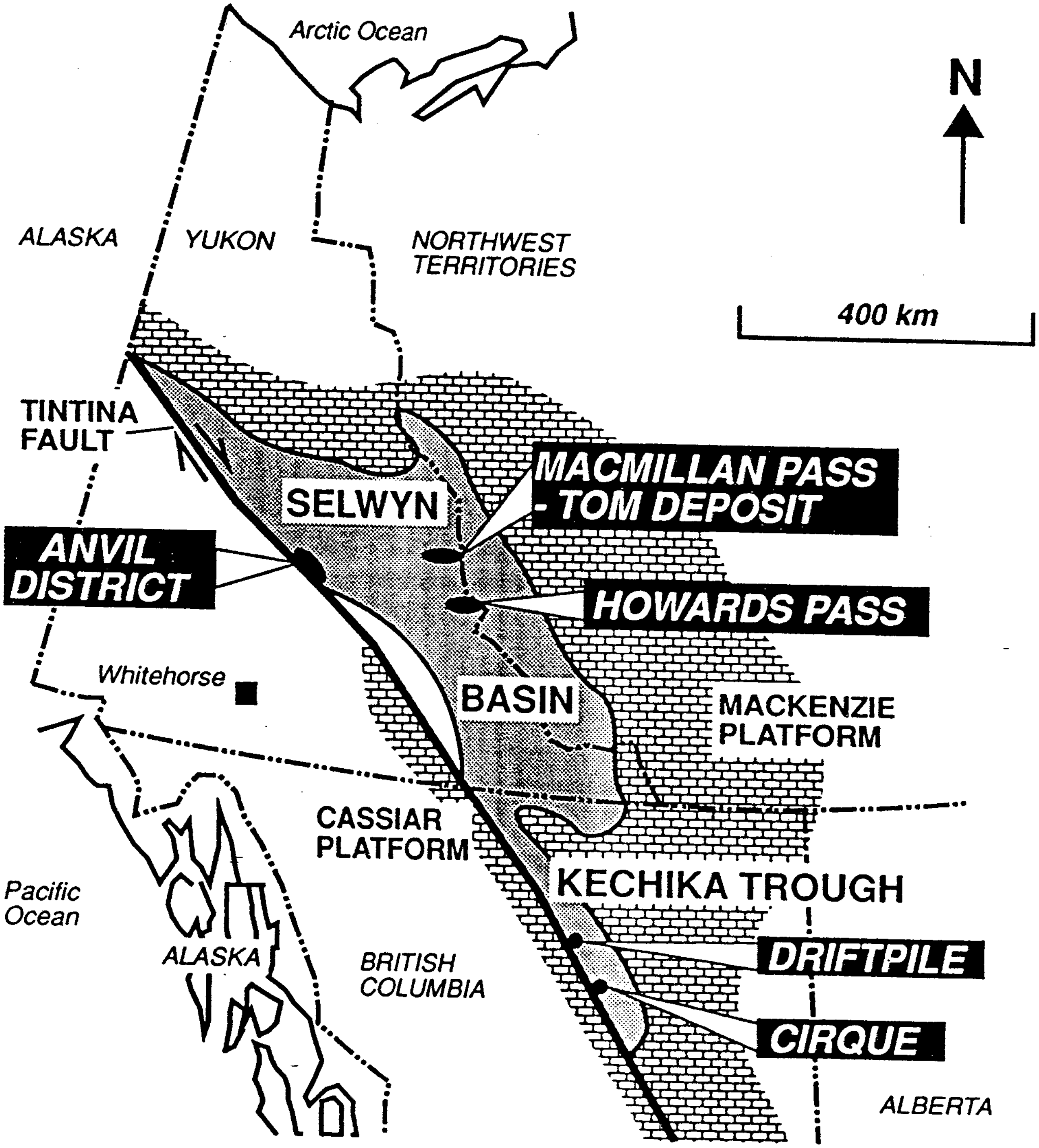

Figure 1. Location of the Anvil District, Yukon (after McClay 1990).

