EXPLORATION METHODS IN YUKON

WITH SPECIAL REFERENCE TO ANVIL DISTRICT

By

Dr. A.E. Aho, Consulting Geological Engineer

Vancouver, B. C.

Presented at

The Second Natural Resource Conference

Whitehorse, Y.T.

March 24, 1966

ABSTRACT

This paper summarises a regional approach to mineral exploration, problems and methods characteristic of Yukon, and methods currently used in the Anvil lead-zinc district.

It is pointed out that Yukon is still sparsely explored and that with a suitable approach several major deposits exceeding a billion dollars in gross value will be discovered and developed. Regional geology, anomalous structure, and favourable stratigraphy can be used to select an area in which further work will determine the most applicable approach.

Special problems and methods in Yukon are discussed under timing, transportation, unglaciated terrain, permafrost, and overburden drilling.

The most logical exploration approach in the Anvil district is outlined from initial district consideration through reconnaissance, airborne magnetic and EM surveys, and ground surveys to drilling. Limitations of each method are considered, leading to the conclusion that no single or rigid approach is the answer, but that all methods must be used with great flexibility and ingenuity for the maximum probability of success.

CONTENTS

INTRODUCTION

Mineral possibilities, metallogenic provinces, and exploration activity in Yukon have been outlined in previous papers by several writers. With some exceptions, mineral deposits of Yukon are typical of the Cordilleran mountain systems but exploration conditions and techniques are unique in some cases, and thus deserve consideration. Against this background the present paper outlines some of the pertinent exploration problems and suitable methods in Yukon and in the Anvil district in particular, in a non-technical manner, but no attempt has been made to cover all aspects of exploration.

Except for existing mining operations like the Klondike, United Keno, Canada Tungsten, and others being developed; and the recent major discoveries of the Crest iron formation and the Anvil (Dynasty) lead-zinc deposits the mineral potential of Yukon is at best only partly discovered. It is difficult for most people, even in exploration elsewhere in Canada, to comprehend that although much of Yukon has been "covered" by reconnaissance prospecting the coverage is still very sparse. Each season significant new prospects can be discovered as outcroppings, float, or gossans, still largely by traditional prospecting techniques such as float tracing and panning, although aided in many cases by geochemistry and geophysics.

Yukon has been considered a high cost area due to remoteness, small tonnage production, short seasons, permafrost and lack of transportation. However, it is no more remote or costly than parts of the interior of British Columbia or northern Ontario or Quebec, and it is 600 miles closer to Japanese markets than Vancouver. Large tonnage operations in Yukon should thus be as profitable as in these comparable areas and, as a result of ever-increasing world demand and recent developments, Yukon is quickly coming to the fore as a long-promised land of mineral wealth, and the last great frontier for the individual prospector.

REGIONAL APPROACHES

General

Since Yukon is geologically very similar to other outstandingly productive portions of the North and South American cordilleras, and since numerous prospects of similar mineralization have been discovered, it is a certainty that several first-magnitude ore deposits exceeding a billion dollars in gross value must exist in this relatively unexplored region. They can be found with a suitable approach. In what geologic environment can these deposits be discovered and by what methods?

In selecting an area to explore, one must consider factors such as accessibility, probable economics, mineral occurrences, and costs of exploration; but regional geology, structure, and stratigraphy are most important. Many of the world's largest mineral deposits are associated with some unique or anomalous structural or stratigraphic condition which, if recognized, can be a regional guide to selection of an area with possibilities of the maximum potential. Many epigenetic deposits of deep source are localized in or near anomalous structures, often with vertical tectonics or uplift, where tensional conditions have provided access to a flood of mineralization which then becomes entrapped in whatever structural or stratigraphic trap is available. Syngenetic deposits are likewise localized under somewhat unique stratigraphic conditions. The search for major deposits can therefore be aided by such approaches.

Structural

The anomalous structural approach has been outlined by the writer in an earlier paper but is reviewed as follows:

Broad-scale geological work around many mining camps has shown that the structure of the mineralized district as a whole - an area of one to fifty or more miles in extent - in many cases differs significantly or uniquely from the regional pattern. This "anomalous" difference may consist of a change or intensification in style of tectonics, irregularity in structural units or in contacts, cross-folding, complex domes or uplifts, plugs or rows of intrusives, belts of dykes or fracturing, bends on en-echelon gaps in fault systems, etc.

Most such ore-bearing districts show heterogeneity of competent and incompetent rocks on an appropriate scale; orogeny with repeated or prolonged deformation; plutonic or hydrothermal activity; long-lived deep transgressive channelways, sometimes with ultrabasics; and transverse structural trends. Heterogeneity of rock types favours variations in distribution and orientation of stress, and therefore in directions of failure, localizing strain in favoured localities of hindered movement. Orogeny with repeated or prolonged deformation not only produces the necessary complexity of structure but keeps the district alive, opening and reopening channelways and stressing the rocks to make them physically favourable for ore deposition. Plutonic activity provides heated channelways and favourable thermal conditions, and deforms surrounding rocks; the plutonic rocks serve as massifs to concentrate stresses, and may form host rocks, as in porphyry copper deposits. Deep transgressive channelways or surfaces of discontinuity such as deep shears, intrusive contacts, steeply plunging folds, ultrabasic zones, or other such structures may not only tap ore fluids and serve as feeder channels for nearby mineral deposits but may also influence the structural pattern.

