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MINNOVA

MEMORANDUM

DATE: February 18, 1991

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TO: D. H. Watkins

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FROM: A. J. Davidson

SUJET
SUBJECT: **R Freisen - Geology Update**

In late 1990 Bob Freisen put together a paper outlining his view of the Samatosum Mine Geology based on his observations in the pit. The following are my comments on his paper and attached are those of Ian Pirie, Al Hill, John Bradford, Dave Heberlein and Keith Glover.

GEOLOGY Bob starts off by stating much more forcefully than anyone in exploration that "the Sam Orebody is a stratabound quartz vein" and that "the ore zone is a product of one or more of the widespread alteration events rather than the other way around." I think that the origins of SAM are still moot and we think that alteration and mineralization are both products of a hydrothermal system(s). All certainly agree that SERT and MUT are alteration overprints rather than purely lithological and all have recognized that the alteration zones are discordant to stratigraphy. It is also recognized that unaltered rocks may be in contact with altered rocks and that the protoliths may either be the same or different depending on whether the units are separated by later faults or "alteration fronts". The "argillite wedge" may be either an unaltered remnant or a different unit but synclinal features have been mapped to the north. The fact is that both interpretations led us to drill near the base of the argillite and that exploration program was carried out in 1990. The drill hole problem that Bob points out exists but as in all interpretations, all of the evidence in each hole is looked at before joining up units.

Bob's chronological outline of the alteration types is useful. However, pyritization may or may not be entirely an alteration feature. Syngenetic pyrite beds are seen in many places

in drill holes and in outcrop. Silicification is also very common and important and may indeed be of more than one event. The term SERT has always bothered me and I hope now that Bob has recognized more than one type of SERT that he has been separating them in his mapping. I would tend to think that dolomitization if late could and does occur in all rock types and can clearly be an alteration feature of mafic volcanics which are seen in the footwal elsewhere on the property.

STRUCTURE It has always been recognized that SAM is a structurally complicated zone and as far as I am concerned the jury is still out on origin. Certainly much deformation has gone on since formation. However, Bob's structural interpretation is confusing as he has the "vein" being thick in the limbs and thin in the hinge area instead of the other way around as is normal. I think we are still dealing with later deformation and vein overprinting of an original syngenetic deposit.

DISCUSSION I appreciate the points that Bob brings up in his discussion and I think that our exploration program has been and is being designed to cover all interpretative possibilities. The drilling pattern is designed to find all minimum sized targets no matter the orientation. We all do think that the CANA intersection may be significant and to that end it will be followed up. However it is still only "noise".

Attached are the comments of some of the rest of the people familiar with SAM.

MINNOVA

MEMORANDUM

DATE: February 18th, 1991

A
TO: AJD

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DE
FROM: IDP

SUJET
SUBJECT: My review of Bob Friesens' update on Sam Mine geology

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I have read Bob's update several times over the last couple of months. While I don't agree with everything he says and much of what he says is not new, nevertheless I must commend Bob on having taken the time to document his views.

The entire issue of protolith being obscured by alteration has been recognized since very early in the exploration of this property. The original logging of RG 1 through RG 15 described the Rea mafics as felsic volcanics. Ever since then we have been very wary of giving genetic inference to the rock names unless there is good evidence for the protolith. Careful core logging of progressive alteration of rocktypes combined with the use of lithochemistry has helped. I am now comfortable with Sam being hosted by sediments and that the various sedimentary lithologies can be recognized in drill core through all but the most intense alteration.

I am also comfortable with the structural interpretation of Glover et al which has succeeded in explaining the internal stratigraphy where previous models have failed. If I have a criticism of Bob's interpretation it is that he fails to recognize the presence of an internal stratigraphy preferring instead to lump everything together as 'sediments' and ascribing all lithologic variations to alteration. At least in part, I think this is due to the difficulty of identifying subtle textural variations in surface samples without slabbing large numbers of samples. In addition, working almost exclusively in the pit area tends to blinker people from the stratigraphic and structural clues offered

by unaltered rocks distal to mineralization.

As far as the comments made about following up intersections such as that in Cana hole C90-6, I totally agree. These intercepts must be followed up and always have been, sometimes overly so as in the case of the 266 zone. However, I don't believe that drilling at right angles to the normal hole direction is the answer. Despite locally crosscutting relationships at Sam, nothing that Bob has described suggests to me that drilling NW or SE would have been better than the usual SW azimuth. Tonnes are developed in the plane of the principal structural grain and we have no evidence to indicate a substantial shift in the orientation of this grain anywhere in the area, let alone on the property. Given the depth of overburden on Cana, this development of tonnes is critical. We will follow up the Cana intercept and similar ones on Sam, but we will do so with a realistic minimum size in mind.

MINNOVA INC
MEMORANDUM

DATE: February 19, 1991.

TO: A. Davidson

FROM: A. Hill

SUBJECT: Comments Re: "Samatosum Mine Geology Update" a memo by B. Freisen, October 1990.

The above mentioned memo provided numerous interpretations regarding the Sam Deposit, from the "in-pit" point of view of the mine geologist. These interpretations are no doubt based on numerous observations, made over a long period of time, and resulting from continual pondering on a daily basis. The value of this kind of thinking cannot be overstated, and the basic "gut feelings" are indispensable.

From my point of view, however, some of the key conclusions seem to be based on observations made in a vacuum, and oblivious to the geology outside of the pit. Furthermore, the rocks within the confines of the pit are some of the most intensely altered and deformed rocks on the property.

Diamond drilling of relatively unaltered and correlatable rocks elsewhere on the property has provided reams of data used for the construction of a working geological model to guide the exploration department. The model has been refined through close scrutiny and systematic testing in the form of: ongoing drilling, re-examination of existing core, regional and property scale mapping, petrography, isotopic and fluid inclusion work, as well as numerous trips to the pit, and examination of pit maps. This work has been documented in the form of several in-house reports (variously by Pirie, Glover, Bradford, Heberlein, Hill, Clarke, Freisen, Curtis, Dixon, Holder, *et al*). This effort represents an extremely large body of work and without a doubt we are gaining a better understanding with every hole drilled.