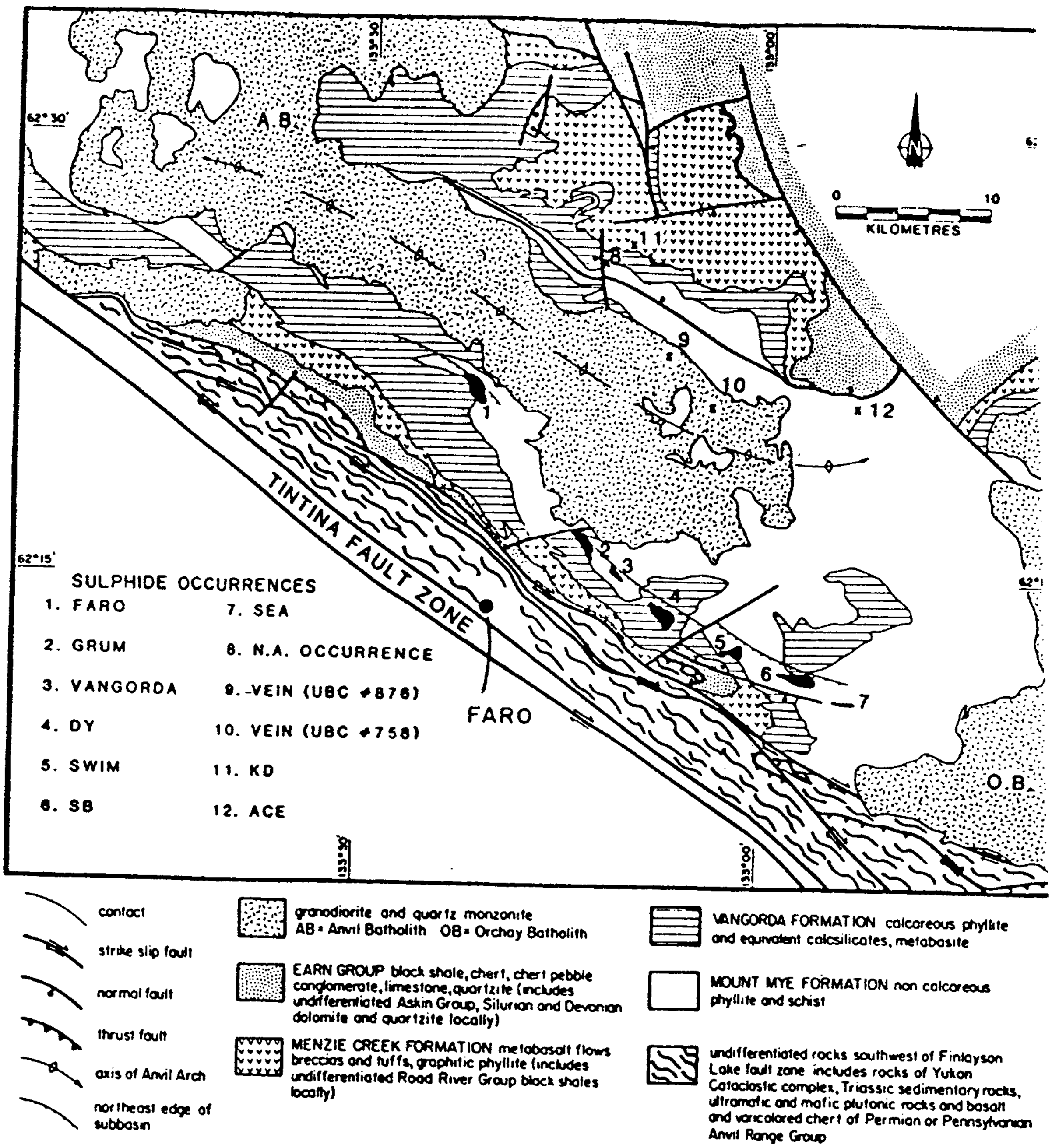

Figure 2. Geological map of the Anvil District showing location of mineral occurrences (after Pigage 1990).

