SUB-BASIN RECOGNITION IN THE PURCELL ANTICLINORIUM

By Andrew Legun

KEYWORDS: Aldridge Formation, Sullivan Deposit, Moyie sills, synsedimentary faults, marker laminites, Fringe marker, stratigraphic isopachs

INTRODUCTION

This study traces the stratigraphy above and below the Sullivan deposit. Thickness trends are assessed within a regional context. The presence of marker laminites within the Middle Aldridge facilitates such a study. Cominco has identified more than twenty marker zones, some of great lateral extent (Heubschmann, 1973). Hagen (1981) used the markers to evaluate sedimentation patterns between time lines. He concluded, "It should be possible to assess the role of syndepositional faulting in the evolution of the basin and in ore formation." The present study pursues this theme. It considers the stratigraphic interval from the Fringe marker to the footwall quartzite below the deposit. The area of study extends from the Kimberley area to Moyie Lake (Figure 1).

THE SULLIVAN DEPOSIT

The Aldridge Formation hosts the Sullivan deposit, a large stratified lens of iron-lead-zinc sulphides. The lens rests on intraformational conglomerate which in turn overlies a tourmalinite pipe consisting of breccia, altered strata and veinlet sulphides.

The orebody is up to 100 metres thick and about 2000 metres in diameter. The orebody consists of massive sulphides that grade vertically and laterally into interbedded sulphides and clastic rock. The sulphides comprise pyrrhotite, sphalerite, galena and pyrite in bands, which are very finely laminated over distances of two kilometres. Synsedimentary features include delicate monomineralic bands, clasts of pyrrhotite indenting sediment laminae, and soft sediment slumps of sulfide rich sediment (Hamilton *et al.*. 1982; Ransom 1989, see photo 15)

The Sullivan deposit formed as a result of discharge of metal-bearing hydrothermal fluids to the seafloor through a vent system. The well-bedded eastern ore formed as a result of precipitation from a convecting brine cell developed over the vent (Höy *et al.*, 1990).

The deposit grades laterally into a fine grained sequence of rocks, the Sullivan facies, located at the top of the Lower Aldridge Formation and lying directly under coarser sediments of the Middle Aldridge.

Regionally the Sullivan facies has elevated values of Pb, Zn, Ag. For this reason there has been extensive drilling to the Sullivan "horizon" in search of other vents.

THE DEPOSIT MODEL

The model for shale-hosted submarine exhalative deposits stresses the importance of sub-basins within a host extensional basin. Subbasins are bounded by faults, and such basins may host ore deposits. The Helena embayment is a second order basin; a re-entrant at the eastern edge of the Aldridge basin in Montana. The Sheep Creek Cu-Co camp is related to the Volcano fault at the edge of the embayment (Himes and Peterson, 1990). Here, dramatic facies changes within the Newland Formation mark the fault.

Winston (1986) notes that it is not easy to discern the faults of the Helena embayment away from the basin edge. Their principal signature within the main basin appears to be dramatic thickness changes and areas of soft sediment deformation.

The Sullivan deposit lies well within the main Aldridge basin (Höy, 1993) within a second order basin. The trace of the Kimberley fault relates to the original bounding fault. The fault parallels offsets in isopachs of overlying Middle Aldridge turbidites (Höy 1993) and is associated with anomalous concentration of tourmalinite and conglomerate (Höy *et al.* 1993). However the Kimberley fault may differ in trend from an original structure. Thickness isopachs as in Figure 2 are a direct means to locate and determine the trend of such a structure. Figure 2 shows the eastern margin of the Sullivan sub-basin defined by a rapid thinning of the Fringe to Sullivan horizon interval.

The Sill Factor

Numerous sills and minor dikes intrude the Aldridge succession. Locally sills may occupy a high proportion of the stratigraphic interval. For example, Turner *et al.*, 1992 estimate the aggregate thickness of gabbro exposed in the Lower Aldridge near Bootleg Mountain is 1000 metres within a sequence 3000 metres thick.

The sediment adjacent to the sills shows features ranging from original bedding, to disturbed areas with fluid escape structures, to homogenized and chemically altered sediments. Höy (1989) concluded that some sills intruded wet unconsolidated sediments at shallow depths.