Superimposed transverse structural trends appear to be particularly productive. While the region as a whole may deform with a certain pattern or style of tectonics in response to orogenic stress, an area of transverse structure or other anomalous variation (e.g. a transverse trend in the basement rocks) forms a resistant knot and becomes the locus of prolonged, hindered, or repeated deformation, of greater structural complexity, and therefore of concentration of activity favourable for genesis and localization of epigenetic ore deposits.

Whatever their origin, ore forming fluids must be localized and concentrated to form epigenetic mineral deposits in their particular metallogenic province, and it is suggested that such localization is often directly or indirectly a result of anomalous variations in regional tectonics.

From the above reasoning the writer suggests that any area which contains anomalous or complex structure, particularly if it shows mineralization or alteration, should be very closely investigated, bearing in mind that structure may be complex without being anomalous and that an anomalous structure may not be mineralized.

In unmapped and unprospected regions anomalous structure may be found by reconnaissance geologic mapping or even by air photo study where bedding, foliation, lineaments, and heterogeneity of rock types are easily visible. Once the area of general interest is selected geology, structure, stratigraphy, mineral occurrences, geochemistry, and geophysics can be used to determine the probable limits of the mineralized district and a flexible systematic exploration approach can be determined. Although most anomalous structures will not contain mines and many major mines do not show such features even if present, the interrelationship with major mining camps is frequent enough to warrant use of this concept as a guide to narrow down exploration in a metallogenic region.

Examples of some of these features in mineralized areas of Yukon and adjacent northern British Columbia are as follows:

(1) Wheaton district - transverse E-W re-entrant or crumple of metamorphic and Tertiary rocks interrupting the trend of the Coast batholith.

(2) Atlin district - ENE transverse structural grain accompanied by ultrabasic rocks.

(3) Mt. Freegold-Nansen area - terminus of Big Creek lineament and Dawson Range batholith in structural complexity with accompanying porphyry intrusions.

(4) Casino Creek area - constriction in Dawson Range batholith with associated transverse faulting.

(5) Mt. Stewart placer gold area - complications of NW cordilleran trend and major lineament near Tertiary syenite stock.

(6) Klondike gold fields - slightly transverse knot-like trend in Klondike schists, cut by faults.

(7) Tombstone Mountain area - regional trends and Keno Hill quartzite wrapped around syenite stocks.

(8) McQuesten mineral belt (Mayo area) - major transverse fold, fault, and intrusive belt.

(9) Anvil Range - complex uplift with intrusive core, cut by fault pattern typical of uplifts.

(10) Little Salmon Lake - transverse E-W fold trend with some intrusives, intersected by regional faults.

(11) Ketza River - half dome uplift cut by faults. Tintina silver area similar but more complex.

(12) Quartz lake - Mt. Hundere lead-zinc belt near Watson lake - regional ESE zone of transverse lineaments, probably tear faults; Quartz lake in an area of fault blocks, Mt. Hundere localized in an uplift.

Stratigraphic

In the broadest sense regional stratigraphic environment often controls the type of deposit: for example, copper tends to occur in a eugeosynclinal environment with basic intrusive or extrusive rocks; tin tends to occur in a slate, schist and quartzite environment with acidic intrusives; and lead-zinc tends to occur in a miogeosynclinal environment with limestone and shale, perhaps also with marine volcanics. Such regional associations appear to be a result of mobilization of the metals from deeply infolded sections of the associated rocks, with deposition taking place at higher levels in the same lithologic environment, for which the metals have affinity.

Many deposits in Yukon are directly localized either chemically or physically by stratigraphy in many places, the following being only a few examples.

(1) Lead-zinc in Lower Cambrian limestones or other limestones and dolomites in Pelly Mountains and elsewhere in eastern Yukon; and in certain schist members in the Anvil Range.

(2) Silver-lead-zinc veins in competent Keno Hill quartzite. (physical).

(3) Copper in certain volcanics, and in beds at Redstone.

(4) Iron in the Rapitan formation in the Crest iron region.

Miscellaneous

Air photo interpretation is one of the most useful tools, not only for location but especially for structural and stratigraphic studies, particularly when used on a day-to-day basis in the actual field work.

Airborne geophysical surveys, using a helicopter, provide very satisfactory data in the central plateau regions of Yukon, over the less rugged mountainous terrain, and in intermontaine valleys, provided magnetic and electromagnetic characteristics are useful in a particular exploration program.

This approach has proven particularly successful in the Anvil (Dynasty) district where massive lead-zinc sulfide deposits are susceptible to detection. This applicability may be expected to extend to many parts of the wooded interior plateaus which are low-lying, wooded, and otherwise tedious to prospect.

Regional prospecting can be guided by many considerations mentioned above and below, including known types of mineral occurrences. One idea that would seem ill-founded is to prospect low areas near high hills but it has some physiographic merit since altered and mineralized zones tend to be eroded into low topography, yet tend to be associated with granitic stocks, uplifts, or areas of older or resistant rocks which stand up due to late Tertiary uplift, isostatic adjustment, or erosion resistance.

