Faro Geology

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PAST AND FUTURE DEVELOPMENTS - ANVIL DISTRICT

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On behalf of Curragh Inc., I would like to thank the organizers of the Yukon Geoscience Forum for providing the opportunity to bring you up to date on Curragh's activities in the Anvil district.

Before I begin, I would like to acknowledge the excellent work of the geological staff at Faro without which this talk would not be possible, and indeed, mining at Faro would not be possible. Many of the new and old ideas originate from years of work in the District by Gregg Jilson and Lee Pigage of Curragh's Whitehorse Office. With the exception of a few recently blasted rocks in our mining operations, I doubt there is a rock in the district that they are not personally familiar with. Finally, much of the work I am presenting here has benefited from years of field work and study by many geologists since sulphides were first discovered 40 years ago.

This talk presents a general overview of the geology and Curragh's mining activities in the Faro area. For a more detailed discussion of the geology of Anvil District and it's sulphide deposits, I would like to direct you to two publications " Geology and Sulphide Deposits of Anvil Range, Yukon", Mineral deposits of Northern Cordillera, CIM Special Paper 37, 1986 authors David Jennings and Gregg Jilson, and "Field Guide Anvil Pb-Zn-Ag District, Mineral Deposits of Northern Cordillera, Yukon, North Eastern B.C. Field Trip 14"; 8th IAGOD Symposium, G.S.C Open File 2169; author Lee Pigage.

SLIDE - LOCATION OF PROPERTIES

Curragh's lead-zinc mining operations are located in Yukon, and include the Faro and Sa Dena Hes divisions. The Faro mining operations consist of three active open pit mines. Underground operations into the pit wall at Faro have recently been closed after nearly three years of successful operation.

The mining operations at Grum and Vangorda are connected to the milling and concentrating facility adjacent to the Faro Pit by a fifteen kilometre haul road. A fleet of ten 90 tonne trucks ferry ore from Vangorda at a rate of 14,000 tonnes per day.

Three kilometres to the east of Vangorda, a fourth major undeveloped zinc-lead deposit, Dy, awaits development and mining by underground methods. Next in line, the Swim deposit is smaller than the deposits to the west and contains about 5 million tonnes of mineral inventory. Further to the east, the SB and SEA are base metal deficient, uneconomic iron-sulphide occurrences.

SLIDE - MILLING COMPLEX

The mining and milling operations at Faro have the capacity to produce up to 600,000 tonnes of lead and zinc concentrates per year, however in the short term due to oversupply of concentrates on world markets, production levels will be cut back from these levels.

SLIDE - HAUL TO SKAGWAY

Concentrates are hauled year round, 24 hours a day via a fleet of specialized B-train trucks, 550 kms to tidewater at Skagway, Alaska. The concentrate is then loaded into freighters and shipped to smelters in Europe and the Far East.

SlIDE - DISTRICT GEOLOGY:

Before I take a little closer look at the geology of the deposits and the individual mining operations, I will provide some context with a brief description of the district geology.

The Anvil district is situated within the Selwyn basin, an important tectonic province which hosts some of the world's largest lead-zinc deposits. The district is bounded to the southwest by the Tintina fault system, a major right lateral slip fault of the cordillera with some 500 km of displacement.

SLIDE - REGIONAL GEOLOGY

The five known stratabound exhalative lead-zinc-silver deposits occur within a 150 metre lower Cambrian sequence of metasedimentary rocks. They are indicted by the series of red dots starting the furthest west at Faro, to the east is Grum, Vangorda, Dy, Swim.

The interval containing the deposits straddles the contact between the underlying noncalcareous phyllite and schist of the Mt. Mye formation and the overlying calcareous phyllite, schist, and calc silicate of the Vangorda formation. (Vangorda formation is indicated by blue and Mt Mye is indicated by brown.)

The deposits were likely formed by geothermically heated metal rich brines venting to the ancient seafloor along growth faults at the margin of an anoxic sub-basin. At the seafloor, the brines would mix with reduced sulphur to induce precipitation of base metal sulphides.

