

GEOLOGY AND SULPHIDE DEPOSITS OF ANVIL RANGE, YUKON TERRITORY

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Introduction:

It is our intent to present a long overdue update on the geology of the Anvil Range lead-zinc district. Because of time constraints, we will restrict our discussions to a structural stratigraphic analysis of the Paleozoic section of the Anvil Range and its included sulphide deposits. We hope to demonstrate the following four major points.

First, there is a recognizable stratigraphic sequence in the Paleozoic section of Anvil Range despite its complex metamorphic and deformational history. Secondly, we emphasize there are two (black shale) horizons host to the presently known sulphide deposits. Thirdly, there is semi-continuous volcanic activity recorded throughout the pile which is related indirectly to a submarine syn-sedimentary origin for the deposits. Fourthly, there are two regional overlapping metamorphic events up to middle amphibolite grade affecting the deposit area.

Anvil Range is located along the southwestern margin of the Selwyn Basin, immediately northeast of the Tintina trench. Pertinent features include the lower Cretaceous Anvil Arch or dome; the Lower to Middle Paleozoic meta-sediments and volcanic rocks shown in various hues of brown, green and blue (slide). Above, in uncertain, probably unconformable contact with the Middle to Lower Paleozoic sequence, lies the upper Devonian-Mississippian Earn Group, in turn overlain in uncertain manner by Triassic rocks of the Tay River Valley. Structurally superimposed on top of the autochthonous sequence are two regional allochthons, the K.D. allochthon shown here (slide), and rocks of the Anvil-Campbell allochthon mapped recently by Dirk Tempelman-Kluit of the Survey in Pelly mountains.

Stratigraphy:

We will represent the stratigraphic relations in the Paleozoic section of Anvil Range shown in this map (slide) by the fence diagram (slide) wherein we point out the stratigraphic sequence for the autochthonous portion of Anvil Range, the two regional allochthonous sequences, K.D. and the Anvil-Campbell allochthon. A provisional stratigraphic breakdown for the autochthonous Lower to Middle Paleozoic section in Anvil Range is proposed as follows:

Faro Group, Mt. Mye Group, Vangorda Group and Rose Mt. Group.

We will attempt to reconstruct the stratigraphic relationships of Anvil Range sequentially, starting at the base of the autochthonous section and working our way up. While the Proterozoic grit unit rocks are not seen in direct contact with rocks of Faro Group, we suggest that the Windermere Proterozoic grit unit is probably the basement in the Anvil Range and is overlain by rocks of the newly named Faro Group.

Principal units within the Faro Group include map unit 1(c), a quartzo-feldspathic biotite-muscovite schist. Analytical results corroborate that 1(c) could easily be average eugeoclinal greywacke which we propose as protolith for unit 1(c). Unit 1(c) is overlain in gradational contact by unit 1(d), a carbonaceous biotite muscovite-andalusite schist, host to the Faro deposit. It should be pointed out that unit 1(d) contains all known graphitic schists within the Faro Group. Additionally, meta-basic volcanic activity becomes prevalent within unit 1(d).

Faro group rocks are overlain by rocks of Mt. Mye Group as newly proposed.

Principal lithofacies of the Mt. Mye Group include map unit 3(d), calc-silicate phyllite, typical of Anvil Range. As protolith, we propose a variably dolomitic interbanded sequence of calcisiltites and calcilutites. They, in turn, are interbanded and intertongue with unit 3(g), variably siliceous, non-calcareous,

muscovite-chlorite phyllite which presumably has a sub-aluminous pelitic protolith.

The Mt. Mye Group is overlain by rocks of Vangorda Group. The base of Vangorda Group is map unit 5(a), variably calcareous black, graphitic phyllite, host to the other recognized deposits in the autochthonous sequence. To reiterate, the Faro deposit occurs in map unit 1(d) in Faro Group, the remainder of the deposits, including Grum, Firth, Vangorda, DY, Swim, SB and Sea occur spatially related to unit 5(a) at the base of the Vangorda Group. 5(a) is overlain by rocks of unit 5(b), a calcareous muscovite-chlorite phyllite. Its presumed protolith is that of a variably calcareous shale. Towards the top of unit 5(b) are sequences of metabasite, unit 5(c), with associated meta-tuffites, 5(d), representing the first major effusive accumulation of basaltic flows and associated tuff. We emphasize the extrusive nature of these rocks as indicated by associated laminarily banded tuffs and stress the existence of episodic volcanism through unit 1(d) of Faro Group, the Mt. Mye Group, continuous up into Vangorda Group with considerable extrusive activity towards the top of the Vangorda Group.

The Vangorda Group is overlain by rocks of the Rose Mountain Group. Two principal lithologic sub-divisions of the Rose Mountain Group include unit 7(a), amygdaloidal chloritic phyllite, made up principally of coarse tuff pillow breccias, pillow lavas and amygdaloidal pillow lavas. 7(a) is overlain gradationally by rocks of unit 7(b) which are black graphitic phyllites enclosing small lenses of unit 7(c) limestone containing typical Middle Devonian two-hole crinoid ossicles. Unit 7(b) is overlain in assumed unconformity by rocks of Earn Group which are largely siliceous rocks that include cherts and chert pebble conglomerates and the like.