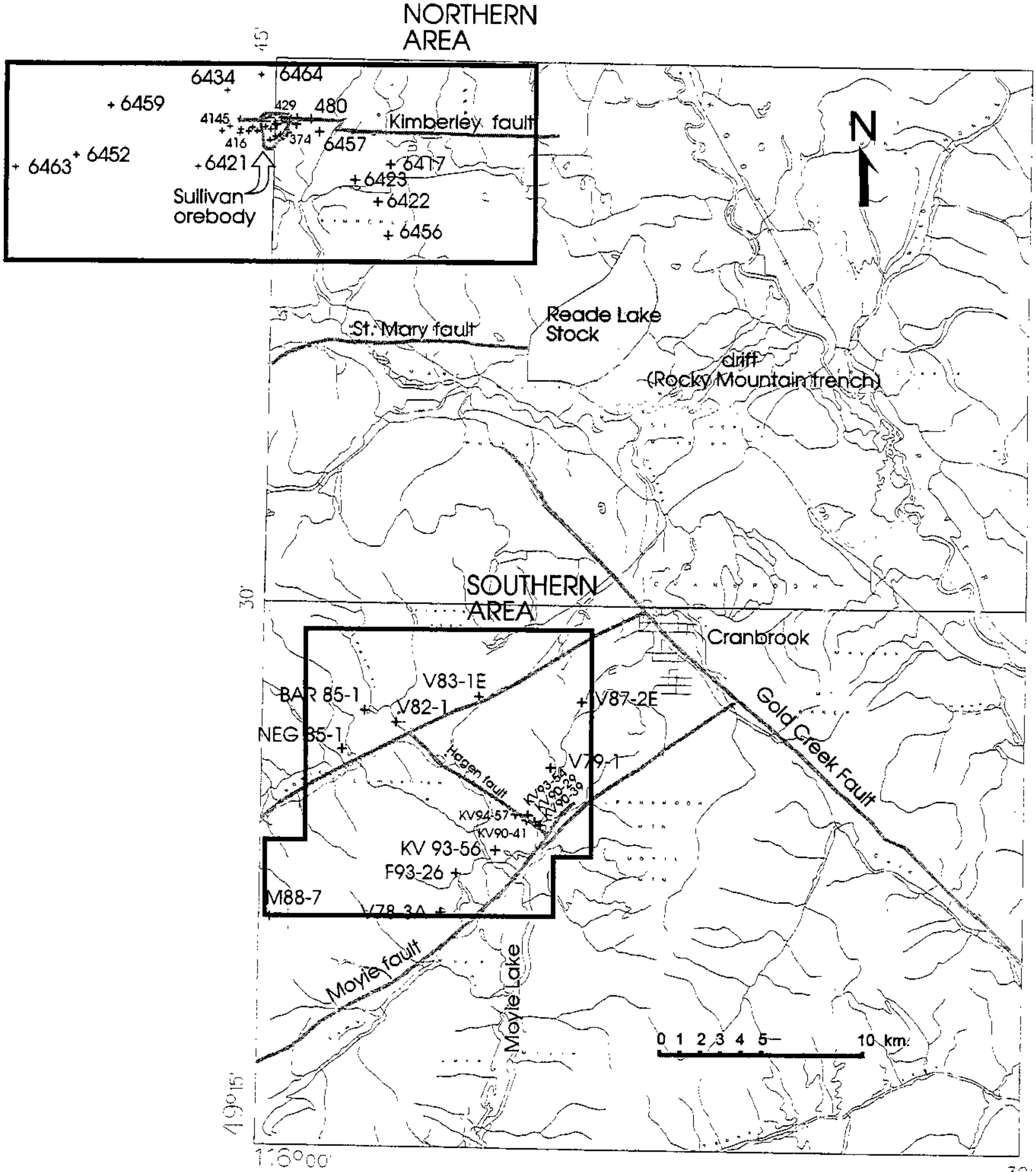

Figure 1. Location of data

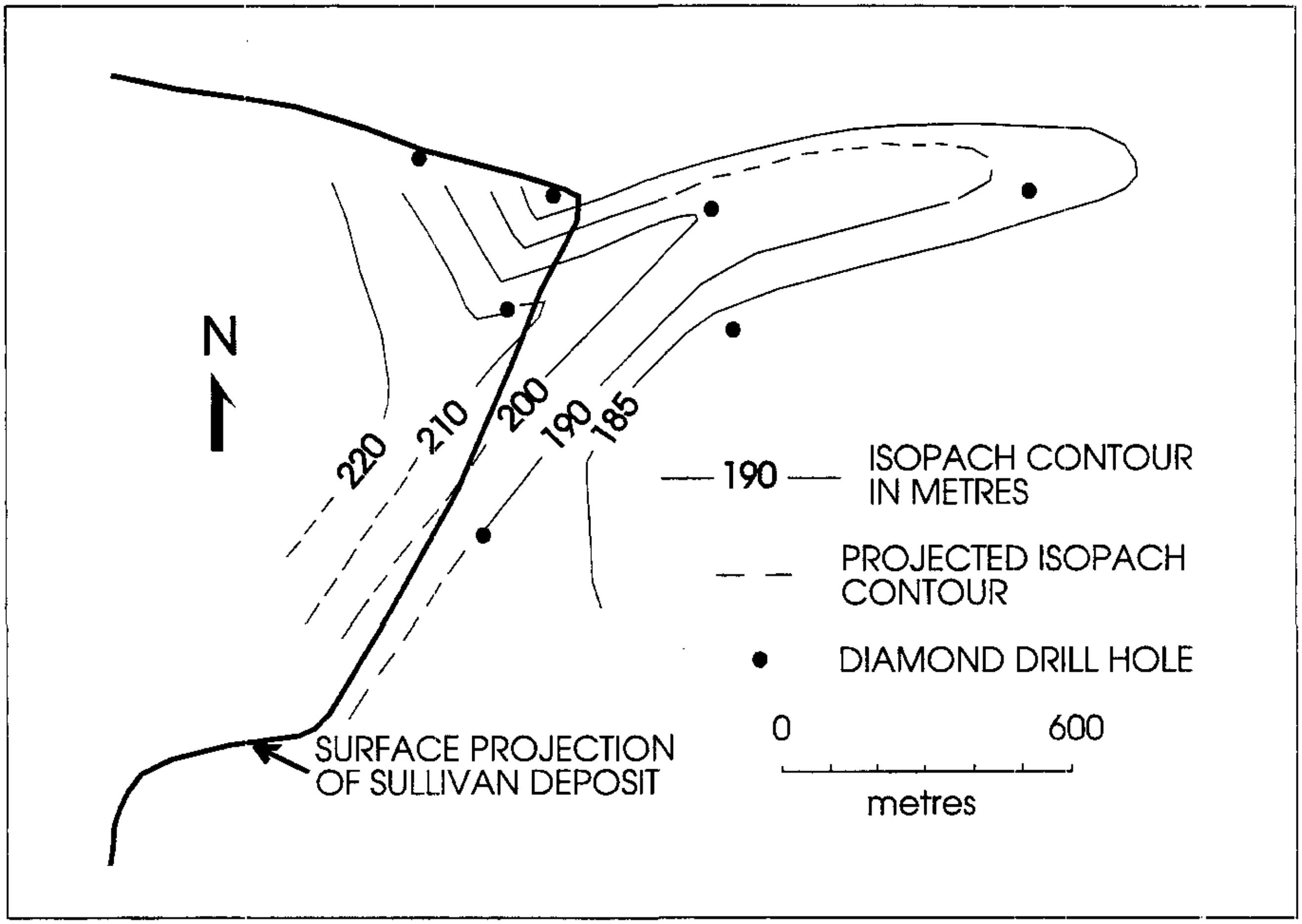

Figure 2. Isopach map of Fringe marker to Sullivan horizon (after Delaney 1983).

These synsedimentary sills are part of the history of subsidence in the Aldridge basin. Höy (personal communication, 1996) suggests they record periods of basin extension, deepening and increased heat flow. Buckley and Sears (1995) give evidence of growth fault development as a result of sill intrusion near Perma, Montana. Such growth faults may be a consequence of differential loading by the dense magma.

The writer sought evidence for changes in the thickness of stratigraphic units at the margins of thick sills where growth faults may occur.

METHODS UTILISED

The writer gathered drill log data from the Vine, Fors, McNeil, Eng, Bar, McNeil, Mt. Mahon properties, as well as Cominco properties extending east and west of the Sullivan mine. The author examined core from the Vine, McNeil and Fors properties, examined a type section at Rabbit Foot Creek with Trygve Höy, and reviewed Cominco exploration reports.

Marker laminite data was collated. The trigonometric formulae found in Ragan (1985) were applied to specific drill hole data. For example holes drilled to intersect the Vine vein were not drilled in a strike-normal direction. The result is an apparent bedding dip in drill core. In these cases, true bedding orientation was sought from geologic maps.

A contouring program - Quikgrid, by W.J. Coulthard (Internet address: w.j.coulthard@ubc.ca) - was used to delineate trends. Due to proprietary interests the data is not complete, ie. marker data is not available.

STRATIGRAPHY

The stratigraphic subdivisions utilised in this study are as follows (Figure 3):

In the Lower Aldridge- Footwall quartzite, Upper Siltstone and Sullivan facies;

In the Middle Aldridge- U quartzite and Fringe marker.

Lower Aldridge

The Lower Aldridge is dominated by rusty wacke which is interbedded with siltstone and quartz wacke.