The current linear distribution of the known deposits is likely a reflection of the geometry of the fault. So far, none have been found off the "trend line" which is partly a result of concentrated exploration efforts along the trend. Once the known trend is adequately explored, successful exploration off the trend may lead us to another string of discoveries in the district. Currently there are remarkably few holes that actually penetrate the favourable stratigraphy off the known trend. There is no reason to believe that the fault responsible for the trend we see today is the only one in the district. Unfortunately, evidence of these early faults has been obliterated by later metamorphism and we may likely only pick up a new trail by discovering another deposit.

In early Mesozoic, the collision of The Yukon Tanana Terrane with the ancient margin of North America and the associated tectonism resulted in the later emplacement of the Anvil Batholith (indicated by pink). These events are responsible for multiple phases of deformation recognized in the district.

The first two are associated with regional metamophism and intense folding. These events are the most important because they greatly influenced the overall shape and character of the orebodies.

Later deformation, possibly related to the final stages of emplacement of the Anvil Batholith resulted in local warping of the stratigraphy and more intense folding near the Faro deposit. Several steeply dipping extensional faults have been identified in the district and are related to these late events. Many of these faults are locally important because they have resulted in known vertical displacements up to 600 metres and they locally define the boundaries of the orebodies.

Starting with the Faro orebody, the remainder of the talk will focus more closely on the geology of the deposits in the district and the mining activities currently taking place.

SLIDE - LONG SECTION FARO OREBODY

In simplified long section, the Faro orebody looks like an open pit miner's dream. Relatively flat, tabular, shallow and large! The red indicates high grade massive sulphide which is sandwiched between a thin interval of lower grade disseminated sulphides in carbonaceous quartzites (indicated by yellow). The cream colour is a sericite alteration halo around the sulphides which is variably developed. The deposit occurs just below the calc silicate of the

Vangorda formation (indicated by green) within the muscovite - biotite - andalusite schist at the top of the Mt. Mye formation. The Faro orebody is unique in that it is metamorphosed to middle amphibolite facies and as a result the sulphides and the host rocks are coarser grained than the plateau deposits. Cretaceous granitic intrusions are indicated by pink.

The highest grade ore was closest to the surface in the Faro # 1 portion of the Faro graben structure. This vastly improved the project economics. The previous owners, Cyprus Anvil Mining Corporation typically averaged mill head grades of 10% to 12% combined lead plus zinc and 1 1/2 ounces per tonne silver in the early stages of mining at Faro.

After purchasing the assets in late 1985, Curragh began mining at the top of Faro # 3 down faulted block at the centre of the orebody. Mill head grades were typically lower, averaging about 3.5% lead and 4.7% zinc for a combined grade of 8.2%. The lower head grades were more than made up for by improvements to the mill and higher mining productivity. Mill throughput quickly rose from levels below 8,000 tonnes per day at the end of Cyprus Anvil's tenure to current rates of 14,000 tonnes per day. Concentrate production, as a result, quickly rose to record levels.

SLIDE - CROSS SECTION FARO OREBODY

We are looking NW at a cross section cut near the centre of the Faro # 3 orebody. Note the location of the final pit walls and the downdip portion beneath the SW pit wall which was mined underground.

The same colour scheme as the long section is used on this section.

In cross section, the complexity of the Faro orebody is more apparent. In reality the structure of the orebody is much more complicated than indicated here. Some of the large scale phase three folds can be seen on the deposit footwall. The distribution of low grade semi-massive sulphides as indicated by orange on the NE side of the pit is likely controlled by tight, isoclinal phase two folds that have been refolded by phase 3 folds.

At a mining scale the mapping and understanding of the fold geometries is important to calculate and predict ore reserves. We discovered this early in our efforts at Faro and diamond drillhole coverage was doubled from a 140 ft. by 140 ft. grid spacing to a 70 ft. by 70 ft. spacing to give us the level of predictability we were looking for.