Briefly, I have listed below some particular points where my thinking differs from Bob's:

1) Stratigraphically, there appears to be three distinct lithological assemblages which occur on the property (as opposed to Bob's two). From oldest to youngest they are: mafic volcanics ("Sam Mafics"), mixed chert-bearing sediments and volcaniclastics ("Sam Sediments"), and black turbiditic sediments ("HW seds or "Argillite Wedge"). This varies with Bob's interpretation that the "Sam Sediments" are the altered equivalent of the "Argillite Wedge".

2) Alteration in the Sam Sediments is much more intense and widespread than in the other rock types. This can be accounted for by higher permeabilities, and/or chemical susceptibility of the package, and possibly by syndepositional hydrothermal activity as well. Many of the unaltered ribbon chert and heterolithic fragmental lithologies contain syngenetic pyrite, and are geochemically highly anomalous in As and Au. In this way they are analagous to the Rea massive sulphide lenses and are thought to represent weak exhalative horizons.

3) These exhalative horizons have been successfully traced across the property by drilling(+2.5 km). The Sam Deposit sits at or near one of these horizons.

4) The grey sericite/pyrite alteration (a.k.a. "Mut") often displays relict textures which reveal the fragmental nature of its host (Sam Seds.). The more argillaceous rocks of the turbidites appear more resistant to this type of alteration, unless first prepared by shearing or tectonic brecciation. The exception to this is some of the sandy or conglomeratic beds within the turbiditic package. I beleive that ascending hydrothermal fluids travelled along structures and selectively through rocks with high permeability, leaving highly altered rocks of one rock type juxtoposed against relatively fresh rocks of another type. Late faulting has further complicated the picture, especially in the pit.

5) Fuchsitic rocks immediately below the ore zone almost certainly represent highly altered mafic volcanics. This interpretation is based on geochemistry, and numerous observations of altered mafics elsewhere on the property.

6) I do not understand Bob's structural ideas completely, but in his fig.3 schematic sketch of the ore vein on 1300 bench he has neglected to show the chaotic buckle folding of the vein which has produced significant structural thickening. I have never seen an ore face with a simple concordant vein, without many phases of quartz-carbonate veining and tight folding of both the veins and the surrounding host.

7) The Sam Deposit quartz-sulphide veins are best developed in the Sam Sediments just below the contact with the black, argillaceous turbidites. This empirical relationship may be the result of the "damming " of fluids by a resistant cap rock, and/or an abrubt change in the chemistry of the fluids by reaction with country rock (either the argillites or the sulphidic exhalative rocks already at this position in the stratigraphy).

Alan R. Hill, B.Sc.
Feb. 19, 1991.

44-3560

MEMO TO ALEX DAVIDSON

THOUGHTS ON BOB FRIESEN'S PAPER:

"SAMATOSUM MINE GEOLOGY UPDATE"

By Keith Glover

Bob's paper emphasises the epigenetic features of the alteration and mineralization, especially with respect to the cross-cutting nature of MUT/argillite contacts and the quartz veins that host the mineralization at Sam. I have no problem with these observations whatsoever - in fact, they underline the main reason why Sam presents such an enigma from a strictly syngenetic viewpoint (and hence the reason for my original involvement and the subsequent involvement of the McGill research group with the project). However, there a some major problems with his structural interpretation, both in terms of our present knowledge of the deposit's geological setting and what is mechanically possible.

The following points are in the same order that these topics are presented in Bob's paper:-

1. GEOLOGY-LITHOLOGY AND ALTERATION

Although most chert occurrences in the pit may be due to silicification, the widespread distribution of thinly bedded to laminated chert and argillite sections of obvious sedimentary origin in the 266 zone, and the occurrence of exhalative chert within the Rea stratigraphy, should make us extremely careful about such generalizations.

2. Contact Relationships of the Deposit Area Lithologies

a) The upright stratigraphic facing of the argillite footwall, based on recent pit drilling, agrees with original observations of small-scale asymmetric folds and bedding/cleavage relationships (Glover, Progress Report: June 1989, p.3, #7). Graded bedding was also found within some of the turbidites intersected in R.G. 67 and R.G. 70 (Glover, Progress Report, September, 1988, p.2). These data are incorporated into the most recent model that I proposed (Glover, Progress Report, June 1990):- the argillite footwall in the vicinity of the pit is on the upright limb of the overturned syncline, the hinge zone of which lies within the argillite wedge.

b) The interpretation that the argillite wedge represents the core of this overturned syncline is not based on the repetition of the MUT on either side of the wedge, but on

the occurrence of small-scale symmetric folds within the core of the wedge and the change in vergence of small-scale asymmetric folds on either side. Therefore, the argillite wedge cannot be dismissed as a remnant within the MUT. However, there is an impressive amount of evidence to demonstrate that the mineralization (and the MUT) predates folding and the associated penetrative deformation. As such, the occurrence of the mafic volcanics, MUT and quartz veins on either side of the overturned syncline, to the northwest of the pit, strongly supports the notion that the "Barite Horizon" and the "Sam Horizon" are equivalent. The axial trace of the overturned syncline has been defined both on section and in plan by drilling, and passes right through the pit. Any model that seeks to explain the geometry or structural evolution of Sam must take this into account.

c) Page four, last two paragraphs:

I find it extremely difficult to attribute sericitic alteration in the lower portions of the mafic pyroclastics to thrusting - the sericite within this zone defines a foliation (flattening fabric) that is not bounded on either side by shear planes, as one would expect. On the contrary, the degree of sericite development appears to be gradational and mimics the increasing abundance of isoclinally folded and boudined quartz veins and stringers from the hanging wall toward the ore zone. This is most simply interpreted as the result of deformation and metamorphism after emplacement of the quartz veins and associated alteration.

The statement that sericitic alteration displaces MUT/argillite from the ore zone may be true, but I would be interested to hear what evidence there is to support this.

d) Fuchsite

The origin of the fuchsite in the immediate footwall of the ore zone is still problematic in mind. However, it seems somewhat coincidental that it occupies the same structural position with respect to the ore zone as the mafic volcanics below the "Sam Horizon" to the northwest.

e) Dolomitization

There is evidence for several phases of dolomitization. Perhaps the major phase is late, but there is also abundant evidence for early dolomitization. For instance, in core from the 266 Zone, where dolomitized clasts of mafic tuff occur in an unaltered argillaceous matrix. The lithologic similarity of these clasts with the "dol seds" that commonly occur close by, and with the footwall sequence structurally above the Rea Horizon is striking, and led to their interpretation as previously lithified and dolomitized mafic tuff beds that were later incorporated within debris flows.