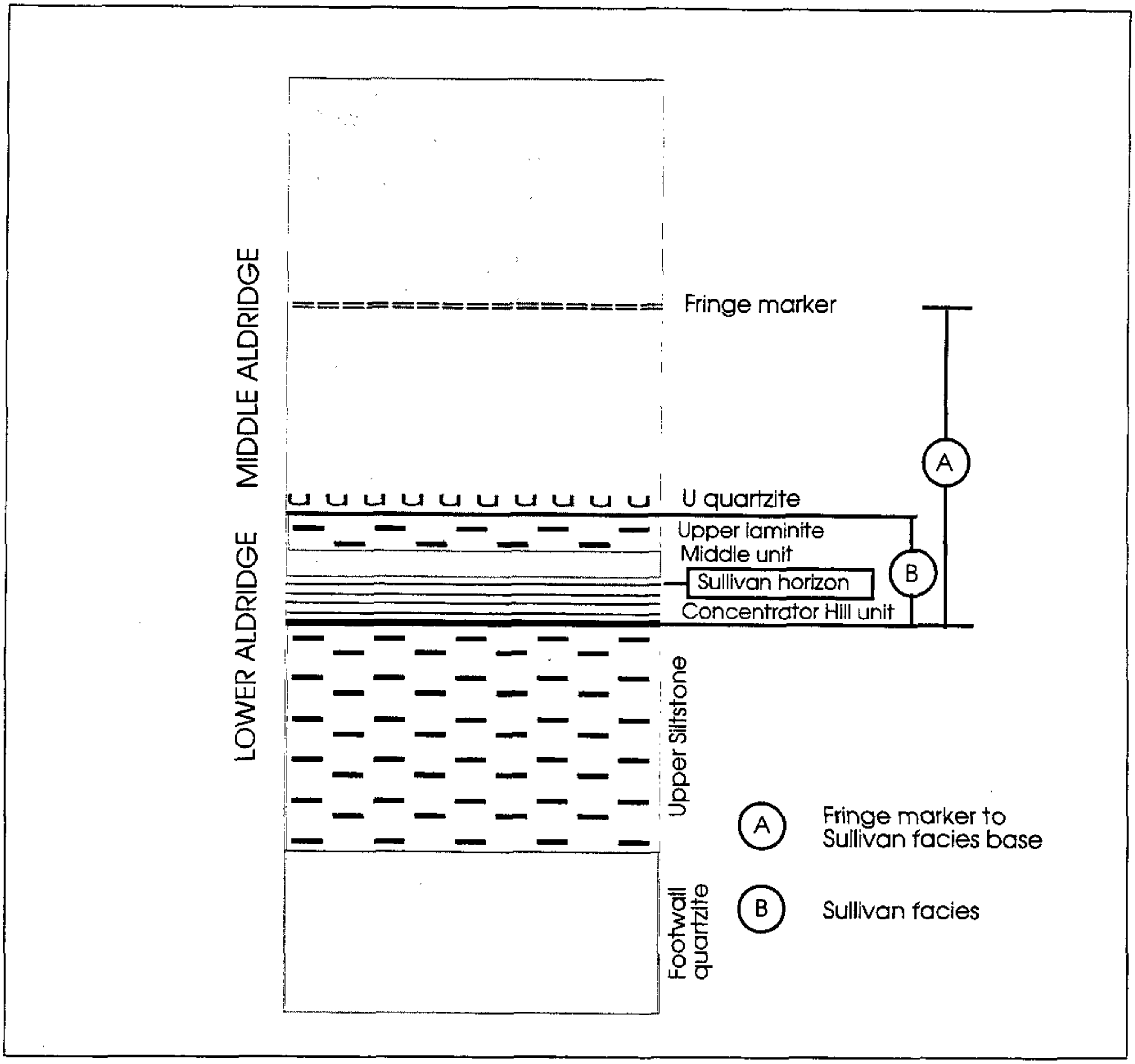

Figure 3. Stratigraphic subdivisions utilised to assess thickness trends in the study area. Not to scale.

The footwall quartzite is similar to the Middle Aldridge, consisting of quartz wacke with thin mudstone tops. Thin quartz laminae separated by pyrrhotite-biotite microlaminae form markers of local extent.

The Upper Siltstone consists of interbedded siltstones and fine grained wacke, subwacke with an occasional quartz wacke bed. The top of the Upper Siltstone is characterised by slates at the footwall of the Sullivan deposit

The Sullivan facies at the top of the Lower Aldridge consists of laminated to non laminated argillite, mudstone, siltstone and wacke. The wacke may be graded. Flat, parallel laminations of pyrrhotite are common. Intervals of slumped sediment are often seen in core as sets of intersecting laminae. The upper contact may be sharp or grade into the U quartzite. In the area of the deposit, the Sullivan facies includes thick turbidite beds, locally derived from slumping, and sulphide bands, intimately associated with argillite.

Middle Aldridge

Beds of quartz wacke and wacke interbedded with siltstone and argillite dominate the Middle Aldridge. Locally the thicker quartz wacke layers have flute or load casts at their bases. The occasional unit is crossbedded, very thick bedded or lenticular. The quartz wackes commonly grade into wacke in the top few centimetres.

The U quartzite is the lowest quartz wacke.

MARKER LAMINITES

Marker beds in the Middle Aldridge are a few centimetres to tens of metres thick and consist of even, parallel, dark and light grey bands of fine-grained sediment from 0.1 to 1.0 cm thick. Each varve-like sequence of light and dark laminae is distinctive for each marker laminite.

The dark laminae are finely micro-laminated but the light bands are massive. The boundaries of the dark and most light laminae are somewhat diffuse but the occasional light laminae has a sharp base.

Petrographically, the dark bands have greater carbonaceous content. Quartz, feldspar, muscovite and biotite grains, about 0.3 mm in diameter, comprise both types of bands.

Marker laminite intervals include non-laminated beds which may comprise the greater proportion of the marker interval. Cominco has shown that these non-laminated beds are distal turbidites. If these beds are subtracted out the marker laminite interval thickens or thins proportionately from place to place. As Huebschmann noted "Over tens of miles, each individual light and dark band varies in thickness proportionally to adjacent bands so that the same sequence remains equally expanded or decreased."

Marker intervals have been matched laminae to laminae for distances to 300 km. These laminae clearly represent time lines that extend across the basin. Occasionally laminae are missing. Fragments of marker laminae are found in turbidite beds, suggesting they were deposited but subsequently eroded by turbidite flow.

The Fringe marker consists of approximately 10 cm of laminated sediment. It is the first significant marker in the Middle Aldridge occuring about 200 metres above the Lower Aldridge contact. The Hiawatha marker, over a metre thick, lies about 250 metres above the Fringe.

Sedimentary Environment

Sedimentary structures indicate that most of the Aldridge Formation represents deposits from turbidity flows. Cominco utilises a submarine fan model to classify the turbidite facies (Delaney, 1983). Aldridge sediments lie on proximal, medial or distal parts of the submarine fan. The lower Aldridge shows characteristics of more distal turbidites while the middle Aldridge is dominated by a mid fan facies. The finer, often laminated mica rich mudstones and argillites of the Aldridge probably represent hemipelagic mud deposited from suspension between pulses of turbidites.

The origin of the marker laminites is uncertain but the carbon content of the dark laminae suggests a biochemical control on sedimentation. Heubschmann (1973) and Turner *et al.* (1992) suggest the light laminae have an eolian component while Cressman (1989) thought suspension of fines contributed by rivers was an adequate explanation of their origin.

THICKNESS TRENDS

The distribution of drill holes studied is shown in Figure 1. Drill holes west of the Sullivan mine are not shown but are listed in the stratigraphic table.

Drill holes are concentrated in two areas, the Kimberley area in the north and the Vine, Neg, Bar, McNeil property area in the south. The intervening area exposes stratigraphy that is either older or much younger. The southern area is also displaced westward based on the known movement of the St. Mary fault.

Trends in the northern and southern areas are described separately.