Regional silt and soil sampling is one of the most direct methods used by many companies to find the best mineralized sections of a generally favourable region. Operation Keno conducted by the Geological Survey of Canada on the Mayo area in 1964 is an excellent example of this type of regional geochemical program that can be very productive.

Silt samples taken from minor drainages rather than larger streams are most effective while soil samples taken at suitable intervals along contours of talus slopes and in frost-heaved solifluxion areas are most effective. On Mt. Haldane in the Mayo area samples of talus fines were successful in pinpointing several lead-zinc vein zones.

In order not to miss any mineral possibilities in a given area, silt and soil samples should be tested not only for the metals sought but for all reasonably expected metals, since the cost of testing for additional metals is minor relative to the cost of obtaining the samples.

SPECIAL PROBLEMS AND METHODS IN YUKON

Timing

Due to the drastic variations in seasonal conditions, timing of exploration projects in Yukon is very important for feasibility and cost minimization. The most obvious problem is that transportation is hindered by breakup in May and June, to a lesser extent by freezeup at creeks and rivers, and by local "glaciering" in winter.

Any surface work from mid-December to mid-February may be hindered by periods of severe cold, even down to -70°F in the lowest parts of Yukon plateau like Mayo and Dawson. At -30°F helicopter work must be suspended, at -40 to -50° most outside activity becomes difficult, and at -60° to -70°F most transportation is curtailed. However, periods of extreme cold are usually not lengthy, and down to -40°F most work can be carried on effectively, especially if motorized equipment is kept in heated buildings when not actively in use.

Normal hardrock prospecting and geologic surveys are possible only between about May 1 and October 15 at the lowest elevations and generally only between May 30 and September 15 at higher elevations. However, placer prospecting is best done in winter, especially in February, March and April when the ground is frozen.

Geochemistry is limited to the period July 1 to October 1 when spring runoff is complete and ground is thawed so that suitable silt and soil samples can be taken. However, on an overburden drill program or with other mechanical means which may be devised for frozen ground, geochemistry can be carried out most of the year.

Geophysical work like magnetic, EM and gravity surveys is best done from March to November; whereas electrical surveys with ground probes are best done from June to October.

Trenching in permafrost is best started in May so that maximum daylight hours will speed thawing in June and is stopped in early September when thawing stops. In non-permafrost areas trenching should be started in late June when seasonal frost is gone, and can be continued until freezeup in October or November.

Drilling is possible year-around but is best done from March until December; however work in a wet muskeg area becomes difficult from July until freezeup.

Underground programs can be carried on throughout the year with adequate winterization in most areas, but may have to be timed with seasonal mobilization and transportation problems.

Transportation

Due to lakes and permafrost or muskeg terrain, vehicular access is often best in late winter, especially if large amounts of supplies and equipment have to be moved. Pack horses are effective in most of the territory from about May 15 to September 30 when feed is available. Dogs are conveniently used in teams in winter and as pack dogs in summer. Snowmobiles are suitable in certain cases, as are bombardiers or 4-wheel drive vehicles in parts of the unglaciated plateaus above timberline. Except for parts of the unglaciated terrain most of Yukon can be readily reached by fixed wing aircraft operating onto lakes, rivers or airstrips, or by boats on rivers and lakes.

As elsewhere, the helicopter has proven to be the most versatile, direct, effective and efficient means of primary transportation, either on a part-time or full-time basis. However, it should not govern a program for it is basically a primary transportation tool; prospecting is still best done by combing creeks and talus slopes and tracing float, pannings, or geochemical anomalies upstream or uphill. The most effective direct use of the helicopter in exploration is in reconnaissance geology, spot checking, and gossan spotting, and in guiding associated ground traverses, standard prospecting and geochemistry. Such a program can be operated from one or more central base camps, and prospecting parties with pack dogs which can be easily moved by helicopter can be set out in subsidiary fly camps for 1- to 2-week periods.

The lack of lakes in the unglaciated part of Yukon plateau and Mackenzie mountains, and the rugged terrain and icefields of the St. Elias, Coast, and Logan mountains make a helicopter advisable in these areas. For greater flexibility and work in the higher terrain a Hiller 12E or Bell B-1 helicopter is preferable to the more common Bell G-2.

Unglaciated Terrain

Except for some of the Arctic islands the unglaciated terrain of Yukon is unique in Canada, and its characteristics greatly affect exploration methods. Rocks and associated mineral deposits have all been weathered down to a maturely dissected plateau surface over vast stretches of time during the Tertiary period. The gradual slopes, especially at lower elevations, are thus thoroughly weathered of any leachable materials; only tin, tungsten, gold, and other resistant placer minerals and asbestos remain near surface. The slopes are very largely mantled with residual overburden and, on the north facing slopes, permanently frozen black muck accumulated from thousands of years of vegetation obscures everything. Only in deeply dissected valleys or canyons and at the higher elevations are fresher rocks and mineral deposits available to the prospector.

Thus the unglaciated sections of Yukon with their sparsely scattered, weathered outcrops and extensive soil and buckbrush cover have greatly discouraged conventional Canadian hard-rock prospectors who are used to seeing fresh rock. Recognition of the weathering products of important economic minerals is also a difficult adjustment for Canadian personnel. In the unglaciated country the prospector must have a light grubhoe or pick and shovel and be prepared to dig, otherwise his work will be too limited.