It would be interesting to compare these lithologies with those intersected in the recent pit drilling in the footwall of the ore zone, which Bob refers to in his paper, especially as they may occupy the same stratigraphic position.

STRUCTURAL INTERPRETATION

I am confused with regard to Bob's evidence for an earlier phase of folding. For my part, I've not seen any evidence for this, either on surface or in drill core. Moreover, I cannot see how isoclinal folds are synonymous with folded folds. All the evidence, both in the pit and elsewhere, points to one progressive phase of penetrative deformation. The local development of a weak crenulation cleavage in the less competent units is probably a consequence of rotation of earlier formed foliation planes during progressive deformation, and cannot be used to explain the geometry of the ore zone. Similarly, regional cross structures, reflected by changes in plunge, are of minor importance and do not represent a significant amount of strain.

Bob's model necessitates thinning in the hinge and thickening on the limbs of his proposed fold structure: this only occurs in folds associated with compaction during sedimentation ("drape folds"); the opposite pattern is universally observed and mechanically predicted for tectonic folds.

The changes in orientation and thickness of the vein(s) within the ore zone are more likely a reflection of original orientation and thickness variations that have been accommodated and, in some cases, accentuated by progressive deformation.

The above discussion is intended as a constructive critique, from which, hopefully, further discussion and data collection will ensue. I hope it's usefull.

Respectfully submitted:

J. Keith Glover

Geological Consultant

MINNOVA INC.

DATE: February 19, 1991

TO: Alex Davidson

COPIES TO:

FROM: Dave Heberlein.

SUBJECT: Re: Bob Freisens' Memo entitled "Samatosum Mine Geology Update".

Bob's memo on the geology of the Samatosum deposit deals exclusively with observations made in the pit area. Although it is a good summary of the pit geology, it does not incorporate the results of recent work by Keith Glover, John Bradford, Al Hill and Jim Clark or the enormous geological and geochemical database on the property and surrounding area. As a result, I feel that Bob's conclusions about the genesis of the deposit are not supported by the overall geological picture.

My biggest criticism of his memo is the comparison of Samatosum to an "epithermal or mesothermal" type system. This is totally unsupported by the data. From work on the property in the last two years it has been shown that the Sam deposit is a very early feature, perhaps coeval in age with the volcanic and sedimentary rocks that host it. Evidence to support this is as follows:

- Pb isotope ages from Sam are the same as Rea Gold (i.e. Devonian), which is almost certainly a syngenetic deposit.

- Sam is spatially associated with syngenetic sulphide mineralization. Conformable bands of massive pyrite have been noted throughout the Sam sediment sequence. The best examples have actually come from the pit.

- Along strike to the north of the deposit, the Sam Horizon is clearly stratabound and almost identical to the Rea Horizon. Here, mineralization and alteration are best developed in and adjacent to heterolithic sedimentary breccia units.

I cannot see the link with an epithermal system. Epithermal deposits are by definition, formed at a shallow depth in a subaerial environment. The host rocks at Sam are entirely subaqueous in origin. If by epithermal Bob is referring to a high level vein deposit, perhaps a feeder to a syngenetic sulphide system (Glover, 1990), then his choice of terms is misleading. His interpretation needs clarification and support with direct field evidence.

I also disagree with Bobs interpretation of the fuchsite in the footwall of the orebody. Bob ascribes this to a shear related alteration, but does not explain how or why. This mica has been probed (Kerry Curtis, 1989) and confirmed as a chrome bearing mica. Where has the chrome come from? Seeing that chrome is a relatively immobile element, I suggest that the fuchsite represents the alteration product of an original chrome bearing lithology, i.e a mafic volcanic. Despite Bob's comment to the contrary, there are mafic rocks in the footwall stratigraphy (e.g. the infamous dol seds) elsewhere on the property.

Identification of the argillite wedge as an unaltered "remnant" also conflicts with our current understanding of the stratigraphy of the Sam package (Glover - June, 1990; Bradford, pers. comm.). From property mapping and interpretation of drill data it has been shown that the argillite wedge is a synclinal keel of turbidite that stratigraphically overlies the Sam "horizon". This sedimentary sequence can be correlated with the Rea "Hangingwall Sediments".

In summary, I feel that the interpretation presented by Bob in his memo, does not take in to account critical lines of

evidence documented by Glover, Bradford, Clark and Hill. He has interpreted Sam from a very restricted database and as a result produced an unsubstantiated and inappropriate conclusion.

Dave Heberlein.

MINNOVA INC.

DATE: February 19, 1991

TO: A.Davidson

COPIES TO:

FROM: John Bradford

SUBJECT: Memo on Sam by Bob Freisen

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1. Contact Relationships

Two main points here: (1) facings in the footwall argillite indicate the "Sam horizon" is right way up, (2) ore veins and associated sericitic alteration crosscut the turbidite "wedge" in the pit. These are significant observations, but some of the implications drawn are inconsistent with observations made away from the pit.

First, an upper, overturned fold limb and synclinal fold symmetry enclosing an unaltered turbidite core is characteristic of the sections around 104-106 and beyond to the north. The upper limb is probably cut out (in part ?) in the pit by the mafic/sediment thrust oontact, which on a gross scale cuts down-section toward the southeast. This, and the intense vein overprint in the pit, might account for Bob's doubts about the synclinal interpretation.

Second, point (2) doesn't imply that all altered sediments are of a common protolith. The pyritic, heterolithic fragmentals, altered volcaniclastics and bedded cherts found along with argillites stratigraphically below the turbidite package have no equivalent within the turbidites to my knowledge, and do not represent an alteration facies. Again, this has been demonstrated fairly clearly in the 266 Zone by Keith, and is supported by Bob's own observations (a volcanic component in the ore zone footwall: p. 5). Observations of MUT "grading into" unaltered turbidite in

the pit (p. 3) should be taken with a grain of salt because of the intense vein overprint and local structural complications.