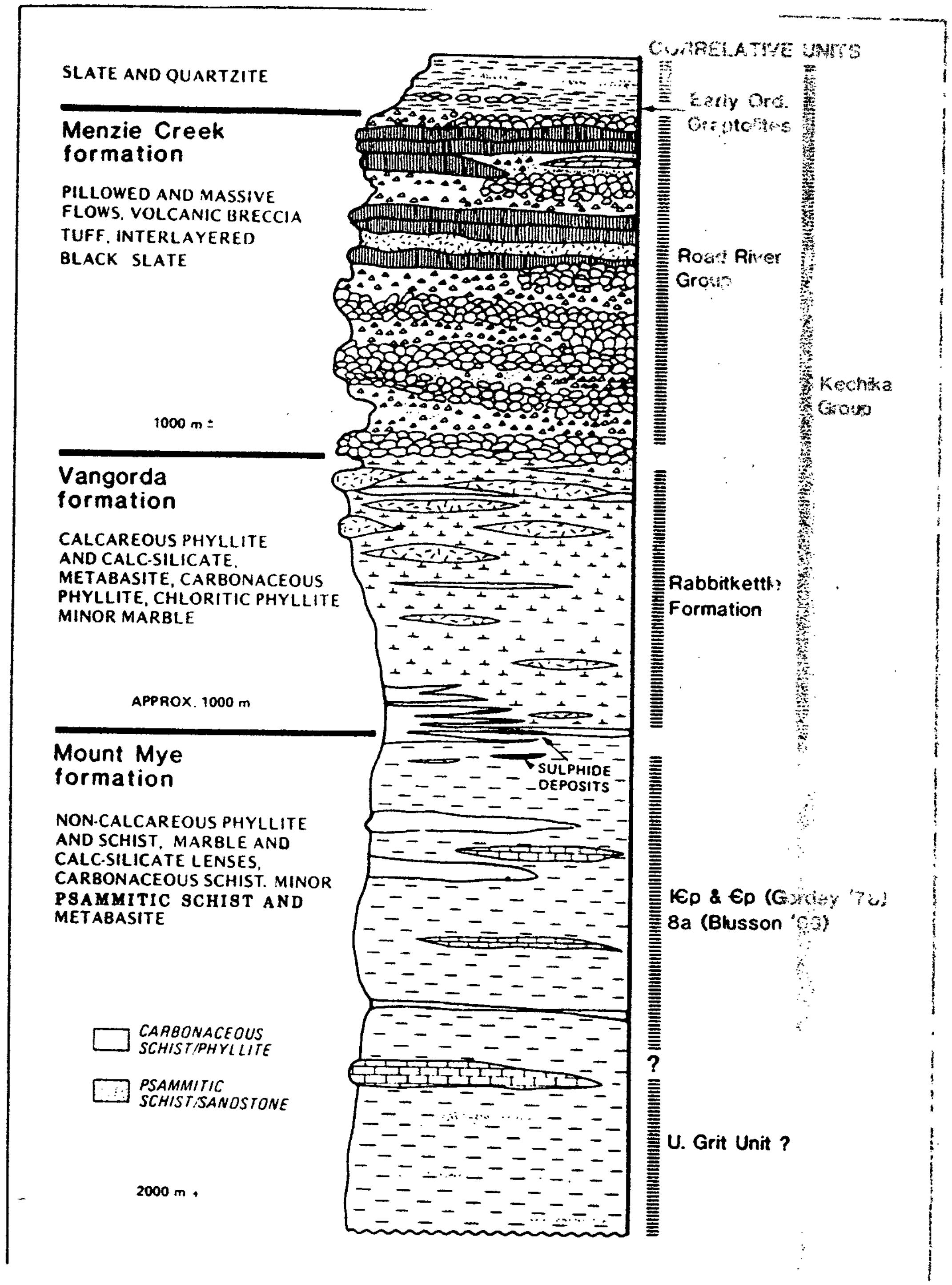

Figure 3. Schematic stratigraphic column of the Anvil District (after Jennings and Jilson 1987).