Sullivan Horizon

In the Sullivan mine area thickness in exploration reports are given in relation to the Sullivan horizon. The Sullivan horizon appears to be the top of the D sulfide band or base of I quartzite on Cominco's ideal geologic column, (Hamilton *et al.*, 1982 and Figure 3). The position of the datum is surmised from notes of Delaney (1983) and the 1977 exploration report of Cominco. Sullivan horizon has also been used on occasion to refer to the entire stratigraphic interval of the Sullivan facies (Hagen and Ransom, 1986). As defined here the Sullivan horizon is a specific stratigraphic position within the Sullivan facies. As a datum the Sullivan horizon is useful only in the immediate area of the deposit where the sulphide sheet or the equivalent CHH is present. For thickness trends reported here, references to the Sullivan horizon are recalculated or approximated to the base of the Sullivan facies (Figure 3).

Fringe marker to base of Sullivan facies

NORTHERN AREA

Delaney (1983) isopached the Fringe marker to "Sullivan horizon" on the eastern edge of the orebody (Figure 2). The interval varies from 180 to 220 metres. Delaney stated "although this database is somewhat limited it illustrates that above the eastern fringe of the Sullivan there is an abrupt thickening of sediment which follows an arcuate trend coincidental with the margin of the orebody. To the northeast, sediment thickness' taper to define a narrow, eastward shallowing trough. These relationships illustrate that ...... immediately after (sulphide) emplacement, there was a steep sided depression."

The thickness of the sulphide sheet (a to d bands of the Sullivan deposit) needs to be added to calculate a total isopach for the Fringe to Sullivan base interval in the area

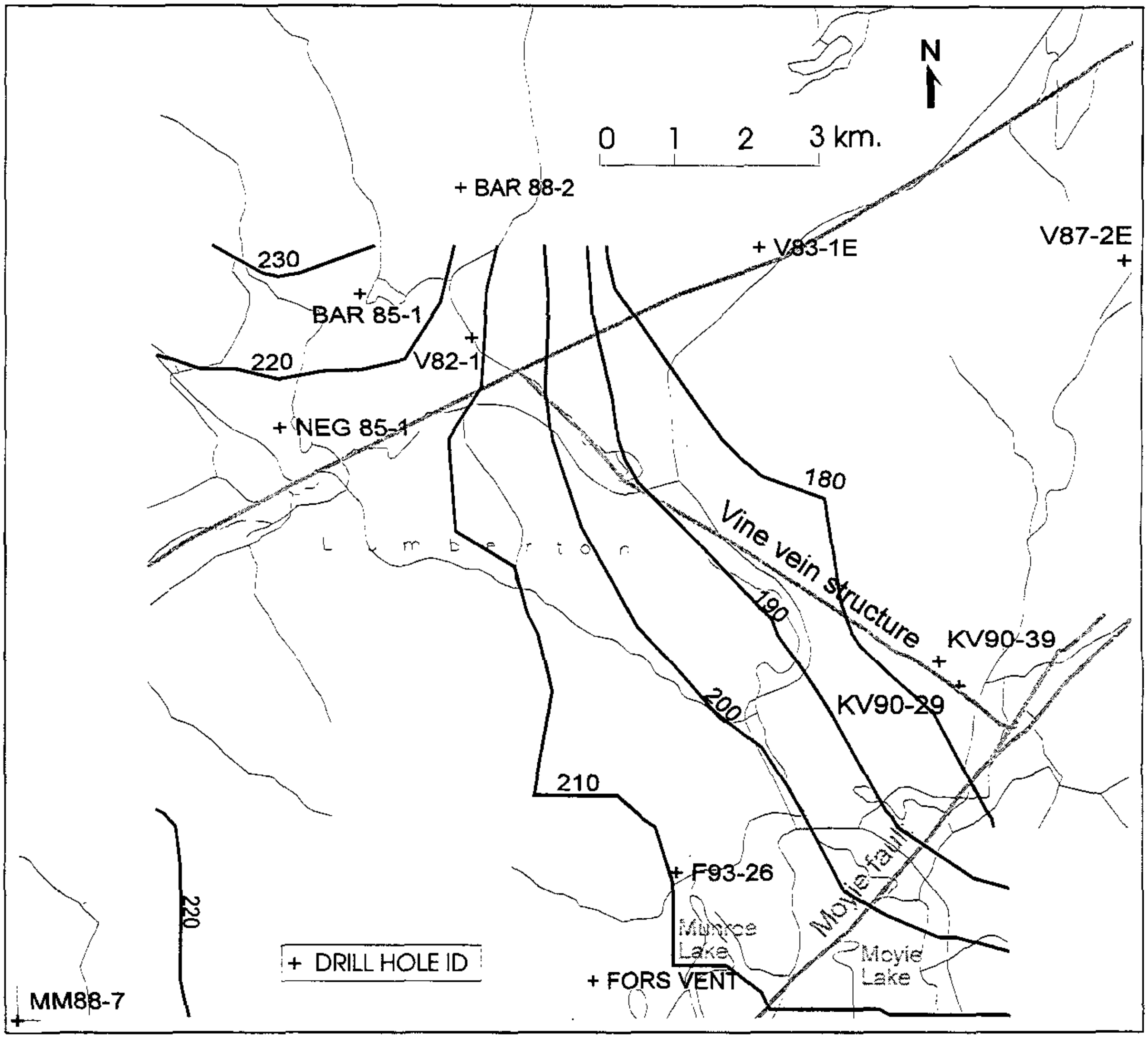

Figure 4. Contour plot of Fringe marker to Sullivan base thickness, southern area. Contour interval is 10 metres.

of the orebody. Outside the ore limit of the deposit, this thickness is insignificant, ranging from 0.5 to 1.5 metres. However, within the eastern part of the orebody the sulphide sheet is reported to vary from 11 to 36 metres thickness (Hamilton *et al.*, 1982). This suggests the interval is 231 to 256 metres thick (220+36 metres). This may increase to over 270 metres in the western part where average thickness of the sulphide sheet is 50 metres. This suggests a considerable down-drop at the very start of sulphide deposition.

Only a few data points are available outside the deposit. Southeast of the deposit thicknesses are about 155 metres. To the north the Fringe to Sullivan interval is not recorded in DDH# 6464, which intersected the faulted northern portion of the orebody. The Fringe to Sullivan base interval is approximately 164 metres northwest of the deposit. This is based on restoring the site of DDH# 6434 to its original location, immediately northwest of the orebody. The restoration is based on the 3.5 kilometres of horizontal component of movement on the Kimberley fault. This amount of movement is based on the relationship of the gabbro and granophyre to the sub-basin facies in DDH# 6464. The relationship of the intruding gabbro to bedded sulphides matches that known only in the northwest part of the mine (Ransom 1989).

Data from the Matthew Creek area farther to the west is unavailable.

Unfortunately the stratigraphic interval of interest is eroded in the area of the North Star trend. Along this trend a sedimentary graben is postulated in lower Aldridge time (Turner *et al.*, in preparation).

SOUTH (FIG. 4)

Within a perimeter defined by DDH's #V83-1E, V87-2E, KV90-39, KV93-54 the Fringe to Sullivan base interval occupies a narrow range from 170 to 178 metres. To the southwest the interval is 201 to 238 metres (DDH's #F93-26, V82-1, Neg85-1, Bar85-1). Further to the southwest the interval is approximately 221 metres on the McNeil property (MM 88-7). Though data is sparse an inflection in the thickness trend is suggested in the Vine-Fors area.