2. Alteration

Bob's observation that pyritization (MUT) is an early, footwall phase is compatible with a pre-ore, syngenetic phase of mineralization, preceding turbidite deposition (this is my bias). At least some of what has been called SERT, on the other hand, clearly crosscuts the turbidites, and occurs in the ore zone hangingwall, as he notes. This is pretty obviously an alteration halo around the vein system, and postdates the onset of turbidite deposition. These observations, coupled with regional correlation of the turbidite with the Rea sediments (=EBP), clearly imply two temporally distinct mineralizing events, the first being the distal stratigraphic equivalent of Rea (the pyritic "Sam horizon"), the second being Sam (the main quartz vein system). I have no opinion on the fuchsite protolith controversy; it could probably be resolved with careful geochemistry. I do know that a volcaniclastic component is present north of the pit in the sub-turbidite package.

3. Structure

I don't understand Bob's structural interpretation very well. He seems to be saying that the fat part of the vein on 1300 level is a relatively unfolded portion, while progressively thinner portions on higher benches are caught up in the hinge of a north plunging fold structure. From this we are apparently to conclude that economic thicknesses occur on fold limbs only (or in broad, flat hinges ?). This is counterintuitive, and doesn't accord with my own observation that the fat part of the vein appeared to be intensely isoclinally folded (and probably structurally thickened). I can't see the thinning on higher benches being <u>the result of</u> tight folding, since vein material is more likely to migrate into hinge zones away from extended and thinned out limbs. I haven't

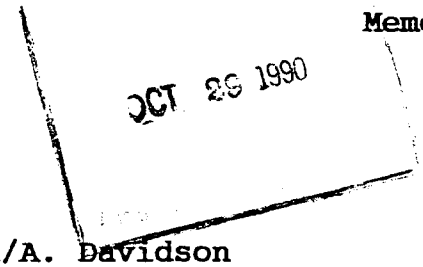
seen as much of the pit as Bob has, but in general, avoiding fold hinges seems like a dubious strategy. Bob's own diagram of the 1370 bench shows why.

I agree that Sam is a bit of an enigma. It certainly lacks most of the diagnostic features of an epithermal vein; a mesothermal P-T regime seems more likely to me. High-level features such as growth zoned quartz (in RG-85) probably belong to the pre-ore, syngenetic phase of mineralization. From my own experience, mineralogically identical veins (e.g., Elan vein) occur within the Erickson vein system as a cooler, silver-rich periphery around the gold-rich core. There is very good evidence that this system is related to a deeply buried pluton.

Controls on ore vein emplacement are not understood at all, although you can speculate about cross-structures and growth faults related to early syngenetic mineralization. The problem is that the vein itself has obliterated most of the evidence, and later folding has obscured predeformation geometry.

MINNOVA INC. Memorandum

SAMATOSUM PROJECT



DATE: October 25, 1990

TO: J. K. Carrington/A. Davidson

COPIES TO:

FROM: J. Purkis

SUBJECT: R. Friesen's Geology Report

Attached for your review is R. Friesen's report on his interpretation and theories developed from pit mapping and other observations. I have also enclosed the McGill Research Program, Research Grant Application.

Since early 1988, Bob has consistently leaned towards a quartz vein model to explain Samatosum. The bulk sample pit did nothing to change this view, nor did the 1988 diamond drill program. As a group, we tended to discount the negative implication of this due to the repeated achievement of high grade intersections in subsequent programs and the fact that ore reserve tonnes and grade did not change with more drilling.

Partially in hindsight, but also an admission of lack of diligence, more study of grade distributions of all metals and the introduction of severe grade cutting after seeing vein type mineral distribution in the bulk sample pit were in order. Although discussed at the time, no action was taken other than initiating the data transfer to Gar Blackwell's student. Nothing came of this and one can only speculate whether this would have impacted interpolation methods.

Until now, we never had a report summarizing the observations and presenting them as an explanation of configuration and genesis. This lack of formalization of the observations has made it too easy to ignore and discredit the ideas.

I am not qualified to pass judgment on the content of the report. It has taken considerable prodding to get it written and I have assured Bob it will be professionally and objectively reviewed. There are no negative repercussions from an unfavourable review as Bob's stature among the exploration group can get no lower.

Bob's work habits always leave him "behind the pack" and feeling to be unheard. His unwillingness or inability to do or say things at the "right" time is his weakness and exploration is correct in eliminating his involvement in the operational end of their programs.

At the same time, no one has spent as much time looking at mine geology, here or elsewhere, as he has. Everyone of us has stressed at some time in our careers the importance of bridging this chasm between the two groups. Hopefully, we are not going to make the same mistake here, but, unless Bob can work with exploration personnel and consultants in an atmosphere of mutual respect, this will happen.

To reach a conclusion, I need this report reviewed. Bob will never perform adequately if he continues to be preoccupied in professional "wars". The fact that he feels the coldness and avoidance is not helping; so, if he is wrong, will somebody please tell him why in writing.

John Purkis

JOHN PURKIS
Mine Manager

JP:im
Attachments (J. K. Carrington)

SAMATOSUM MINE GEOLOGY UPDATE

INTRODUCTION

Pit mapping over the past several months has provided new geological information on the Sam Deposit area. Apart from providing the mine with much needed data for its interpretive work, the data is also significant enough for consideration in the development of future exploration programs in the vicinity.

The alteration and structural history of the Sam Deposit is incredibly complex. The following notes represent my current thoughts on the geology and genesis of the Deposit, developed after more than a year of observing, walking over, and mapping the Deposit. This detailed view has led me to conclude that certain geological relationships are visible in the pit which would otherwise be extremely difficult to interpret correctly from diamond drill core examination. In my opinion, good solid geological mapping information should carry the most interpretive weight. Now that good rock exposures are available in the pit, drill core evidence and laboratory data should be used to complement, and confirm or guide geological observation and thought—not necessarily control it. Although much fact–finding remains to be done, the ideas expressed in this report should help us better understand Sam and should be considered for both future exploration planning and in the McGill research program.

GEOLOGY—LITHOLOGY AND ALTERATION

The Sam Orebody is a stratabound quartz vein deposit of probable epithermal or mesothermal origin. In the Deposit area, the original lithologies are mafic pyroclastics structurally overlying a sedimentary package of turbidites—predominately argillites, wackes, and argillaceous "mixed sediments" (mixed sericitic argillite/chert unit at the northern and southern extremeties of the Deposit) and their altered equivalents. Alteration is widespread and complex throughout the Deposit area; so much so that on the basis of scale, it is probable the ore zone is a product of one or more of the widespread alteration events, rather than the other way around. Certain originally interpreted lithologies such as SERT, MUT, quartzites, and cherts are essentially systematically altered equivalents of these original lithologies—such that the area is presently underlain by a **combination** of the original turbidites and their altered equivalents.