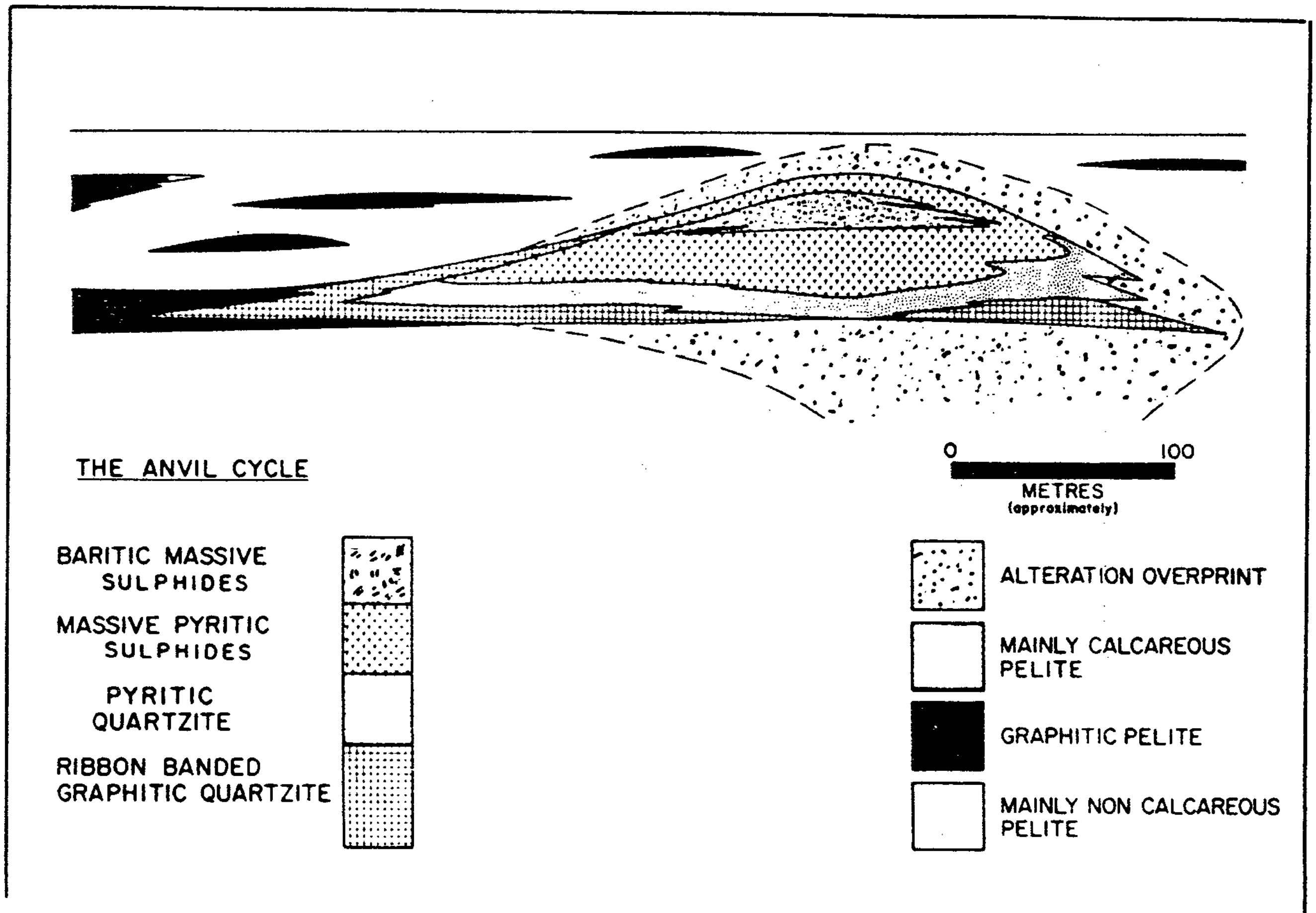

Figure 4. A schematic cross-section of an idealized Anvil Cycle (after Jennings and Jilson 1987).