This area is characterised by the westward appearance and thickening of sills in the Lower Aldridge, (Cook and Van der Welden; 1995). One sill, over 250 metres thick, is exposed immediately SW of Fors and is traceable westward (Fig. 2 in Britton and Pighin, 1995). The sill is intersected just below the Sullivan unit in DDH# V-78-A some 400 metres southwest of Fors. However the sill was not intersected in two holes to the appropriate depth at the Fors prospect. The sill must cut up or down section, or terminate in this area. The sill is not recognised in drill core on the Vine property to the east but gabbro of unknown thickness is present at a lower stratigraphic interval (ibid).

At Fors there is evidence of a dewatering pipe associated with hydrothermal activity (Britton and Pighin, 1995). The pipe contains up to pebble size clasts of sandstone and siltstone. The writer noted an abundance of bluish grey (hydrothermally altered) mudstone clasts in Fors core (DDH #F93-26). Klewchuk *et al.* (1983) report that several fragmentals, stacked in vertical sequence, extend northwest from the Fors along a minor fault. Banting (1989) describes one of the fragmentals as a conglomerate comprising elongate shaly fragments in an argillaceous matrix. A stratabound "homogenised" quartz wacke is thickest near this fault. The Fors dewatering vent may thus be related to an early northwest trending zone of weakness. The zone of weakness may in turn be related to differential subsidence along a northwest trend.

Lithologically, the Fringe to Sullivan interval is sporadically calcareous; the carbonate distribution is irregular from hole to hole.

Sullivan unit (sub-basin facies)

NORTHERN AREA

A threefold lithologic subdivision is recognised in the Sullivan facies east of the Sullivan deposit (1985 Sullivan Exploration Annual Report). The basal unit is known as the Concentrator Hill horizon (CHH). The middle unit consists of turbidites that are described as beds of quartz wacke, sandy wacke and calcareous wacke. The upper unit is described as the "upper laminite" but includes graded beds of siltstone. It extends to the base of the U quartzite.

The Sullivan facies is about 15 metres thick near Concentrator Hill, 5.5 kilometres southeast of Sullivan and thickens northwest toward the orebody. At the orebody it varies from about 50 to over 100 metres thick.

The CHH correlates with the pyrrhotite fringe of the orebody. The base of the CHH is equivalent to the footwall slates (Paul Ransom personal communication, 1995). The equivalent top is uncertain. According to Ransom, markers in CHH are split in the ore-bearing sequence and the top of CHH may be as high as the HU ore. The CHH has a geochemical signature that is similar to the waste bands of the A to D ore interval (Ransom, 1988). The CHH can be considered, at a minimum, to be the equivalent of the main stratabound ore at Sullivan (bands A to E). The top of this interval is the Sullivan "horizon" previously mentioned. The CHH thus thickens from a few metres at Concentrator Hill to as much as 36 metres at the ore zone in the eastern part of the orebody (Hamilton *et al.*, 1982).

A comparison of drillhole logs (1977 Cominco Exploration report) suggests the CHH thins dramatically southwest of the orebody (DDH# 6421) and may not be present in the Matthew Creek area to the west. Here the middle unit is not developed either, and the Sullivan facies may be represented by the "upper laminite" alone. CHH is present north and west of the Kimberley fault (DDH# 6464) where 30 cm of sulphides were intersected. Interestingly, the thickness of the Sullivan unit (U-quartzite to Sullivan base) is recorded as 100 metres by Ransom (1988). This suggests that the basin continues northward though it is lacking in sulphides. The Sullivan facies immediately to the northwest of the orebody (in DDH# 6434) is much reduced in thickness.

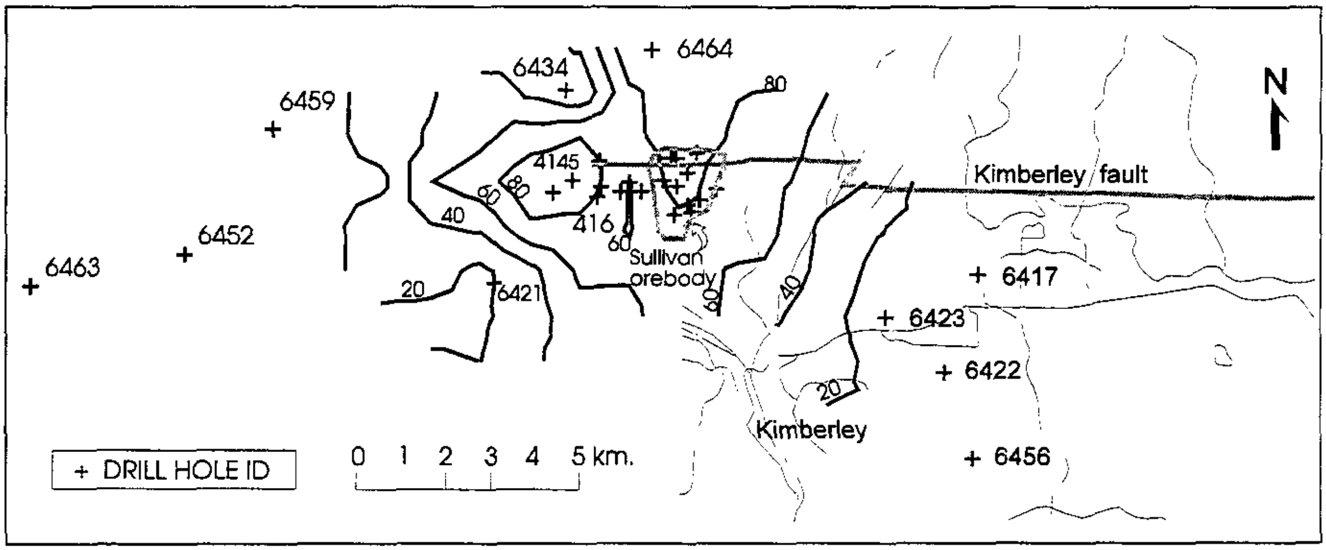

Figure 5. Contour plot of Sullivan facies, northern area. Contour interval is 20 metres. Data compiled from assessment reports, cross sections and sulphide isopachs. Data is incomplete immediately east of the orebody.

There is data from immediately west of the orebody. from a stratigraphic drill plan titled Exploration Drilling Surface Holes. The plan indicates thickening of the interval U quartzite to Sullivan horizon. The writer has simply used a ruler to measure the interval and incorporated it into the database utilised for a contour plot. It is assumed that the thickness of the CHH or sulphide sheet is negligible in this area.

In the area of the mine, orebody cross-sections (eg. latitude 11600 north in Hamilton, 1982) indicate 60 metres between the U quartzite and the top of the sulphide sheet. Sulphide isopachs are added to this 60 metres to estimate the thickness of the Sullivan unit in the central region of the deposit where the U quartzite is not shown (ibid). The result of the compilation is shown in Figure 5. It suggests a second depression west of Sullivan bordered by thinned strata to the north (relocated hole # 6434). These areas of thickening correspond to a north-widening zone of stratabound and cross-cutting breccias and conglomerates along the North Star corridor. Interestingly fragmentals were not intersected in hole# 6434.

SOUTHERN AREA

The trend surface map (Fig. 6) shows variations in the thickness of the Sullivan facies. In the Fors area, the Sullivan facies is obscured by alteration at the contact with a sill. Hence the thicknesses of 7.6 metres at F93-26 and V78-3A are tentative. There are two areas of greater sediment accumulation named here basins area 1 and 2. They are separated by an arch of thinned strata.

Basin area 1

In this area, the Sullivan facies ranges from 11.8 to 21 metres in thickness.