SLIDE - AERIAL SHOT FARO PIT

Since re-activation of mine and mill by Curragh in 1986, up until two years ago, the Faro open pit was the sole source of millfeed at an annual rate of approximately 4.2 million tonnes. This shot was taken directly above the mill looking almost due east towards the Faro pit with the Anvil range in the background. In the foreground are the various waste dumps and ore stockpiles. The haulroad on the bottom right hand side connects the mill to the mining operations 12 km to the east.

The first truck load of rock was hauled out of the Faro pit in 1970. 22 years and 240 million tonnes later, the orebody is essentially mined out. Of that 240 million tonnes, 60 million tonnes of ore was fed to the mill, the remaining rock resides in the various wastepiles situated in and around the Faro Pit.

Since 1990, millfeed has been split between the Vangorda deposit, the waning Faro pit and an underground mine collared into the pit wall at the bottom of the Faro pit. In July of this year the last shovel at Faro was moved to strip waste rock at Grum.

With the exception of some Faro low grade ore in stockpiles and some additional ore recovered from the old Faro pit walls, the company currently relies almost entirely on Vangorda production to supply the mill. Grum will not make a significant contribution until the beginning of the second quarter 1993.

SLIDE - TAILINGS PIPE INTO PIT

The Faro pit is now being filled with tailings from processing the Vangorda ore. The pit has a large enough capacity to store tailings from the remaining orebodies in the district. Once the pit is filled with water in three years, most of the mill's water requirements will be recycled from this immense reservoir.

SLIDE - UNDERGROUND PORTAL

In 1989, an underground portal was collared near the pit bottom into the southwest wall. After chasing the downdip extension of the Faro # 3 orebody, the last tonne of underground ore was mined a month ago.

SLIDE - UNDERGROUND IN RELATION TO PIT WALL

Up until a month ago, underground operations at Faro contributed 15% of the millfeed on a daily basis throughout its three year life. Originally slated to produce 1.2 million tonnes of high grade ore, the honey-comb development you see here produced 1.8 million tonnes. This exceeded expectations and underground operations continued 8 months beyond the original expected completion date.

Production was in two zones called north and south which are separated by a zone of thinner low grade sulphides. The south zone was higher grade and measured approximately 350 metres square with an average width of about nine metres. The north zone was about half that size and average thickness was about 6 metres.

SLIDE - ROCK BOLTERS

The underground mining method was conventional mechanised room and pillar. Mining recovery was 70%, average dilution was 12%. Ore cutoff grade was 9% lead plus zinc and average daily production was about 2,200 tonnes grading 4.65% lead and 6.92% zinc and 62 grams per tonne silver. Here, miners are bolting the back with a two boom Jumbo.

SLIDE - CROSS SECTION UNDERGROUND

This cross section parallels the main haulage ramp. Abundant small faults which we would not be able to react to in open pit mining are very important when controlling dilution in an underground operation. Continual diamond drilling from the underground workings was carried out in advance of the mining to locate the hangingwall and footwall contacts. The information used for layout design so that advance in waste rock was minimized. Mapping of the walls and faces was ongoing and extremely important to identify structures which may effect the integrity of the back.

SLIDE - FAULT IN UNDERGROUND

One of the major normal faults which dropped a block of the orebody about 15 metres. A quick sharp turn and dive through the hanging wall was required to reenter the ore zone.

MINERS WITH PITCHFORKS

In the final days of underground operations, the miners were given the task of spreading a layer of hay and sawdust over the entire floor of the workings. The hay will become a comfortable home for billions of sulphate reducing bacteria who are going to recreate the chemical process which formed the orebody and precipitate metal ions out of drainage from the rock dumps. Desulfovibrio Desulfuricans will reduce sulphate and provide sulphur anions to combine with zinc and lead cations to form base metal sulphides. All we have to do is initiate the reaction by pumping down a mixture of cow dung to inoculate the bugs and sugar to feed the bugs.