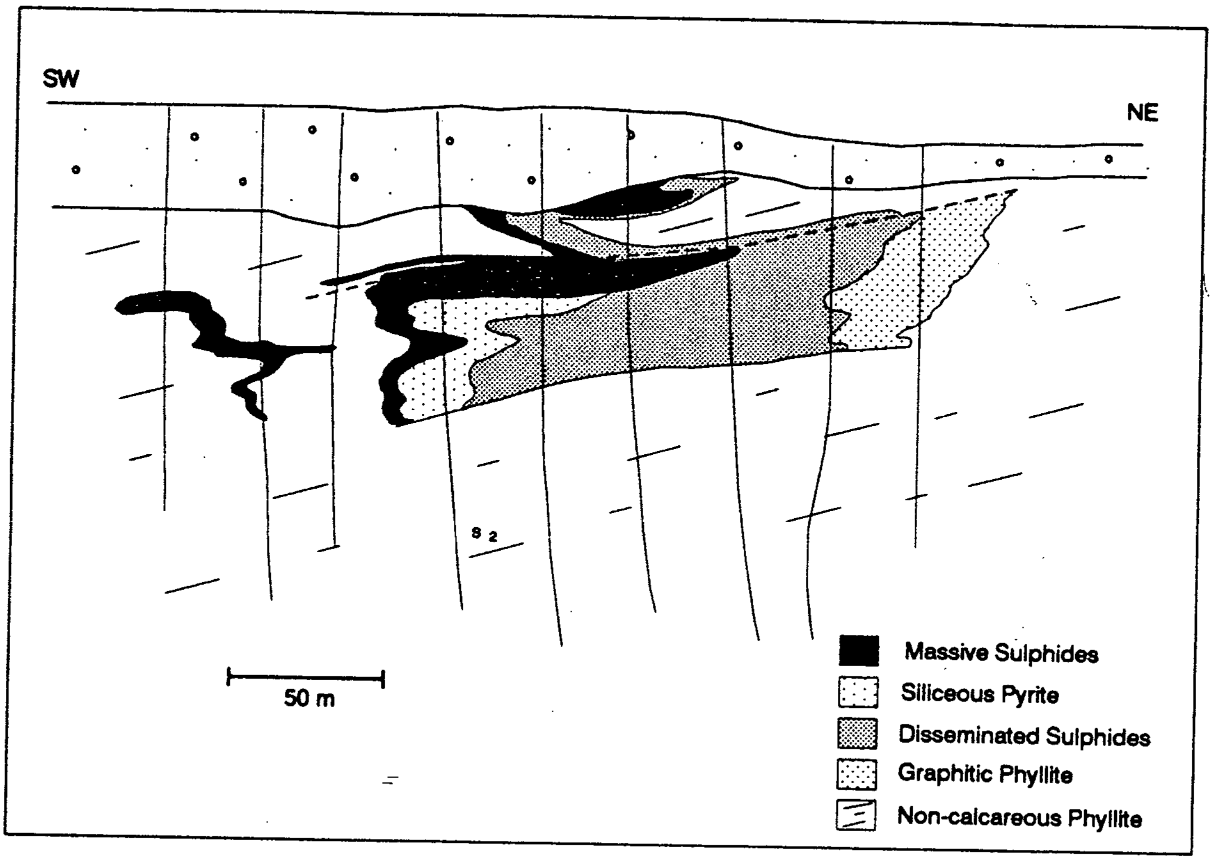

Figure 5a. Schematic cross-section (6+00E) through the northwest Vangorda deposit.