Although the alteration trends appear conformable, there are local strong discordancies as explained below. There is also the possibility these alteration features with the ore zone follow a low angle crosscutting trend through the original turbidite sequence, from the structural footwall to the north into the structural hangingwall to the south—giving the

impression of separate hangingwall and footwall components of unaltered turbidites (argillite "wedges" or remnants).

Contact Relationships of the Deposit Area Lithologies

Of more significance to regional interpretation, the Sam Horizon appears to be "right way up"; as evidenced by the majority of facings in the recent pit drilling in the footwall argillite. In the pit, local overturning of the structural base of the mafic pyroclastics can be explained by drag folding near the sheared contact with the Sam Horizon sediments. However, because of the existence of at least 2 phases of deformation, and the resultant isoclinal style of folding yielding maximum amplitudes of only a **few meters** (producing facings in both directions), final resolution of this problem could be accomplished by a statistical comparison of overturned vs "right way up" observations across the **entire stratigraphic sequence**—with the final decision made on the basis of the numerically dominant facing direction. Detailed examination of Rea Horizon core by Keith Glover indicates it is overturned; however, to my knowledge, Sam has not been similarly examined.

I believe a true understanding of the geology of the area will be achieved with the recognition of the importance of distinguishing altered vs unaltered rocks, and that the altered sedimentary rocks essentially had a common protolith of a predominately argillaceous nature. Thus, altered rocks in the Deposit area should not necessarily be interpreted as totally different lithologies from the unaltered rocks with which they appear to be in contact. This is especially true for the symmetrically synformal interpretation given to the "argillite wedge" and its encompassing MUT immediately northwest of the Deposit. Bedding within the argillite "wedge" could easily be discordant to the contact with its altered counterpart—the hangingwall and footwall MUT; and the interpreted fold axis through it could be at a considerable angle to the remnant.

These relationships reveal a potential diamond drill core interpretation problem:

- On a section with a single argillite intersection in one hole and an argillite and MUT intersection in another down–dip hole, it is almost certain the two argillites will be correlated, with little consideration given to correlating the argillite to the MUT. Yet in the pit, argillites and MUT can be correlated within the same lithological horizon.

Alteration Types and Relationships

Excluding the regional greenschist facies grade and its ubiquitous chlorite alteration in the mafic pyroclastics, pit mapping reveals the significant alteration components to be (in chronological order as per current thinking):

- Pyritization (MUT)
- Silicification (includes ore event) and
- Sericitization/pyritization (SERT)
- Fuchsite
- Dolomitization (+/-calcite)

Sorting out the true chronological order of the alteration events is still at best, very confusing due to the presence of conflicting relationships—the result of multiple stages of overprinting and later modification by at least two phases of deformation and thrust faulting. Pyritization is currently thought to be pre–ore, and silicification/sericitization is thought to be ore–related; fuchsite is spatially related to the structural footwall of the ore zone in sheared wallrocks. The major dolomitization event is thought to be a later, possibly post–ore event.

The following subsections discuss these alteration phases in more detail.

Pyritization

In the Deposit area, the light to medium grey MUT dominates the immediate footwall and lower, down–dip hangingwall of the ore zone. The MUT units are interpreted to represent an early, intense "pyritization" form of alteration in the argillites within the Sam Horizon—often containing up to 60% or more very fine grained pyrite. In the mine area, MUT are more extensive, but always intimately associated with their unaltered argillite equivalent. They often contain an argillaceous component as "lithic fragments". Evidence in support of this pyritization process lies in the hangingwall of the Phase 1 ore zone, where a large MUT unit (as an "alteration front"), surrounded by SERT, could be seen to grade **along strike** southwards, into an unaltered argillite, typical of the many "remnants" found along the Sam Horizon.

Evidence of accompanying silica may be explained by a cherty component often associated with the MUT ("cherty MUT").

This alteration event was intense and destructive as in many instances the original turbidite textures have been obliterated.

The reason for believing it to be an early alteration phase is that MUT can be seen to be locally silicified in the footwall of the ore zone.

Silicification and Sericitization/Pyritization

Silicification is common in the Deposit area as localized ore–related silicified wallrocks (eg., former "quartzites") to the orebody and as silicified graphitic argillite/wackes (formerly "black cherts" footwall to the ore zone, and in the hangingwall rocks at or near the mafic pyroclastic/sediment contact). Early, silicification is generally intense but localized as for example, on the Phase 1, 1280 Bench, where only a few meters of the footwall portion of a 20m thick argillite remnant nearest the ore zone is silicified; the rest is unaltered. This event may be directly ore–related, although it is not yet known with certainty when and how many episodes of silicification there have been. Another phase of silicification may be represented by the hangingwall silicified argillites which are riddled with deformed, unmineralized, quartz veins and veinlets.

The altered wallrocks enclosing the orebody consist of SERT on the structural hangingwall side of the ore; and MUT and their unaltered equivalents—the turbidites—on the footwall side. It has been observed numerous times in the pit and in drill core, at all scales, that quartz

veining may occur at the contact of two differently altered rocktypes. On the 1280 Bench, the quartz vein ore zone terminates along strike northwards within the sheared contact between the MUT and SERT.

Sericitization is abundant and well–developed in the Deposit area and is regional in proportion. Collectively, any strongly sericitic rock in the Mine area is termed a SERT; however in reality, there are at least two types:

- sericitic mafic pyroclastics—recognizable by the greenish brown colour, and location; which is often in the highly strained, sheared mafic/sediment contact area, and generally surrounding the nearby silicified hangingwall argillite.
- sericitic sediments (argillite/wacke)—recognizable by their yellow to buff colour, and location: in the immediate hangingwall and sometimes footwall of the ore zone and lower down in the footwall of the ore zone. Often, original centimetre scale syngenetic (yes, syngenetic!) pyrite beds from the original argillite/wacke protolith still remain.