Turning to rocks within K.D. allochthon, a newly recognized package of volcanic rocks soled by Kangaroo thrust on the north flank of Anvil Arch, the K.D. Formation of basaltic to dacitic volcanoclastic rocks forms the structural base of the pile.

Within the K.D. Formation, there is a very interesting stringer zone occurrence of sulphide mineralization known as the K.D. deposit. The K.D. Formation is overlain and is interlayered with dark grey or brown graptolite-bearing rock of Howards Pass Formation which contain Lower Ordovician to Silurian graptolite bands. The Howards Pass is, in turn, overlain by the informally named Mag Mt. Formation of basaltic volcanoclastics. Because of the inclusion of the Howards Pass in apparent conformity with the underlying K.D., we therefore ascribe a lower Paleozoic age to rocks of the K.D. allochthon.

The Anvil-Campbell allochthon is well documented by Tempelman-Kluit. This diagram (slide) is somewhat schematic, with serpentinite, 9(a), at the base, or inferred to be the base of the pile, succeeded upward by unit 9(b), various cherty lithologies in turn overlain by Anvil Range Group basalt, 9(c), which are bracketed by Permian and Pennsylvanian fossils giving an overall upper Paleozoic age to the package.

Regional Stratigraphic Correlations:

With respect to regional correlations, we would suggest that rocks of unit 1(c) are in part equivalent to the Atan Group. Lithologically this doesn't seem to hold up too well. Timewise it should be equivalent to the Atan or basal Kechika, based on multi-stage lead ages. Unit 3 rocks are Kechika Group equivalents. Unit 5(a) would presumably be equivalent to the Road River or Howards Pass, which is corroborated reasonably well by the Middle Ordovician faunas contained within Howards Pass. The calcareous phyllites of the Vangorda Group are very tentatively assigned a Middle Silurian age on the basis that they may correlate to Askin Group rocks elsewhere in the Selwyn Basin.

Structure:

The Anvil District is a poly-deformational, poly-metamorphic terrain showing two

regional, penetrative, dynamo-thermal events and five superposed periods of folding. Diagrammatically, rocks of Anvil Range can be portrayed with this cartoon (slide) where the earliest planar metamorphic fabric element, S_1 , is axial planar to folds in S_0 producing F_1 folds. This fabric was formed during the first regional dynamo-thermal event termed D_1 . S_1 is cut and folded by a second regional metamorphic foliation, S_2 , producing F_2 folds schematized here (slide). The S_2 foliation results in a crenulation foliation during the D_2 regional metamorphic event.

We would illustrate F_1 folds here (slide) in the Grum sulphides. This is a type 3 interference figure with an F_1 hinge here, cut and folded by S_2 into an F_2 fold. This is an example (slide) of drill core showing an early F_1 hinge zone with the entire fold being a microlithon between bounding S_2 surfaces, cutting and folding S_1 (and, of course, S_0) into second phase folds as shown.

Three periods of brittle deformation are superimposed on top of the regional penetrative metamorphic fabrics. For time considerations, we will emphasize only the fourth phase folds produced by flexural slip folding of S_2 resulting in generally close to tight third, fourth and fifth phase folds in the S_2 foliation with resultant geometry schematized here (slide). This is a fourth phase fold (slide) in the northeast margin of the Anvil ore body showing the incorporation of the sulphides into the fourth phase folds.

We will illustrate next the megascopic geometry of the first and second phase folds using the best studied map area of the Anvil Range, the Faro-Vangorda-Swim map areas. The Lower to Middle Paleozoic outcrop patterns here are governed largely by first phase folds illustrated by two cross sectional cartoons through the Grum and Swim deposits. I would first acknowledge the kind co-operation of Kerr Addison Mines in allowing us access to their core and we extend our thanks to

Mr. Bill Sirola. Looking first at the cross section through the Grum deposit, you can see first, second and fourth phase folds in the Vangorda Group rocks. Specifically, unit 5(a) is here folded into a first phase, northeasterly verging Z symmetry, F_1 fold with parasitic F_1 's on the southwesterly limb going from southwest to northeast. The rocks involved in this folding are also involved in the second phase folding shown by the general asymmetric pattern in the Grum deposit here (slide) as schematized on the limb of the F_1 fold. The trace of S_2 , shown here in the broad dashed lines, is folded into an open upright flexural slip synform of F_4 generation.

The next slide suggests that the Grum might represent one single sulphide band which is first folded into first phase M symmetry and re-folded by second phase S symmetry as shown here. The geologists at Kerr Addison think this is a lot of "hoey" and it therefore should be treated pretty lightly.