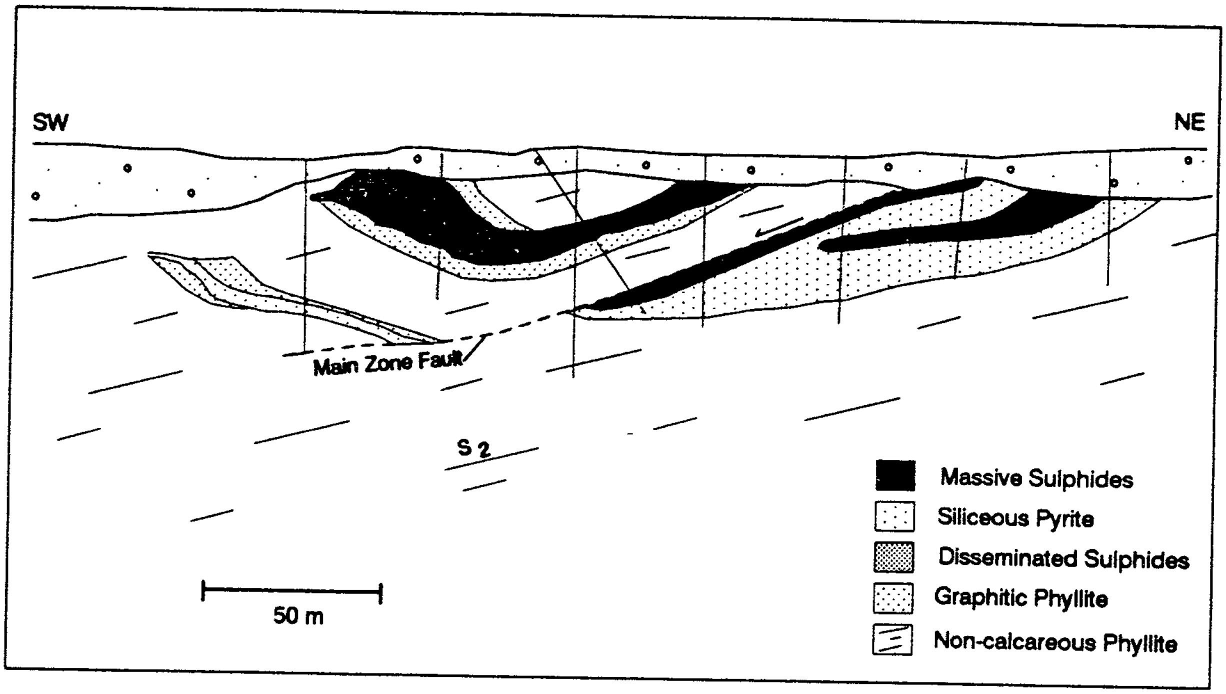

Figure 5b. Schematic cross-section (22+00E) through the southeast Vangorda deposit.