However, the resistant minerals have only migrated downslope or downstream with frost, gravity, and water and can therefore be logically traced and their source easily found if overburden is light, as compared to the frustrations of trying to trace float or pannings in a glaciated area. Moreover, depth of leaching and weathering is much less than in temperate unglaciated areas, so that geochemistry is very effective and primary sulfides are usually within reach of geophysical techniques. (Secondary enrichment of sulfide deposits is also limited.) Promising parts of the unglaciated section of Yukon thus offer unusual opportunities for modern geochemical and geophysical techniques combined with intensive use of the pick, shovel, gold pan and bulldozer.

On the other hand, traditional methods using the gold pan and other placer techniques can still be productive in this terrain for other minerals as well as gold. Although many creeks have been effectively tested for placer gold by standard methods of pit sinking, churn drilling or open cutting, other minerals have not been as closely checked and some creeks have not even been effectively tested for gold. An effective test consists of testing bedrock across the entire channel in the sections of the creek that are most likely to contain economic placer concentrations due to stream characteristics and nature of bedrock.

Initial reconnaissance should consist of silt sampling and panning of streams, and of collecting soils for geochemistry and panning at intervals of a few hundred feet along contours at suitable levels of slopes between each drainage. In this region many drainages have been stabilized over a long period of time, so stream sediment sampling may not be as effective as in the glaciated areas, whereas soil samples are more effective. Soil samples for both panning and geochemistry should be obtained from the "B" soil horizon or where rock material begins to show up. Near-surface organic material or volcanic ash is useless; organic material tends to concentrate Zn, Cu and Hg, whereas volcanic ash dilutes values. Coverage on the north-facing slopes would be limited by frozen organic muck accumulations but enough samples can usually be taken during initial reconnaissance to determine promising areas.

Once an area is found to be mineralized either from pan concentrates, geochemistry, or other indications, the mineralization can be traced in detail with geophysics, if applicable; with direct physical methods such as trenching by hand or bulldozer if bedrock can be easily reached; or with overburden drilling if overburden is deep or consists of permafrost.

Bulldozer trenching is often the most effective way to trace and expose mineral deposits in this unglaciated terrain, depending on permafrost and depth of overburden. Thawed south-facing slopes can be trenched most effectively, while permafrost slopes have to be trenched cyclically from May to September, often through much or all of the season before bedrock is exposed. Care must be taken to go deep enough to be absolutely sure that bedrock is actually in place, since the creeping residual overburden can very deceptively appear quite compact and "in place" in a trench, especially in permafrost.

Contour trenching to pick up float, pannings, or geochemical trains is very effective and has been used in several areas, the best example being the Klondike Lode Gold Mines program. Variations in placer gold in the most richly productive area of the Klondike, on Upper Bonanza and Eldorado creeks, pointed to several probable sources either near the creek bottoms or on the mature buckbrush- and soil-covered sidehills. Several miles of contour bulldozer trench were cut to bedrock along the lower hillsides except where overburden was too deep near gulches or where permafrost slopes were too steep to work. These trenches were essentially soil sampled for gold from the surface to bedrock every 100 feet by means of a vertical channel sample about 1 foot wide and 2 - 3 inches deep, giving about 1/9 cubic yard of sample. The sample was then run through an 8-foot steel sluice box, the number of colours of gold were noted and plotted up, and the panned concentrates were saved. Where significant results were obtained a trench straight up the slope rapidly revealed the source, otherwise a higher contour trench was used to pinpoint the source. Several vein and stringer zones with pyrite and gold were found very readily, but the main sources still appear to remain hidden in lower topography or swales which contain permafrost and are difficult to trench because of steepness of the slopes. In some places bulldozers slide off the hill but it may be possible to use a slusher-type dragline to cut these trenches.

At Mt. Nansen some wildcat trenching was done to discover float but most of the trenches were placed in a grid transverse to strike of the vein zones and was very effective in tracing them. Geochemistry, using antimony as the best indicator, was particularly useful in determining where vein zones were passed over in trenches that could not be deepened to bedrock in a given season due to permafrost. The necessity for carrying a trench deep enough to be sure bedrock is in place again cannot be overemphasized.

Permafrost

Permafrost occurs over much of Yukon, especially north-facing slopes, and although it is generally a hindrance, some of its characteristics are advantageous to certain methods of exploration.

Geochemical sampling with portable hand-held augers and diamond drills has been proposed for permafrost but such mechanical methods have not yet been effectively tested or used in Yukon. Hand methods to date have consisted of driving in a sampling tube usually consisting of a sharpened and slit core barrel.

Geophysical methods that appear to be interfered with by permafrost include seismic and self potential surveys.

In bulldozer trenching in permafrost, cyclic removal of material has to be kept up with the pace of thaw, for although rate of thaw will slow down and even stop, the trench may thaw deeply enough to become impassable and unworkable due to mud. On steep permafrost slopes trenches or roads may have to be started by blasting a ditch to start thawing, and ripping frost with a bulldozer. Ripping of permafrost is more costly than any other method and is normally not advisable except on a specific target where results are necessary within a time limit and conditions will allow no other alternative. On a sidehill with a suitable source of water, ground sluicing with an automatic gate may be faster and much cheaper than bulldozer trenching, provided a workman is always present to remove obstacles, attend to the operation, and prospect for float.