An illustration through the Swim deposit again shows the position of Swim on the upper limb of an original northeasterly verging, Z symmetry, F_1 fold presently complicated by an F_2 antiformal syncline on the southwestern limb of the F_1 . Again, S_2 is flexed into an open antiformal structure shown here as F_4 .

Major Tectonic Aspects:

Returning to the 1:100,000 scale map, a provisional tectonic map of the Anvil Range (slide) shows the following important structural features. The local, first phase fold axes are shown here as blue traces, the K.D. autochthonous package on the north side of Anvil Range is shown here and the Anvil-Campbell allochthon, shown here towards the southwestern edge of the map area. The central portion of the area is monopolized by what we believe is a D_4 intrusive culmination of Anvil Arch produced by forceful intrusion of Anvil Batholith in the Lower Upper Cretaceous. Concomittant with the final diapiric emplacement of this batholith,

two long, linear, gravity detachment zones or gravity slides developed sub-parallel or parallel to the S_2 regional metamorphic foliation which have resulted in shedding of the supracrustal sequence off the underlying batholith.

We would suggest that the D_1 metamorphic event is Permo-Triassic, perhaps as young as Jurassic in age, on the following lines of evidence. There is a D_1 penetrative, regional, metamorphic fabric in the Anvil Range Group. This dates the D_1 event as, at least, Permo-Pennsylvanian. The northeast vergence of the first phase folds fits with northeasterly directed Taltanian deformation elsewhere in the northern Cordillera and therefore we suggest the D_1 event to be Taltanian. The D_2 event is most probably Lower Upper Cretaceous as evidenced by second phase folds in offshoots of the early phases of Anvil Batholith, and the fact that younger phases of Anvil Batholith cross cut S_2 . Therefore, the age of the second deformation is reasonably well bracketed by the intrusion of the Anvil Batholith.

Sulphide Deposits:

Turning to the sulphide deposits of Anvil Range, we have illustrated several times the two horizons of known sulphide occurrence plus the K.D. deposit in the Lower Paleozoic allochthon on the north side of Anvil Range.

The next two slides are sections through the Faro deposit. Relevant features to be noted are the structural position of the Faro ore body which lies on the upper limb of a northeasterly overturned, Z symmetry, first phase fold. These chevron-shaped crenulations (slide) are fourth phase folds, superimposed on the earlier fabric. With respect to the lithofacies distribution within the ore deposit, the black (slide) indicates ribbon-banded, sulphide-bearing, graphitic quartzite, the various hues of yellow and ochre indicate various sulphide-bearing quartzites, the orange indicates massive pyritic sulphides which are generally base metal deficient,

the red indicates massive sulphides relatively enriched in base metals. It is difficult to see, but the little white blobs here and here (slide) are zones of barite development. We would summarize the lithofacies distribution of the Faro deposit by saying that the disseminated siliceous sulphides occur toward the base and northeasterly and southwesterly margins of the deposit. These siliceous, disseminated sulphides are succeeded upward by massive, base-metal rich sulphides hosting a central baritic core. Additionally, in long section (slide) you can see a typical, strong zonation in the massive sulphide facies with respect to base metal content being enriched and depleted from northwest to southeast. With respect to the base metal zoning, the base of the deposit is zinc rich relative to a silver-lead-barium rich top. There is no apparent pattern of copper distribution within the deposit.

Genetic Model:

Turning to our model of genesis for the deposits of Anvil Range, we advocate a submarine, syn-sedimentary, exhalative model roughly envisaged as follows:

Evolved connate brines are convectively overturned in response to high heat flow producing additional base metal leaching and with resultant exhalation through submarine fumeroles into local reduced basins.

The following points can be cited in favour of this model. The fact that we can observe a monotonically increasing volcanic component throughout the Lower to Middle Paleozoic pile as shown by this green curve (slide) from the base of unit 1(d) right on up to the Middle Paleozoic volcanic accumulation in the amygdaloidal chloritic phyllite unit suggests anomalously high heat flow in Anvil District during the Paleozoic. It is this high heat flow that could drive base metal leaching, convective overturn systems responsible for the production of potentially exhalative metalliferous brines. Secondly, upon re-construction of the original stratigraphic sequence in Anvil Range, the K.D. allochthon is

presumed to be an oceanward equivalent of the autochthonous sequence in Anvil Range and the K.D. Formation, host to the K.D. deposit, would be sub-middle Ordovician in age, since it underlies the Howards Pass Formation. The K.D. deposit itself is a typical stringer zone-type deposit and would be approximately equivalent in age to unit 5(a) of Vangorda Group, providing a direct oceanic time correlative to exhalative activity in the Anvil pile. The salient feature to be noted in the Swim deposit is the stringer zone in the footwall rocks. It would appear as though we have a fossil stringer zone beneath the Swim deposit again in support of the submarine syn-sedimentary exhalative model. Lead isotopic data, generated by Folinsbee and Kuo in 1973 and Kuo in 1976 indicates a multi-stage model involving protracted crustal histories for the evolution of Anvil District leads in support of this genetic model.