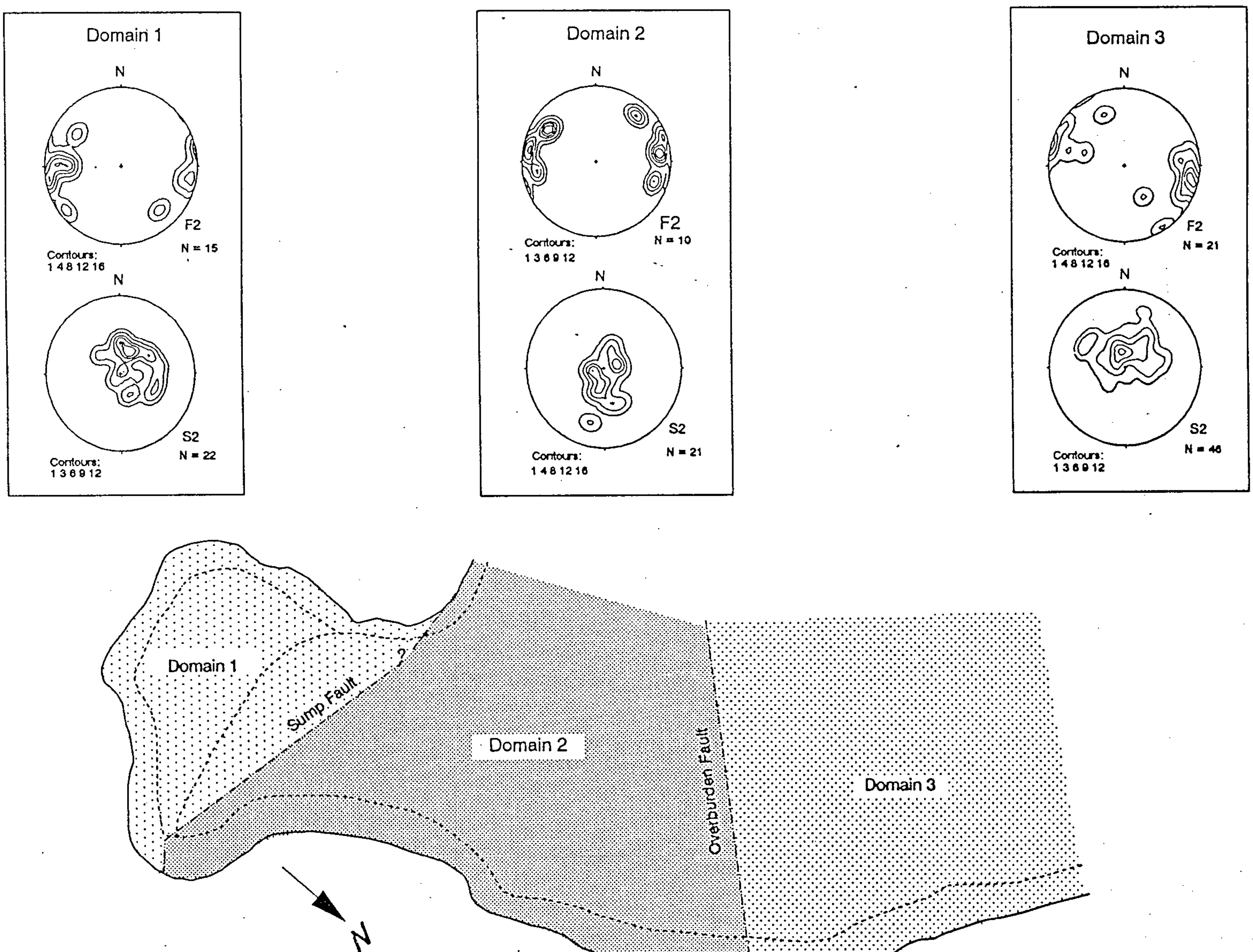

Figure 6. Domain map of the Vangorda deposit showing the position of domains and the orientation of fabric elements within each domain. Orientation data are lower hemisphere equal area projections. Contour intervals are in percent per 1% area.

Figure 7. Sump Fault in the Vangorda pit wall. Photo taken looking northeast.