DRILLING HOLE INTO UNDERGROUND

To accomplish this, an 8" diameter 300 metre hole into the underground workings was drilled and cased. Apart from some test runs in the near future, full initiation of the reaction is not required until abandonment of mining operations. This new technology for acid nine drainage abatement is new and experimental. It has happened naturally in a mine in Norway where the wooden timbers appear to be providing the required carbon source. Even if the experiment is only partially effective, the cost savings over running a conventional water treatment plant in perpetuity are substantial. The process results in the dissolved sulphates and metals in the water being precipitated as a sulphide solid within the underground chamber. Conventional water treatment would require the periodic dredging and disposal of carbonate sludge; a problem which will not occur with sulphate reduction where the underground offers hundreds of years of storage capacity.

SLIDE NE WALL FARO PIT

The company is currently squeezing some additional life out of the Faro pit. This summer, after detailed mapping of pit walls in the Faro # 1 pit and following up with diamond and percussion drilling, two separate zones on each side of the pit were outlined. Together, they contain about 900,000 tonnes mineral inventory grading about 8.5% lead plus zinc. About 675,000 tonnes is open pit minable by steepening the pit walls from the current 50^0 to 60^0.

Mining began in the AY Zone on the NE side of the pit 3 weeks ago. A contractor is drilling 3" diameter holes on a 10'x 10' grid, cast blasting and pushing the ore over the pit face onto pit floor below. Curragh is then loading the ore into haul trucks and transporting the ore to the mill. 490,000 tonnes of ore is expected to be mined from the AY Zone when it is completed at the end of December.

Directly across the pit, another zone has been defined by diamond drilling and pit mapping. This zone is the down dip continuation of the zone 1 orebody and is actually the upfaulted extension of the orebody which was mined by underground methods. It is thinner and lower grade than the underground, however about 188,000 tonnes is minable by open pit methods at a stripping rate of 3 tonnes waste to 1 tonne ore. The zone remains because the main haulage ramp crosses over it. The ramp will be mined out and the wall steepened to 62^0. Ore will be hauled from the pit on a secondary service ramp using trucks smaller than we normally use. Blast holes will be drilled using a regular production drill and mining of this zone will commence in the near future.

SLIDE - TRUCKS LOADING, VANGORDA PIT

The Vangorda pit is at the site of the original discovery of lead-zinc mineralization in the district. The Vangorda creek was diverted around the northwest pit wall and the small discovery outcrop on the bank of the creek has since been mined. Mining began in the spring of 1990 and since that time 4.9 million tonnes of Vangorda ore has been hauled to the crusher. The remaining 1.6 million tonnes will be mined out by May next year.

The next speaker, Dennis Brown, is going to talk at great length on the geology and structure of the Vangorda deposit, so I will leave that topic to him and continue with a discussion of Grum.

SLIDE - LOADING TRUCKS AT GRUM PIT

Two of the company's four shovels are currently removing waste rock and overburden from the first stage of the Grum open pit and the third is walking from the Vangorda pit to Grum as I speak. The three shovels will muck at an average rate of about 100,000 tonnes per day.

The tip of the fold structure that is the Grum orebody was recently exposed and the first truckload of ore has been sent to the ore stockpiles. Unfortunately, this part of the orebody which we call "the Gnome's cap" is lower grade carbonaceous quartzite and is not thick enough to make a significant contribution to millfeed until July next year.

The deposit was discovered in 1973 when a diamond drillhole was collared to test a geophysical anomaly northwest of the Vangorda deposit. Surface diamond drilling was started followed by an underground exploration program in 1975 and 1976. The underground workings consist of a ramp which splits into two parallel declines and follows the trend of the main ore zone. The declines extend 700 metres in length and chase the ore zone down plunge to the northwest at an angle of 11 degrees to a depth 200 metres.

A total 525 surface and underground diamond drillholes delineate the deposit which is about 80 kilometres of drillcore. Of the 512 drillholes, Curragh has drilled 112 holes since 1986 to better define the shallow portion of the reserve and to provide additional samples for metallurgical testing.

The final pit will not be quite as large as the Faro pit when it is completed. The top bench is about 1.2 km long by 0.8km. wide. The pit will sink to a depth of about 320 metres.

SLIDE - GRUM LONG SECTION

Red on the section indicates high grade massive sulphides, yellow indicates lower grade disseminated sulphides in quartzite, grey is carbonaceous phyllite. The calcareous phyllites of the Vangorda formation are indicated by blue. The older, Mt. Mye formation is indicated by brown.