Throughout the Deposit area, well developed sericitic alteration (as sericite schists) appear most commonly as a concordant feature; however, local strongly discordant sericitic alteration is also evident (eg. 1330 Bench, Phase 2, in the footwall of the ore zone where there is a substantial crosscutting SERT "alteration front" in the argillite unit).

Disseminated pyrite is a common feature of sericitized rocks, as are thin lenses and beds of cherty silica which may often form a major component of the SERT—indicating a quantity of silica accompanied the sericitization process.

As with the other alteration events, not enough is known about the relationship of sericitization to the ore and its timing; however, because sericitic alteration extends structurally upwards into the strained, lower portions of the mafic pyroclastics, some of the sericite may actually have a tectonic origin—during the later thrusting process—in the vicinity of the volcanic/sediment contact.

Sericitic alteration (at least the yellow variety) is thought to be later than MUT and silicification because it is known to "displace" MUT/argillite from the ore zone.

Fuchsite

Fuchsite alteration is very intense for 1–2 meters into the immediate footwall of the ore zone along its entire exposed strike length, regardless whether the footwall rocks are SERT, silicified argillite, argillite, or MUT. I have always held to the belief that by quantity and association, it is a shear–related alteration feature where thrusting and sericitic alteration in contact with MUT and argillite is strong. I realize this is contrary to another belief (e.g. Keith Glover) that by the chemical association with chromium, and the relatively common occurrences (much lesser intensity though) of fuchsite throughout the mafic volcanic units on the property, this footwall fuchsite occurrence represents a highly sheared original mafic volcanic horizon. The problem I have with this interpretation is that I have yet to see any

convincing sign of a significant mafic volcanic unit in footwall contact with the ore zone—it is **all sediment.**

Dolomitization

The major dolomitization event appears to have been late. When at its strongest, it produces a weakly to non–foliated texture, often distinctly mottled. It is most abundant in the mine area within the sheared mafic/sediment contact in the Sam Horizon. Also, recent pit drilling has revealed a distinct zone of dolomitization in the footwall of the ore zone beginning about Section 100+00mW and trending northwards away from the ore. In this latter instance, it is believed most of the protolith was sediment; however, in one instance, a texture resembling dolomitized lapilli was noted; indicating the possible inclusion of a volcanic component in the mine stratigraphy at this end of the Deposit.

Summary

Figure 1 schematically represents the above lithologic and alteration relationships as they now appear in the pit.

The ore body is still an enigma. As a quartz vein, it is well mineralized with tetrahedrite, sphalerite, galena, chalcopyrite, and minor pyrite. It is surrounded by extensively altered rocks described above; yet with all this alteration, including numerous other base metal and pyrite mineralized quartz vein occurrences, we do not yet understand why it is the only quartz vein in the area containing significant tetrahedrite.

STRUCTURAL INTERPRETATION

Regardless of genesis, it is now generally accepted by most who have seen Sam, the orebody is an unusual **stratabound** quartz vein occurrence; generally tabular in shape, and averaging about 5 meters thick, 450 meters long and varying about 100–150 meters in dip length.

Thrust faulting with its associated folding, and cross faulting were thought to be the dominant structural features affecting the ore zone.

Within the last two months however, a more complicated structural picture has emerged. In addition to the abovementioned features, the Deposit area stratigraphy shows increasing evidence of an earlier phase of folding, such that what really occurs is isoclinal or "folded folds". There is also evidence of original ore vein discordancies.

It appears we are mining the thicker, flattened, down–plunge portion of the ore zone which upwards has been caught up in a north plunging fold structure. Figures 2 and 3 schematically illustrates the development of this structure and its effects on the ore zone from the 1330 Bench, upwards to the 1350 and 1370 Bench where the ore vein has been tightly folded and thinned to only a few centimetres. Axial planar cleavage/foliation is very strong. It can be seen that the ore zone is only economic in the limbs and flattened portion of the fold where

it is thickest (possibly original dilatant zones suitable for thickened veins to occur; or more probably, zones of less strain during development of the drag fold and thus are relatively undeformed by this structure). It is significant to note that in the area of the ore zone, the ore horizon (ore and SERT) between the mafic volcanics on the hangingwall and the MUT/argillite on the footwall) is 80 to 100 meters thick; whereas on the 1370 Bench, in the area of the tightest occurring fold structure, this same package of rocks is now only 10 meters thick.

This fold structure may be either a large–scale equivalent to the isoclinal style folds which are very well developed in the hangingwall silicified argillite unit on the 1330 Bench, the ore zone itself, and the footwall argillite; or a completely different third phase of folding. Until now, very little has ever been said about folding other than Phase 1 as we have only been able to observe them reliably and consistently in the Phase 2 mining.

Together with the previously recognized folding and thrust faulting, this new structure adds a whole new dimension of structural complexity to the deposit. Isoclinal folding may explain the sudden disappearance of the northern, down-dip portion of the orebody between Sections 100+20mW and 100+40mW; from a 30m+ thick zone of quartz vein, to virtually nothing in the space of 20 meters!

DISCUSSION

So how do these interpretations affect the progress of future geological work at Sam?

I believe the thoughts and interpretations expressed here on alteration and structure should be applied and tested in future exploration ventures in the area. As stated before, we must realize and appreciate the extreme geological complexity of Sam:

- We are being exposed to a deposit with an extremely complex multiple alteration and deformational history.
- The ore zone and alteration are mostly concordant, producing a stratabound effect; however, local strongly discordant ore–related veining and alteration is becoming more apparent.
- As the alteration package (especially sericitization, pyritization and dolomitization) is very complex and extensive, the original argillite/wacke protoliths now form only remnants within the horizon.
- These remnants are common within the Mine Series rocks and probably represent the sole protolith for much, if not all of the Sam Horizon .

The argillite/wacke remnants always have their altered equivalents (MUT) closely associated with them. We must be careful to not always interpret a lithological change simply because two differently altered rocks are in contact with each other. For example, a MUT

in contact with a zone of strongly dolomitic alteration may be interpreted to be a MUT/dolomitic mafic volcanic contact. Why? If there is no obvious lithological boundary, or apparent volcanic texture remaining, it could also be a dolomitic MUT or argillite.

The Deposit area—including the ore zone—has been subjected to more than one phase of folding producing isoclinal fold styles with resultant undulatory fold traces within the entire package.