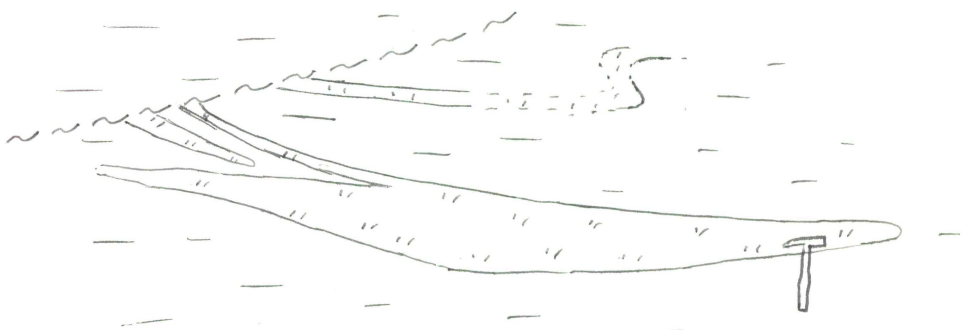

Figure 8. Photo and sketch of a south-verging S-fold in metabasite from the overturned limb of a macroscopic F_2 fold in Domain 3.

Figure 9. Photo of extensional fault breccia, Domain 3.

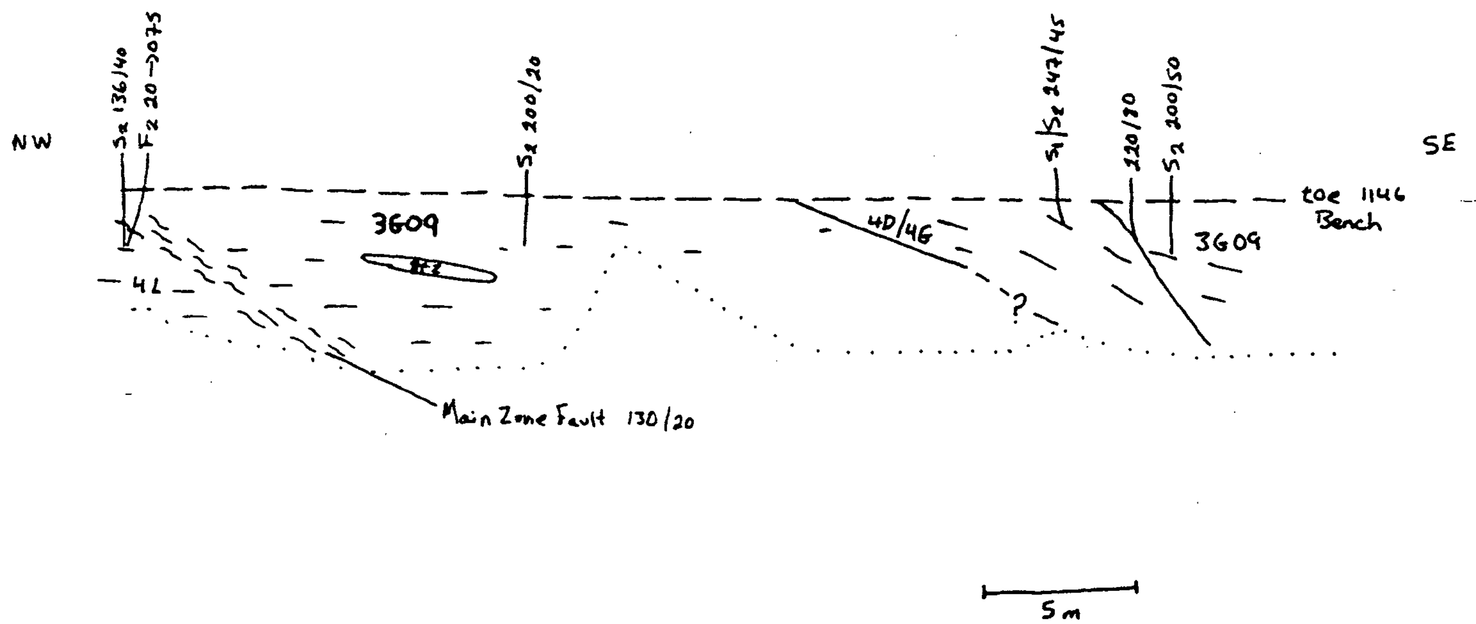

Figure 10. Field shetch of the Main Zone Fault in an active shovel face on the 1140 bench, Vangorda pit.