Drilling in permafrost presents no unusual problems; calcium chloride is sometimes used if equipment has to be left in the hole.

In underground work permafrost is an initial advantage in holding openings in loose ground but timbering must be done before the ground thaws from ventilation.

Road building and maintenance in permafrost requires experience in coping with various conditions.

Many methods of exploration in permafrost were developed by placer miners of the Klondike and Alaskan gold fields. One common method for placer and hard rock prospecting is to thaw prospect shafts to bedrock with a boiler and steam points, panning the overburden and soil sampling it at intervals. This must be done during winter or early spring when average surface temperatures remain near or below freezing in order to prevent excessive thawing of the sides of the shaft. Costs at present are $30 to $40 per foot to depths of 30 to 50 feet. Silver Titan Mines used this method to prospect for silver-lead veins in permafrost till in McQuesten Valley in the Mayo district and found that only within 3 to 5 feet of bedrock did any significant geochemical anomalies or pannings appear to be effective in determining presence of lead or zinc float.

However, except for the advantage of seeing geology and structure in such a shaft, overburden drilling is more effective in spite of capital cost.

Overburden Drilling

The overburden drilling technique has proven to be very effective in the Mayo and Mt. Nansen districts for testing overburden and bedrock to 150 feet depth in permafrost. It can be carried on throughout the season and is inexpensive if the program is large enough.

In the Mayo district United Keno Hill Mines have drilled almost 200,000 feet of holes down to and into bedrock to trace silver-lead float trains on bedrock by pannings and geochemistry, this being the most applicable technique for trying to trace veins in the area. Holes are drilled on a grid until resistant bedrock is reached. The entire setup consists of a 600 cfm compressor, an overburden drill mounted on a skid base, and a D-6 cat to haul it around, which is a considerable capital investment for pan and geochemical sampling; however, direct costs proved to be substantially less than $2.00 per foot.

On Keno and Galena Hills, United Keno Hill Mines found that float and geochemical trains were easily traceable uphill, but it was not possible to tell whether the source was large or small. Lower on the slopes in the McQuesten Valley, float or geochemical concentrations could not be traced easily to their sources.

At Mt. Nansen the overburden drill was used to drill angle holes to sample complex gold-silver veins and was very satisfactory in producing completely representative samples across the vein zone.

The overburden drill also promises to be a very effective tool for testing the creek or valley bottoms for placer gold, especially in frozen creeks. Whether for hard rock or placer, it is especially suitable in permafrost whereas in thawed ground problems may develop in loose sandy material, clay, broken bedrock, or watery sections.

METHODS IN ANVIL DISTRICT

Background

Massive flat-lying sulfide replacement deposits of pyrite, pyrrhotite and associated lead-zinc and copper with silver values were first found in conventional prospecting of the Vangorda area by Alan Kulan in 1953. The main Vangorda deposit was drilled by Prospectors Airways Company between 1953 and 1955 and proven to contain 9.4 million tons grading 3.16% lead, 4.96% zinc, 0.27% copper, 1.76 oz/ton silver and .02 oz/ton gold.

Beyond the main discovery two smaller deposits, the Champ and Firth, were also discovered and other indications were found in several areas. However, lack of transportation and poorer metal price futures resulted in curtailment of exploration until 1961 and 1962 when Kerr Addison Mines, who had taken over Prospectors Airways, resumed prospecting in the area, then flew a local aeromagnetic survey at Swim Lakes in 1963 and staked 82 claims on magnetic anomalies.

Dickson Yukon syndicate staked 200 claims in the fall of 1963. In the spring of 1964 principals of Dynasty Explorations staked several adjoining properties, incorporated the company April 23, 1964, and carried out aggressive exploration. In 1965 Dynasty entered into a joint venture with Cyprus Mines Corporation of Los Angeles, and the main Faro lead-zinc deposits were discovered by drilling a geochemical, magnetic and EM anomaly area 12 miles NW of Vangorda creek in June 1965. In December 1965 Anvil Mining Corporation was formed on the joint venture. Further exploration and development for production is being carried out by Anvil, and their present holdings total about 2500 claims.

In 1964 Kerr Addison discovered uneconomic sulfides by drilling under Swim Lake, and in 1965 discovered what appears to be a sizeable lead-zinc deposit by drilling a magnetic, EM and gravity anomaly zone west of Swim Lakes. Staking by other companies and individuals in the area has now brought the total of claims held in the area to about 7500 scattered over an area some 70 miles long and 30 miles wide.

The main known deposits occur as massive or near-massive sulfide replacements in phyllite or schist which occur around parts of a broad but complex antiform uplift some 60 miles long and 30 miles wide, here called the "Anvil district". This uplift is cut by a pattern of faults typical of vertical uplifts and bounded on the southwest by the regional Tintina fault trench along Pelly River. The deposits appear to be localized by the following factors:

(1) Favourable horizons, usually graphitic, in schist (no known depth limitations).

(2) Possible NW faults subsidiary to the main regional Tintina fault zone.