Finally, I believe we can relate the abovementioned fold interpretation in the pit to what may be a **very significant tetrahedrite–bearing intersection** made recently on the Cana Property. We can no longer pass this sort of intersection off as "noise".

As discussed earlier, the 1370 Bench of the open pit reveals the ore vein(s) have been subjected to tight folding and subsequent thinning to only a few centimetres. On the Cana Property, drill hole C90–6, intersected a 2–3 centimetre discordant tetrahedrite/sphalerite–bearing quartz vein in a chert unit. Immediately below this intersection the cherts displayed a well developed cleavage normal to bedding—indicating a fold hinge structure possibly analogous to what is described above at Sam; i.e., this intersection may represent a tightly folded, thinned vein, **high up** in the fold structure. If this is so, we should continue exploring this area (and any other similar occurrences) at depth—trying to follow the limbs of the fold in the hope the vein flattens and produces a thicker vein structure. It would be necessary to work out the orientation of the fold structure as it would not necessarily be the same as occurs at Sam. This may even require some drilling be done off grid azimuth—to the northwest or southeast.

Bob Friesen

17/10/90

SCHEMATIC PLAN OF SAM ORE HORIZON - SOUTH TO TOP OF MAP.

≈ 1300 ELEVATION.

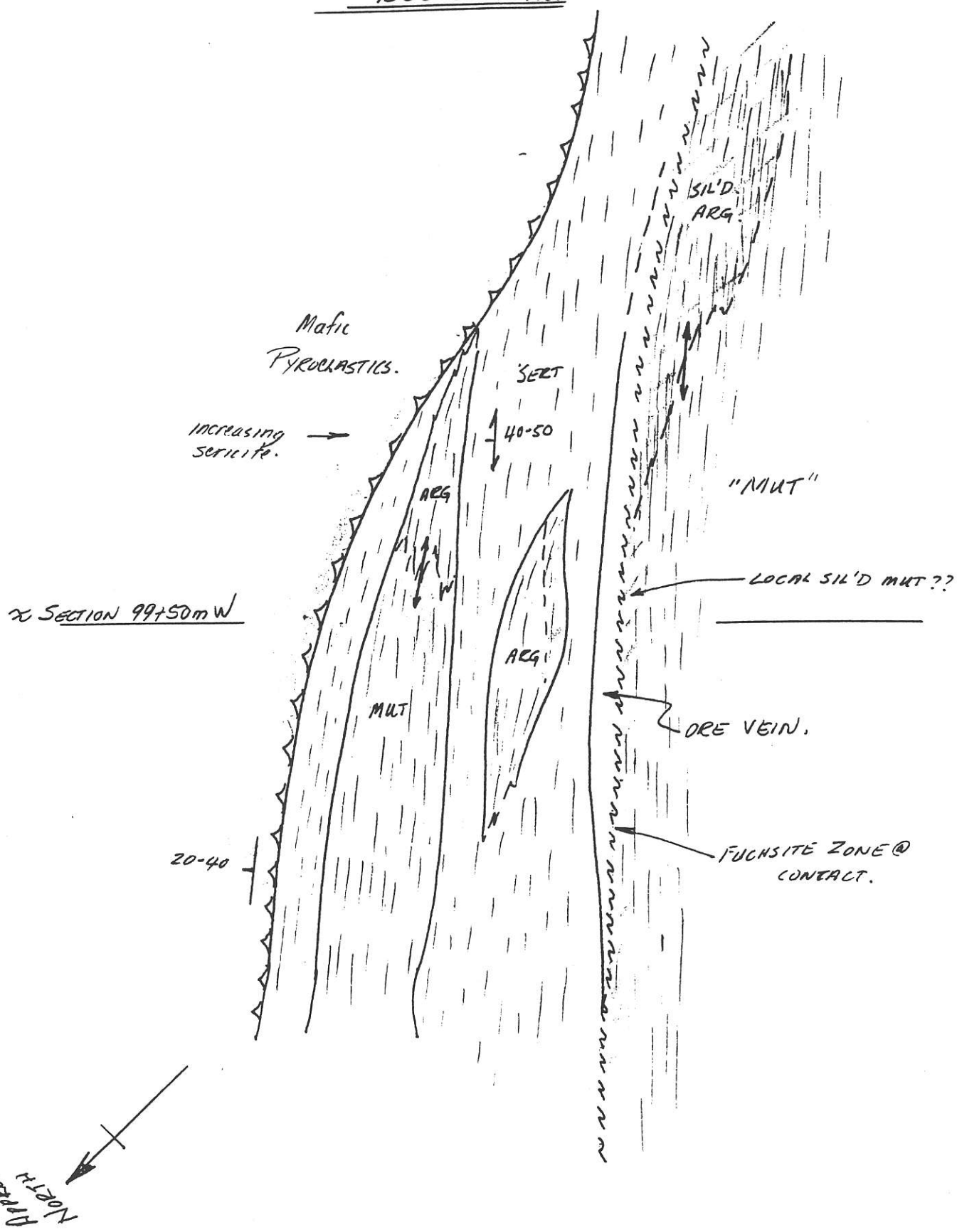


Fig. 1.