In the area of the Vine vein the Sullivan facies is 11.8 to 16.4 metres thick and consists of laminated and microlaminated silty argillite and argillite. Rock geochemical plots suggest an anomalous interval , 1 to 2 metres thick, is present a few metres above the base of the Sullivan facies in the Vine vein area.

Höy and Pighin (1995) note that the Sullivan facies is thicker to the west and east. In DDH# V79-1, 19.4 metres is present, characterised by a pyrrhotite laminated zone with a slump feature at its base and subwacke interbeds at the top. To the southwest, in KV93-56, the facies is interpreted to be 21 metres thick.

The thinner values over the Vine structure suggested to Höy and Pighin that a seafloor high existed in this area flanked by shallow basins. The regional contour plot supports this. They also suggests a depression parallel to the Moyie fault based on 50 metres of fragmentals at the Sullivan "horizon" in the Munroe Lake area. Additional details of this data would assist in defining trends in basin area 1 and help relate them to geochemical trends.

Basin area 2

Basin area 2 has few data points but the Sullivan unit has a wide range of interpreted thicknesses (17.6 to 47 m.). Some thickening is expected toward the basin axis, but the thickness in hole Bar 85-1 seems anomalous.

In hole V-82-1 the Sullivan facies interval consists of 17.6 metres of massive to laminated wacke with evidence of slumping at the top. In Neg N85-1 it consists of 24.3

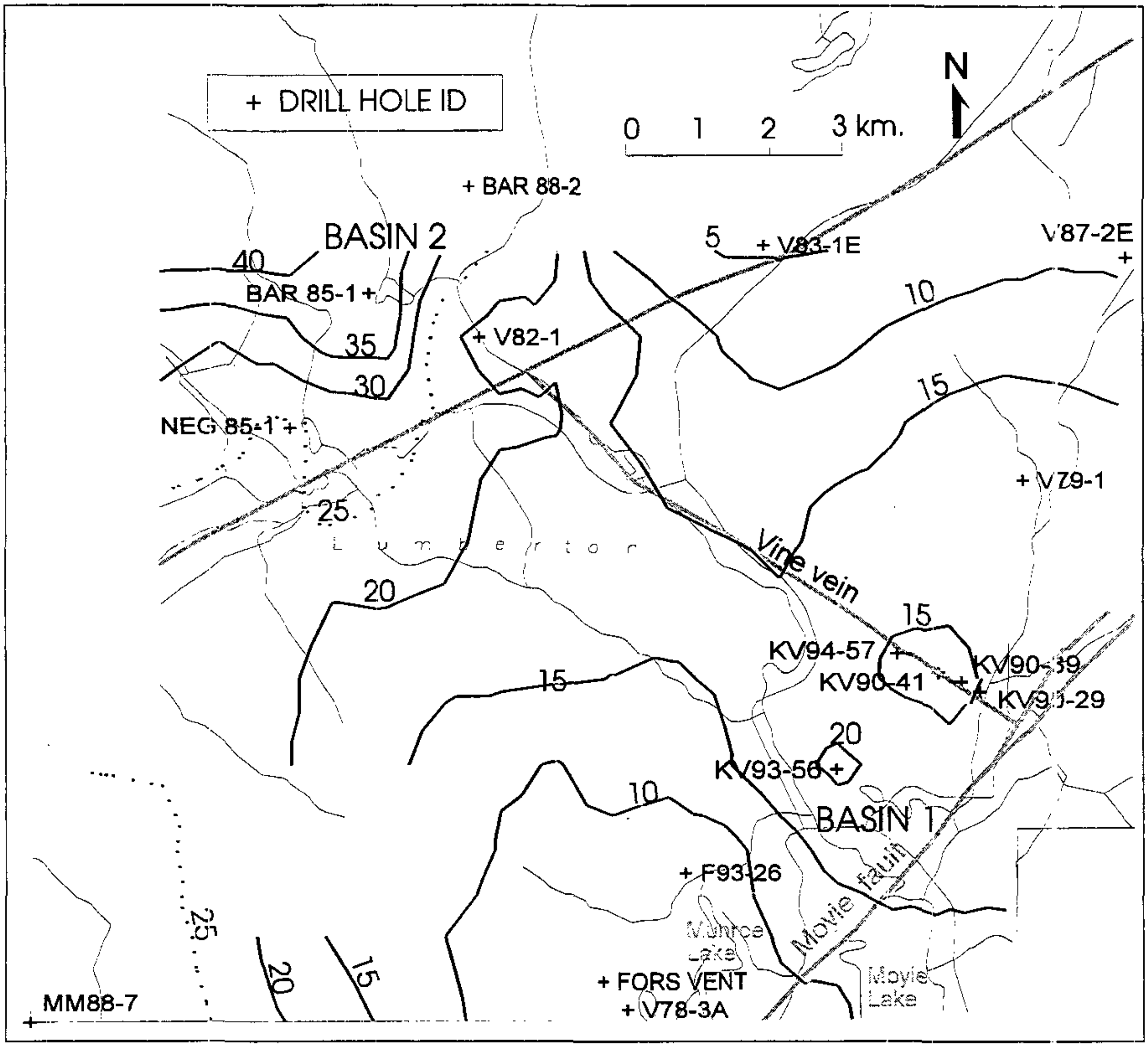

Figure 6. Contour plot of Sullivan facies thickness, southern area. Contour interval is 5 metres.

metres of wacke that is thin to medium bedded, flat lying and very finely laminated throughout with pyrrhotite.

In McNeil drillhole# MM 88-7 the Sullivan facies is thick (about 25.3 metres). Massive altered siltstone grades into pyrrhotite laminated silty argillite. This is overlain by an interval of interbedded matrix-supported fragmental and laminated sediment. In the interbeds, clasts are rounded and indistinct, some have pyrrhotite rims and internal laminations (slump unit). Overlying siltstone is abruptly overlain by quartzite.

In hole Bar 85-1, 42.6 metres of Sullivan facies rocks with thin interbeds of intraformational conglomerate are underlain by 20 metres of conglomerate consisting of subangular to rounded clasts of mudstone(blue-grey), siltstone and sulphides in a matrix of siltstone and fine sandstone. The percentage of clasts decreases upward. Laminations (to 0.5 cm) of pyrrhotite are common on the top of the conglomerate (CHH equivalent?). The conglomeratic interval is probably a product of sediment extrusion, given the rounded nature of the locally derived clasts.

UPPER SILTSTONE

The Upper Siltstone is a distal turbidite facies lying between more proximal turbidites represented by the Footwall quartzite and the Middle Aldridge. The Sullivan facies, though treated as a separate sequence is essentially a period of low sedimentation at the very end of distal turbidite (i.e. Upper Siltstone) deposition in this part of the Aldridge basin.

In the north, data is lacking regarding westward changes in the thickness of the Upper Siltstone unit. The Upper Siltstone appears to be thick below the Sullivan orebody (drillhole# 6793) but thinner just to the east in drillhole #6423 (195 versus 168 metres). More data would be required from the area west of the orebody to define thickness trends.

In the south in the Vine and Neg area, the Upper Siltstone facies appears to be more calcareous in the east (drillhole V-83-1e, V-87-2e) and siliceous in the west (Neg 85-1). The proportion of quartz wacke to wacke increases toward the west. The unit is thinner than it is in the vicinity of Sullivan mine.