The Grum ore lenses are stratigraphically situated from about 100m above to 50 m below the Mt. Mye / Vangorda formation contact. The main lens is immediately below the basal carbonaceous phyllite of the Vangorda formation. The overall strike length is about 2 kms.

In the down plunge direction to the northwest, the deposit is truncated against the Tie fault, a late extensional fault dipping about 45 degrees to the SE. Bits and pieces of the Grum deposit and remobilized sulphides are caught up in the fault zone. In fact, mineralized outcrop occurs at the Firth showing and several drillholes were collared to investigate it. Results confirmed low tonnage and its relationship to the main Grum orebody was not known until Grum was discovered several years later.

The final pit design is not shown on this section, but a sizable portion of the deposit to the northwest will be minable by underground methods. More drilling and economic analysis is required to determine the feasibility and timing, but if the underground zone is to be accessed it will be through the northwest highwall near the bottom of the final pit. There is potential for two to three million tonnes of underground minable ore.

The next slide is a cross section cut about half way on this long section

SLIDE - GRUM CROSS SECTION

Like all deposits in the district, the true nature of the beast is not seen until you look at it in cross section. The geometry of the orebody is strongly controlled by phase 1 and phase 2 folding. A NE verging phase 1 anticline - syncline pair has been refolded by coaxial south-west verging phase 2 folding. The fold axes of both phases plunge gently at 11 degrees to the northwest.

Late faulting resulted in the present day distribution of the ore horizons.

The final pit design is shown and the underground workings and diamond drilling are visible in the centre of the section.

SLIDE - DEFORMATION OF GRUM

The complex deformation history of Grum is depicted in this cartoon.

First - primary deposition of Grum in a series of stacked lenses.

Second - Phase 1 fold event, likely related to the collision of Yukon Tanana Terrane into North America immediately to the southwest. This resulted in large scale NE verging folds and the imparting of a well developed moderately SW dipping axial planer foliation.

Third - Phase 2 deformation related to the emplacement of the Anvil Batholith immediately to the NE. This resulted in smaller amplitude "S" shaped refolding of the earlier "Z" shaped phase 1 structure. The moderately SW dipping phase 1 foliation is overprinted by a shallower SW dipping foliation which is axial planer to the second phase folds. The interference of the two deformation phases and later faulting is responsible for the present day deposit geometry.

SLIDE - BACK TO CROSS SECTION

OVERHEAD - DY DEPOSIT

Dy is currently defined by 77 deep drillholes which probe the deposit to a depth of 1000m. Several sulphide horizons which dip moderately to the SW have been intersected. The deposit remains open in all directions.

On this slide, in the top left corner, I have included a cross section of Grum at the same scale for comparison. In reality the Dy deposit likely looks more like Grum. Early interpretations of Grum at a similar drill hole spacing look remarkably similar. With more exploration and drilling at Dy, It is likely that a complexly folded, multi-layered deposit will emerge. It is interesting to note that fill in drilling at Grum lead to an overall increase in mineral inventory, not a decrease which is often the case.

To date, a mineral inventory of 21 million tonnes grading 5.54% lead, 7.33% zinc, 81 g/mt silver and .87 g/mt gold has been indicated by drilling at a 9% lead plus zinc cutoff.

Currently, access by a decline and/or shaft is being studied. A proposed shaft location which sinks 730m into the low grade sulphide core of the deposit is indicated on this slide by the vertical red line.

A go-ahead decision for development at Dy largely hinges on the price of lead and zinc. At this time no physical work is being carried out in the DY area, however a feasibility study for underground mining is just being completed.

It is expected that once a go-ahead decision is made, It would take about 1 1/2 to 2 years to put the mine into production

CONCLUDING STATEMENT

As you have seen, the level of activity in the Anvil district remains at a furious pace. The potential to extend the exploration success to sustain development in the district is extremely high if the potential to mine at a profit in the district remains high.

Thank you for your attention.