(3) N-S to NNW fault and porphyry dike zones.

(4) Proximity to NE-striking fault zones.

(5) General association with granitic porphyry, and perhaps the Anvil batholith (granitic).

Although light to moderate overburden covers much of the district the main known deposits consist of massive to near-massive sulfides usually with associated pyrrhotite or magnetite and are therefore susceptible to discovery by a combination of geochemical, magnetic, electromagnetic and gravity surveys; also by induced polarization. Vein-type silver-lead deposits and disseminated lead-zinc or copper deposits also occur. The above characteristics have determined the following exploration approach used by Dynasty Explorations.

Dynasty Approach

Initially it was realized by the writer that the potentially mineralized district was much larger than the immediate vicinity of the existing properties and known mineral occurrences, probably the entire southwest schist belt shown as Unit 7 on GSC map 13-1961. It was this initial district approach that governed the scope of the program but the structural limits of the district were not defined until the 1965 reconnaissance was completed by the writer.

Early in 1964 Dynasty carried out magnetometer surveys on their existing claims, accompanied by soil sampling, geological surveys and general prospecting of the schist belt. This resulted in discovery of mineralized outcrops and a geochemical, magnetic and gravity anomaly on the SEA property. The anomaly zone was diamond drilled late in 1964, further tested with rotary holes in March 1965, and shown to be caused by a zone of pyrrhotite lenses with submarginal lead-zinc and copper values.

In September 1964 Dynasty flew an aeromagnetic survey over most of the favourable schist belt, a 220-square-mile area, and defined a number of magnetic anomalies which were staked, bringing the total number of claims to 805. Although it was recognized that an airborne electromagnetic survey should also be conducted to qualify the magnetic anomalies and that most of the area should be susceptible to airborne EM, considering probable overburden depths and ground clearance, this survey was deferred until the 1965 season due to additional cost and equipment availability.

The 1965 program was started by running ground magnetic, EM and gravity surveys over the aeromagnetic anomaly zones and testing the most promising targets by rotary drilling. Limitations of the rotary drilling are discussed later. After breakup geochemistry, geologic mapping and standard prospecting were added to the program.

In June 1965 an airborne EM survey was flown over the original aeromagnetic survey coverage, and in August and September the entire district was covered by helicopter-supported geologic and geochemical reconnaissance done by the writer, and parts of this were selected for a larger combined airborne magnetic and EM survey. Several gossan zones and geochemical anomalies were found during the reconnaissance, airborne geophysical anomalies were checked by semi-detailed geologic and geochemical reconnaissance, and the promising targets were staked to bring the total number of claims up to about 2500.

The past program was dictated partly by available capital and partly by search for the best approach, and the most logical exploration sequence developed for the area was as follows:

(1) Initial regional considerations of probable district extent, which determined how large an area should be covered.

(2) Helicopter supported geologic, geochemical and standard prospecting reconnaissance to select the areas over which airborne magnetic and EM surveys should be flown.

High areas of abundant rock outcrop above timberline were largely eliminated by spot checks, aerial inspection and some geologic and geochemical traverses. Overburden areas and areas below timberline were covered in a similar manner but with closer traverse density, taking stream silts and contour soil samples from all downslope migration areas. Results of this work determined the areas to be flown.

All gossans, rusty areas, alteration zones, and rust seepages on stream banks were noted and checked. Several were found to give high geochemical results in lead, zinc or copper; but most such rust areas, especially those on gravel bars, showed no anomalous metal content, being merely accumulations at the ground water table.

(3) Airborne magnetic and EM surveys, using a Hiller 12E helicopter at 1000-foot spacing and minimum ground clearance with flight lines across the expected trend of mineralized zones.

For the Lockwood Survey system used, a stripped-down Hiller 12E or Bell B-1 helicopter was barely able to carry the equipment and had little or no safety factor. In fact, it was not possible to hover and lift the equipment off the ground without a wind at elevations over 3000 feet, so the equipment had to be based on the Pelly River. A larger helicopter is thus necessary for such combined magnetic and EM work.

(4) Detailed follow-up soil sampling, prospecting and geologic inspection of all areas where geochemical anomalies occurred, or where they generally coincided with either airborne magnetic or electromagnetic anomalies, followed by staking of the promising anomaly areas.

(5) Soil sampling, electromagnetic, magnetic, and gravity surveys on grid lines cut at 400- and, if necessary, 200-foot spacing with 100-foot stations on specific targets to define possible drill targets; and further semi-detailed work on general targets to establish the areas on which to carry out such detailed ground surveys.

Where overburden cover was moderate or light, geochemistry determined the approximate position of a mineralized zone and electromagnetic and magnetic surveys defined specific drill targets. However, targets should be narrowed down further with gravity surveys, especially if overburden is too deep and extensive for geochemistry to be effective.

Induced polarization should be used to test for disseminated lead-zinc deposits which may be of economic grade but do not have enough associated pyrite, pyrrhotite or magnetite to give sufficient electromagnetic, magnetic, or gravity indications.

(6) On the basis of the above procedure, drilling of top priority targets and possible elimination of the poorest.

As exploration and development progresses in the district more guides to discovery will be developed.