On the Vine property, the facies consists of purple-grey (biotitic) to brownish siltstone and minor fine grained feldspathic arenite. It is weakly calcareous and predominantly thin to medium bedded.

On the McNeil property, the siltstone facies is often silicified. Two intervals of maroon quartzite are present in drillhole MM 88-7.

The Upper Siltstone facies thus becomes more quartzitic to the south and west. This probably indicates a lateral facies change from wacke to quartz wacke. Further to the southwest quartz-rich sediments of a major turbidite fan are present (Rampart facies, see Brown and Stinson, 1995).

FORS-VINE EXPLORATION PLAY

The isopach trend for the Fringe to Sullivan interval in Fig. 4 suggests a northwest trend. Along this trend to the north a sill is present near the stratigraphic position of the Hiawatha marker. This sill is crosscutting and varies from 160 to over 200 metres in thickness. Its base is 490 metres above middle Aldridge contact in drillhole Neg 85-1 and 400 metres above the contact in Bar 85-1. In Bar 88-2 the top of the same sill is intersected about 90 metres below the middle Aldridge. It appears to be downcutting to the southeast and it is not found in drillhole V82-1 which penetrated 97 metres of Lower Aldridge. The relationship of this sill to the one at Fors is not known as they are in different fault blocks. However both show a change in geometry possibly related to exploitation of early fault structures. Both are on the general trend of thickening of the Fringe to Sullivan base interval.

Leask (1988) noted stratigraphic thickening in Bar 88-2 relative to Bar 85-1 based on a marker above Hiawatha time. There is considerable hydrothermal carbonate alteration in Bar 88-2. Carbonate and tourmaline alteration extends above the Hiawatha marker. Edmunds (in Leask, 1988) thought the drillhole was close to a boron source. Further work was not done in the area because the Sullivan horizon is too deep. However, the area is prospective for a Fors type vent at a higher stratigraphic position.

CONCLUSIONS AND SUMMARY

Sedex deposits occur in structural sub-basins within a host extensional basin. Abrupt facies changes and thickness changes define structural boundaries of sub-basins. When a sub-basin develops away from the edge of the main basin large scale depositional processes such as axial turbidite fans mask recognition of the sub-basin. In this regard thickness isopachs become relevant in defining the margins of second order basins.

In the study area variations in the thickness of the Fringe marker to Sullivan base interval suggest differential subsidence and original structural boundaries. The best example of this is the linear depression that extends east from the Sullivan deposit (Delaney 1983).

This study suggests there is differential subsidence outside the Sullivan deposit, albeit of a gentler gradient. For example, differential subsidence is indicated southwest of the Vine vein toward the Fors property. The Fors vent is also along a linear trend of fluidisation that is parallel to the thickness isopachs. A similar vent may be present in the Vine and Bar area to the northwest along this trend.

More data is required to authenticate isopach trends, and to relate these to sill intrusion.

Isopachs of the Sullivan facies suggest a basin extension north of the mine and another basin to the west. The northern extension corresponds to the discovered northern fringe of the orebody across the Kimberley fault. The western area corresponds to the north star trend.

In the southern part of the study area, the Sullivan facies appears to be thick near Bar 85-1.

The equivalent of the CHH (Concentrator Hill Horizon) may be present near the southern end of the Vine vein. Some potential for a thickened Sullivan facies exists toward the Moyie fault.

ACKNOWLEDGEMENTS

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TABLE 1. STRATIGRAPHIC DATA

Note values for locations Sulliso 1 -10 reconstructed from sulphide isopach data. Values for holes 976, 4145, 5487, 5451, 423, 4142, 416 obtained from cross-sections.

DRILL HOLE ID	UTM ZONE	UTM NORTH	UTM EAST	FRINGE	SUL_TOP	SUL_BASE	SUL_THIC	FRINGE-SUL_BASE
6464	11	5510100.00	567700.00	0.0	0.0	0.0	100.0	0.0
6434	11	5509250.00	566050.00	0.0	0.0	0.0	18.1	170.0
6459	11	5508600.00	563810.00	0.0	594.4	607.7	13.0	0.0
SULLISO1	11	5508140.00	572280.00	0.0	0.0	0.0	90.0	0.0
429	11	5508060.00	572500.00	0.0	0.0	0.0	0.0	202.0
478	11	5508000.00	573100.00	0.0	0.0	0.0	0.0	199.0
480	11	5508000.00	573740.00	0.0	0.0	0.0	0.0	187.0
3303	11	5508000.00	572740.00	0.0	0.0	0.0	0.0	183.0
SULLISO2	11	5508000.00	571660.00	0.0	0.0	0.0	72.0	0.0
SULLISO3	11	5508000.00	571740.00	0.0	0.0	0.0	90.0	0.0
420	11	5507920.00	570240.00	0.0	0.0	0.0	98.0	0.0
6414/468	11	5507780.00	572700.00	0.0	0.0	0.0	0.0	210.0
3660	11	5507680.00	573070.00	0.0	0.0	0.0	0.0	183.0
976	11	5507520.00	570860.00	0.0	0.0	0.0	61.0	0.0
SULLISO4	11	5507500.00	571500.00	0.0	0.0	0.0	72.0	0.0
4145	11	5507500.00	569700.00	0.0	0.0	0.0	98.0	0.0
SULLISO5	11	5507420.00	571700.00	0.0	0.0	0.0	90.0	0.0
5487	11	5507420.00	570360.00	0.0	0.0	0.0	73.0	0.0
6457	11	5507350.00	574200.00	0.0	276.9	0.0	0.0	0.0
SULLISO6	11	5507340.00	572660.00	0.0	0.0	0.0	72.0	0.0
5451	11	5507320.00	571000.00	0.0	0.0	0.0	37.0	0.0
374	11	5507300.00	572620.00	0.0	0.0	0.0	0.0	190.0
423	11	5507280.00	570680.00	0.0	0.0	0.0	61.0	0.0
4142	11	5507260.00	569320.00	0.0	0.0	0.0	104.0	0.0
416	11	5507240.00	570260.00	0.0	0.0	0.0	61.0	0.0
SULLISO7	11	5507140.00	572260.00	0.0	0.0	0.0	90.0	0.0
SULLISO8	11	5507000.00	572040.00	0.0	0.0	0.0	90.0	0.0
SULLISO9	11	5506840.00	571720.00	0.0	0.0	0.0	72.0	0.0
SULLISO10	11	5506840.00	572040.00	0.0	0.0	0.0	72.0	0.0
6452	11	5506020.00	562100.00	0.0	146.4	161.7	15.0	0.0
6417	11	5505800.00	577650.00	0.0	0.0	0.0	14.0	154.1
6421	11	5505450.00	568100.00	0.0	0.0	0.0	15.3	185.3
6463	11	5505400.00	559050.00	0.0	275.4	283.8	8.2	0.0
6423	11	5504900.00	575950.00	0.0	73.3	86.4	12.5	0.0
6422	11	5503850.00	577100.00	397.3	540.3	557.5	17.3	155.7
6456	11	5502150.00	577650.00	409.0	531.3	546.6	15.4	0.0
V83-1E	11	5478600.00	582750.00	0.0	1116.7	1121.4	4.7	169.7
V87-2E	11	5478550.00	587650.00	737.5	906.5	916.3	9.5	175.9
BAR 85-1	11	5477800.00	577400.00	0.0	1435.0	1482.0	42.6	237.6
V-82-1	11	5477200.00	578900.00	0.0	855.9	873.5	17.3	201.3
NEG-85-1	11	5475800.00	576350.00	741.0	933.8	958.5	24.3	214.2
V-79-1	11	5475150.00	586350.00	0.0	458.0	474.0	16.0	0.0
KV 94-57	11	5472680.00	584720.00	0.0	391.0	408.0	14.6	0.0
KV 93-54	11	5472650.00	585300.00	233.6	405.7	420.3	14.0	177.6
KV 90-41	11	5472400.00	585300.00	0.0	0.0	0.0	11.8	0.0
KV 90-39	11	5472300.00	585600.00	184.2	362.0	378.2	16.3	171.0
KV 90-29	11	5472200.00	585900.00	0.0	0.0	0.0	16.4	0.0
KV 93-56	11	5470841.00	583783.00	0.0	1075.7	1100.0	21.0	0.0
F93-26	11	5469550.00	581850.00	463.3	669.6	677.2	7.5	210.7
V 78-3A	11	5467500.00	581150.00	0.0	191.0	198.7	7.5	0.0
MM 88-7	11	5467100.00	573050.00	612.6	810.0	835.7	25.3	220.6
MM 84-1	11	5439500.00	574050.00	0.0	385.9	402.3	0.0	164.0
E 90-3	11	5437400.00	566550.00	75.9	249.0	256.0	6.8	174.0