B.F. 24/9/90

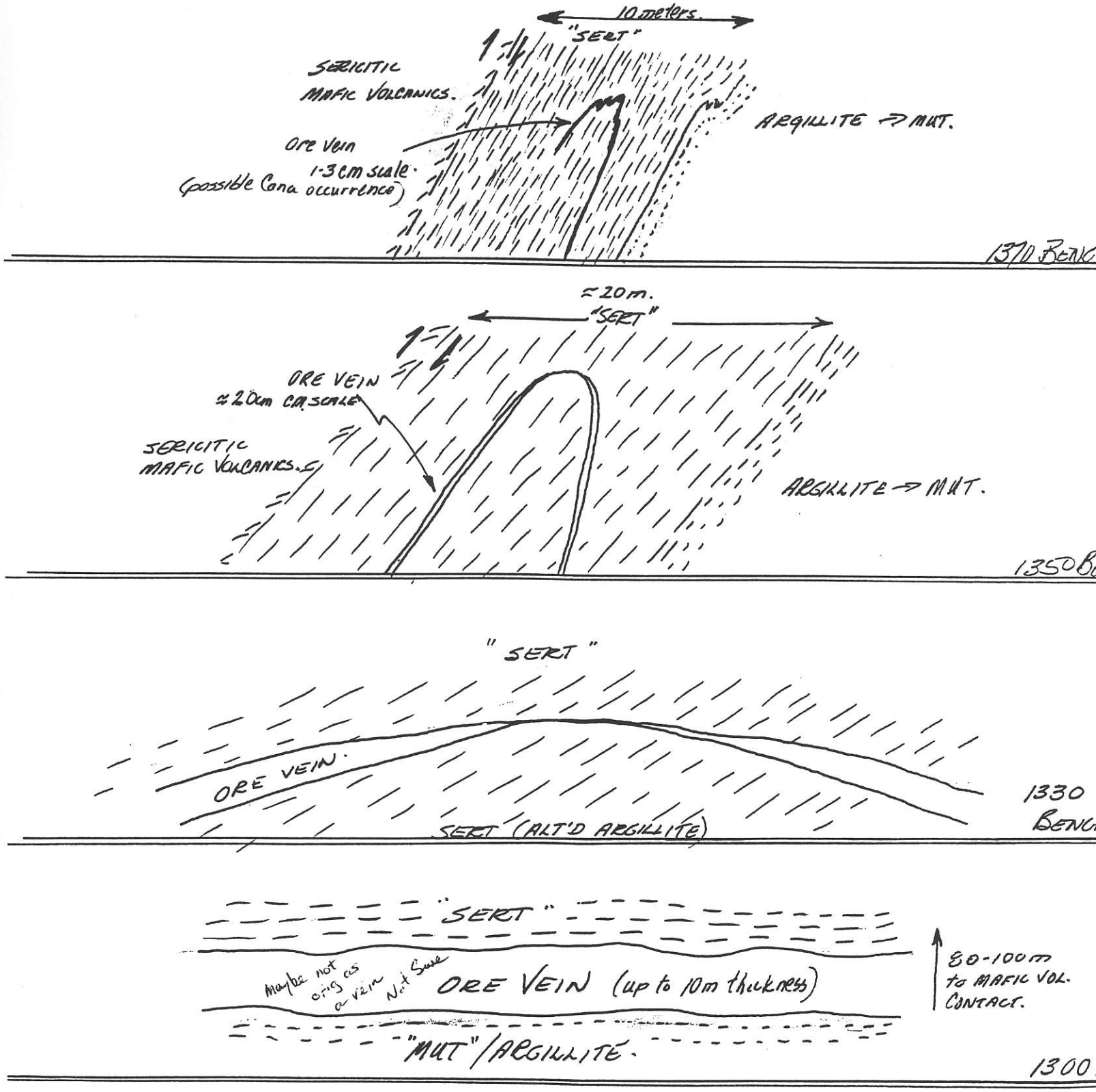
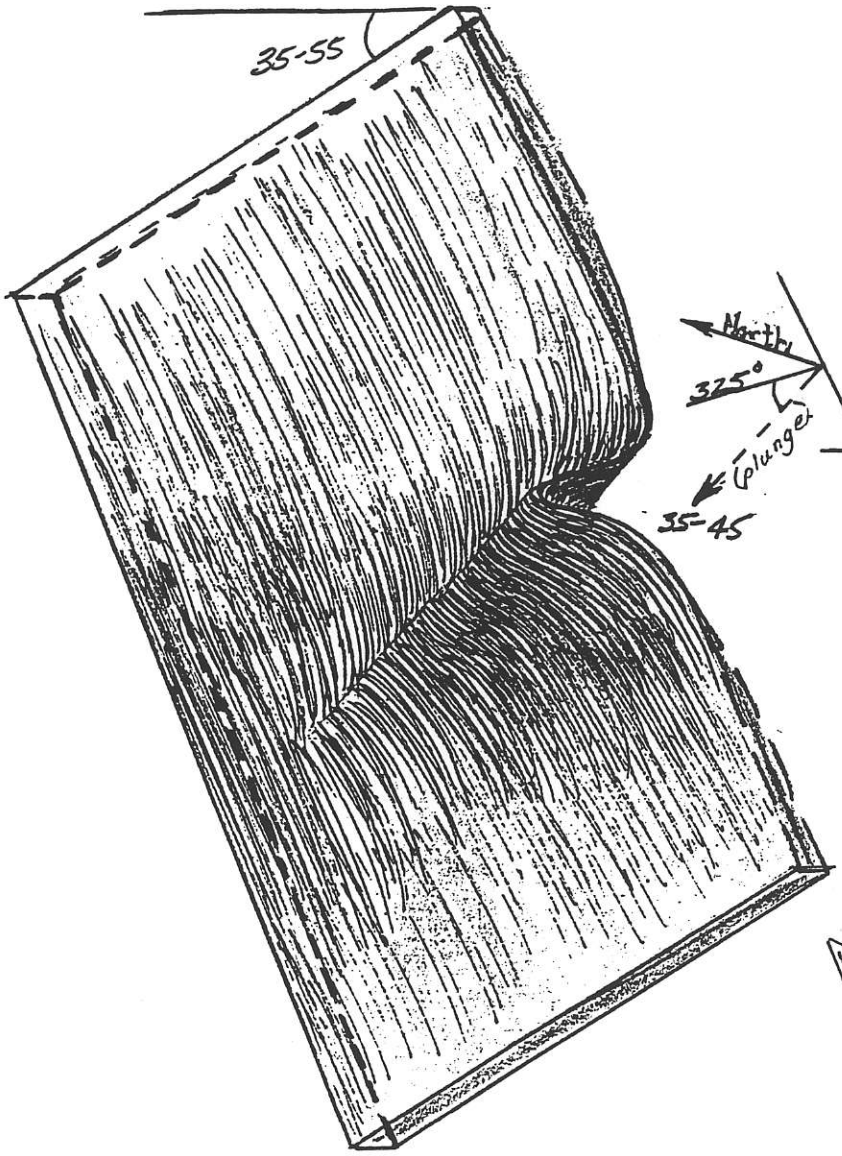


Fig. 3. SCHEMATIC SECTIONS LOOKING WEST. B.F. 24/9

SHOWING DEVELOPMENT OF FOLD STRUCTURE.

Schematic Portrayal of Interpreted Fold Geometry @ Sami



B.F. 24/9/90

Fig 2.