Facets of the Dynasty program which contributed to its success were knowledge of the region and its mineral possibilities, a major district outlook, adequate and capable financing, great flexibility and ability to make and carry out decisions quickly, a close-knit group of competent personnel each with personal incentive, careful attention to detail, extreme persistence, and aggressive optimism. Aside from other personnel, each director of the company not only helped finance the project but worked intensively on it; one on overall administration, exploration, camp management and reconnaissance; one on target preparation and drilling; one on expediting and transportation, and one on office administration and financing.

LIMITATIONS OF METHODS IN ANVIL DISTRICT

Conventional Prospecting Limitations

Except in the more rugged higher elevations, conventional prospecting in the district is greatly hindered by extensive cover of glacial overburden, volcanic ash, and organic accumulations with permafrost. These materials mantle most of the gentler topography where ore deposits are most apt to occur. Except for the fortuitously exposed showing in the bank of Vangorda creek, not a single outcrop of massive sulfides is known in the district; only erratic disseminations and minor vein type mineralization has been found in a few places. However, residual and transported gossans and altered wall rock are good indicators, if accompanied by geochemical anomalies.

Float is rarely found because of the volcanic ash and vegetation or organic cover. For example the Faro area was intensively prospected by very capable men several times and until 1965 the only mineralization found was one piece of magnetite float with silver-bearing bornite and a trace of molybdenite disseminated in porphyry. In early June, 1965 sizeable pieces of float showing heavily disseminated chalcopyrite in green tuff and outcrops of calc-silicate hornfels (skarn) with traces of disseminated galena and sphalerite were found and it was thought more likely that copper rather than lead-zinc would be found. Float of massive silver-rich galena and of massive pyrite and pyrrhotite with lead and zinc was not found until much later in the season, but neither massive sulfide zone has yet been exposed.

Although severely hindered, conventional prospecting in the district is therefore valuable but must be guided and supplemented by geochemistry and other tools.

Geologic Limitations

Geologic work is largely limited to eliminating the least favourable rocks such as granite, massive volcanics, greenstone bodies and perhaps massive chert sections.

Certain linears or fault and porphyry dike trends are favourable, and the presence of altered rock, if visible, is a promising sign. Sericitization, silicification, and choritization appear to be localized to varying degrees with the sulfides, the most typical surface indication being a rusty-weathering sericite schist alteration halo. Mineralization of some type has been found in every rock unit in the district except Tertiary volcanics, so no geologic formation can yet be completely eliminated as possibly ore-bearing. Even the granite contains vein type silver-lead mineralization.

Except for the presence of graphitic material at Vangorda and in Faro No. 2 sulfide zone, graphitic members of the schist sequence are not yet recognized as being definitely favoured. Little or no graphite occurs in or near the main Faro No. 1 zone which is in barren-looking quartz-mica schist, or in the Sea sulfide zone which is in chloritic phyllite and sericite schist.

Geochemical Limitations

Geochemical limitations are varied. In reconnaissance work stream silts of the best character cannot always be obtained. They are often too coarse, organic, or laden with volcanic ash; and the metal ion content varies with the coarseness, fineness and type of sediment so anomalous threshold can be quite variable. Soil sampling is limited in some areas of permafrost or thick organic cover, and in areas of deeper overburden where the geochemical approach is only of superficial value.

Sample density relative to drainage and downslope migration is also important. The Faro discovery could easily have been masked by overburden cover over the main rusty swamp area and only one or two reconnaissance soil samples would have shown high zinc, lead or copper. The stream silts from the vicinity showed only background values, but it is not certain if the samples were of the best character.

Although some transported gossans show high zinc content, others show less than background values with a buildup some distance downstream, probably because of low Ph near the source, (as suggested by C.F. Gleeson for some rusty springs sampled by Operation Keno in the Mayo district). Therefore, even if a transported gossan is not anomalous, it should not be concluded that its source contains no economic metals until the general vicinity has been sampled.

Zinc is the most abundant and mobile metal and therefore is the best guide to lead-zinc deposits in the area. Although mobile, copper occurs in lesser amounts and is not as good an indicator since some greenstone areas also contain anomalous copper concentrations. Lead is the most certain indicator of significant mineralization but is much more immobile and therefore occurs almost exclusively in soils near the source.

Even in individual mineral soil profiles the content of zinc, copper, and lead varies considerably and generally not consistently, apparently being a result of irregular metal or float concentrations on the glacial overburden.

Geophysical Limitations

Limitations of geophysical methods are depth penetration, conductivity of sulfides, and response from other sources.

Disseminated or vein type deposits might be detected by standard prospecting or geochemistry, but not by the geophysical methods used so far. Blind deposits of either type would be missed, as would any such deposit if it were not in an area to which attention was directed by the initial reconnaissance. Geophysically, this limitation can be overcome only by using induced polarization or perhaps self potential methods.

The airborne electromagnetic equipment used is said to have a maximum depth penetration of about 350 feet which, with 150 feet of ground clearance in the wooded areas, leaves only 200 feet penetration so that overburden much in excess of 100 feet would largely, if not entirely, mask the response. However, on this basis about 70% of the area flown was considered to be susceptible to airborne EM. Ground EM methods can achieve greater penetration but the reconnaissance instrument used so far by Dynasty was limited to about 150 to 200 feet.