REFERENCES

Banting, R.T. (1989): Engineering Report on the Fors Grid, Fort Steele Mining Division; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Assessment Report 18575.

Bapty, M. & Klewchuk, P (1989): Summary of the Geological, Geochemical Geophysical, Diamond drilling and Physical Work Programs on the McNeil Creek Property; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Assessment Report 19277.

Britton, J.M. and Pighin, D.L. (1995): Fors - A Proterozoic Sedimentary Exhalative Base Metal Deposit in Middle Aldridge Formation, Southeastern British Columbia (82G/5W); *in* Geological Fieldwork 1994, (eds.) Grant, B. and Newell, J.M.; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, p. 99-109.

Brown D.A. and Stinson, P. (1995): Geological Mapping of the Yahk Map Area, Southeastern British Columbia: An Update (82F/1); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1994, Paper 1995-1, p.111-125.

Buckley and Sears (1995): Emplacement of Sills into Wet Belt Supergroup Sediments at Perma, Western Montana; *Montana Bureau of Mines and Geology*, Belt Symposium III.

Cominco Ltd., Kimberley B.C. (1978): Sullivan Exploration 1977 Annual Report.

Cook, F.A. and van der Velden, A.J. (1995): Three-dimensional Crustal Structure of the Purcell Anticlinorium in the Cordillera of Southwestern Canada; *Geological Society of America Bulletin*, v. 107, p. 642-664.

Cressman, E.R. (1989): Reconnaissance Stratigraphy of the Prichard Formation (Middle Proterozoic) and the Early Development of the Belt basin, Washington, Idaho and Montana; *U.S. Geological Survey*, Professional Paper 1490

Delaney, G.D. (1983): Middle Aldridge Stratigraphic Study Progress Report; *Cominco Ltd. internal report*, 17 pages.

Hagen, A. (1981): Variations in Sediment Thickness in Equivalent Middle Aldridge Stratigraphy in the Kimberley area; *in* Sullivan Exploration 1980 Annual Report; *Cominco Ltd. internal report.*

Hagen , A.S. & Ransom, P.W. (1986): Sullivan Exploration 1985 Annual Report; *Cominco Ltd. internal report.*

Hamilton, J.M., Bishop, D.T., Morris, H.C., Owens, O.E. (1982): Geology of the Sullivan Orebody, Kimberley; *in* PreCambrian Sulfide Deposits, H.S. Robinson Memorial Volume, *G.A.C. Special Paper 25.*

Heubschmann, R.P. (1973): Correlation of Fine Carbonaceous Carbonaceous Bands Across a Precambrian Stagnant Basin; *Journal of Sedimentary Petrology*, Volume 43, p. 688-699.

Himes, M.D. and Petersen, E.U. (1990): Geological and Mineralogical Characteristics of the Sheep Creek Copper-cobalt Sediment-hosted Stratabound Sulfide Deposit, Meagher County, Montana; *Proceedings of the Gold '90 Symposium*, p. 533-546.

Höy, T. (1989): The Age, Chemistry and Tectonic Setting of the Middle Proterozoic Moyie Sills, Purcell Supergroup, Southeastern British Columbia; *Canadian Journal of Earth Sciences*, v. 29, p. 2305-2317.

Höy, T., Berg, N., Delaney, J., McMurdo, D. and Ransom, P.W. (1990): The Sullivan Orebody; *in* Geology and Regional Setting of Major Mineral Deposits in Southern British Columbia, *G.S.C. Open File 2167.*, pp 29-43.

Höy, T. (1993): Geology of the Purcell Supergroup in the Fernie West-half map area, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 84, 157 p.

Höy, T., Dunne, K.P.E. and Wilton, P. (1993): Massive Sulphide and Precious Metal Deposits in Southeastern British Columbia; *Geological Association of Canada, Mineralogical Association of Canada*, Joint Annual Meeting 1993, Field Trip A-7, Guidebook, 74 p.

Höy, T. (in preparation): Tectonic, Magmatic and Metallogenic History of the Early Synrift Phase of the Purcell Basin, Southeastern British Columbia; *in* The Sullivan Deposit and its Geological Environment, (ed.) J.W. Lydon, T. Höy, M. Knapp and J.F. Slack; *Geological Survey of Canada*; Sullivan Volume (1997).

Klewchuk, P., Pighin, D.L. and Anderson, D. (1983): Exploration Implications of Aldridge Sulfide Occurrences; *in* Workshop on Lead/Zinc/Silver Deposits in Clastic Sediments, *Cominco Exploration Internal Report.*

Leask, J. (1988): Assessment Report, Bar Property; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Assessment Report 17886.

Ragan (1985): Structural Geology, An Introduction to Geometrical Techniques, 3rd Edition; *John Wiley & Sons Inc.*, 393 pages.

Ransom, P. (1988): 1988 Sullivan Exploration Annual Report, *Cominco Internal Report*, 8p.

Ransom, P. (1989): Submarine Debris Flows at Sullivan Mine; *Cominco Internal Report*

Turner, R.J.W., Höy, T., Leitch, C.H.B. and Anderson, D. (1992): Guide to the Tectonic, Stratigraphic and Magmatic Setting of the Middle Proterozoic Stratiform Sediment-hosted Sullivan Zn-Pb deposit, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Information Circular 1992-23, 53 p.

Turner, R.J.W., Leitch, C.H.B. and T. Höy (in preparation): Structural Controls and Physical Evolution of the Sullivan-North Star corridor; *in* The Sullivan Deposit and its Geological Environment, (*editors*, J.W. Lydon, T. Höy, M. Knapp and J.F. Slack); *Geological Survey of Canada*; Sullivan Volume (1997).

Winston, D. (1986): Sedimentation and Tectonics of the Middle Proterozoic Belt Basin and Their Influence on Phanerozoic Compression and Extension in Western Montana and Northern Idaho; *in* Paleotectonics and Sedimentation in the Rocky Mountain region, United States, Peterson, J. (Editor) *American Association of Petroleum Geologists*, Memoir, Part II, p. 87-118.