Interference from conductive overburden in hollows and lakes also has a marked masking effect.

Moreover, graphitic phyllite members are so abundant in the district that several belts of complex EM response have been encountered, and EM anomalies are widespread.

EM anomalies have been graded on strength and conductivity but these are still of doubtful use, because an economic sulfide zone could be either a good or poor conductor and thus cannot be sorted out from graphite.

Many magnetic anomalies or anomaly belts in the district are caused by greenstone and probably magnetite-bearing schist members so that magnetic anomalies are also numerous and often coincide with graphitic conductors which give EM response.

The use of gravity is therefore advisable to narrow down possible targets, but the method is slow and costly so smaller areas must be covered. Unless a gravity anomaly is strong, or supported by other strong evidence from the other methods, it may also be caused by differing rock and overburden densities such as basic rocks or a buried bedrock knob or ridge.

Limitations of Faro Property

On the Faro No. 2 zone massive sulfides within 20 to 50 feet of surface gave a strong soil geochemical anomaly, a strong ground EM response, and also showed up as a minor high conductivity anomaly on the airborne survey. However, this sulfide zone contains no visible pyrrhotite and gives no magnetic response on either airborne or ground instruments.

In contrast to No. 2 zone, the main Faro No. 1 zone contains much pyrrhotite and shows up as a well-defined magnetic anomaly on both ground and airborne magnetic surveys. This sulfide body, mostly at a depth of 100 to 250 feet, barely showed up as a 3^{o} deflection on the ground EM, but a part of the ore body closer to surface showed up as a faint broad high conductivity anomaly on the airborne survey. It also shows a marked geochemical anomaly where overburden cover is light to moderate. At one point rust occurring in a small stream had given a strong geochemical anomaly on a previous reconnaissance.

Although the airborne magnetic survey of the Faro area shows an east-west string of similar magnetic anomalies, with No. 1 ore zone in the middle, the easternmost and westernmost parts of this anomaly zone are caused by dioritic and gabbroic intrusives respectively, not by sulfides. Without these fortuitous magnetic anomalies, neither the airborne nor ground magnetic or electromagnetic anomalies over the Faro deposits showed any real coincidence except in a very general way, certainly not enough to have caused much interest without supporting geochemical results.

Moreover, although attention was directed to the general anomalies in the Faro vicinity by a single float occurrence, a transported gossan, and strong reconnaissance soil geochemical results, all of these indications could have been completely masked by a slightly greater cover of glacial overburden.

However, a gravity survey over the Faro property outlined No. 1

orebody very well and gave a rough estimate of its tonnage when drill hole intersections were introduced into calculations. No. 2 zone, being much thinner, barely showed up, but a sulfide body at the gossan swamp north of No. 2 zone showed a definite although a slight anomaly and several other gravity anomalies were defined. A properly conducted gravity survey therefore appears to be the best tool for defining position of massive sulfides.

Drilling Limitations

Several rapid methods of drilling the anomaly targets were considered and a detailed comparison was made between an Atlas Copco overburden drill versus a Nodwell-mounted Mayhew 1000 rotary drill. Mainly because of the depth limitations and possible attendant drilling problems with the Atlas Copco, it was decided to use the rotary and to drill with air. This method proved satisfactory during the entire 1965 season; however, insufficient air capacity made it impossible to drill with air except in dry ground or permafrost even though various bits and a down-the-hole hammer were tried. Drilling with water proved to be slower and therefore more costly than anticipated, resulting in a total of about \$6.00 - \$7.00 per foot direct costs for this type of drilling. In all, some 18,000 feet were drilled at this average cost, the holes averaging about 300 feet in depth, maximum depth being 790 feet. Rotary drilling with water therefore proved to be comparable in cost to diamond drilling but the rotary had greater mobility.

Rotary drilling with air did not present any problems of reliable sampling, being similar to the Atlas Copco which checked out well at Mt. Nansen. All cuttings were panned so that no trace of mineralization was missed; massive sulfide cuttings were assayed as obtained; and cuttings, pannings and magnetics were pasted onto typical sample boards showing footage, a standard practice.

However, with water drilling and recirculation of the drilling mud it was found that soft minerals were ground up and lost to a considerable degree in the mud. Diamond core drilling on the Faro Nos. 1 and 2 zones later showed that the true lead-zinc grade was up to 50% higher than shown by the wet rotary drilling in which interstitial galena and sphalerite were ground up in the presence of coarser and harder pyrite, pyrrhotite and quartz.

It appears that rotary drilling with sufficient air would still be faster and cheaper than diamond drilling and would be suitable for initial testing of anomalies provided the contract footage is large enough to justify setting up properly. However, diamond drills are being used on the present phase by Anvil Mining Corporation because of (a) the necessity for maximum information from development drilling on the Faro deposit, and (b) greater flexibility in contract footage, logistics, and tie-in with existing equipment and contractor.

Conclusion

In conclusion, it is certain that the present approach or modifications of it will reveal other deposits in the Vangorda district, but it is equally certain that because of the extent of the mineralized district and limitations of any combination of methods, it will not find all deposits, so the district should remain a fertile field for exploration for a long time, limited only by justifiability and cost.