COBALT-BEARING DEPOSITS RELATED TO MINERAL TERRANES OF ALASKA

by: William S. Roberts
Alaska Field Operations Center, Juneau, Alaska

**********Open-File Report 175-84

UNITED STATES DEPARTMENT OF THE INTERIOR

William P. Clark, Secretary

BUREAU OF MINES

Robert G. Horton, Director

CONTENTS

ILLUSTRATIONS

COBALT-BEARING DEPOSITS RELATED TO MINERAL TERRANES OF ALASKA

by William S. Roberts[1]

*** ABSTRACT

Cobalt minerals or anamolous concentrations of cobalt associated with sulfide minerals have been identified in 21 deposits in Alaska. Undoubtedly other deposits exist because there has been little economic incentive to search for cobalt in Alaska and none has been produced. In the known deposits, cobalt occurs in trace amounts recoverable only if the deposit is mined for other minerals and if the cobalt can be concentrated during mining and milling. Two of the known cobalt occurrences (Brady Glacier and Yakobi Island) are in large copper-nickel deposits. A third (Bornite) is associated with a large copper sulfide deposit. A fourth occurrence (Jarvis Glacier) was recently discovered in a geologic setting possibly favorable for massive sulfide deposits similar to the Windy-Craggy copper-cobalt deposit in nearby British Columbia. Seventeen of the known cobalt occurrences are in mineral terranes that have been mapped as favorable for finding cobalt. Four of the occurrences are in areas where information had been too scanty to map terranes. This emphasizes both the lack of data on Alaskan mineral resources and the need to periodically update the mineral terrane maps.

[1] Physical scientist, Alaska Field Operations Center, Bureau of Mines, Juneau, AK.

*** INTRODUCTION

The United States, the world's single largest consumer of cobalt, imports more than 90% of its annual requirement (12). At present no domestic mines produce cobalt. Since the end of 1983, it has been produced worldwide solely as a byproduct because of low market prices.

Mining operations in Alaska have not produced cobalt although several nickel-copper or copper deposits are known to have significant amounts of the metal. Resource estimates of cobalt are tentative because the efficiency of recovery of cobalt from the nickel-copper or copper deposits using commercial beneficiation circuits is largely unknown, and the distribution and grade of cobalt-bearing minerals is poorly understood. For example, in one deposit there is spatial separation between the copper and cobalt-bearing minerals. Recovery of cobalt is a mining-economics problem as well as a possible recovery-economics problem.

This compilation is part of the Strategic and Critical Minerals program of the U. S. Bureau of Mines. This report 1) provides a synopsis of cobalt-bearing deposits in Alaska, and 2) identifies mineral terranes favorable for hosting undiscovered cobalt deposits. A brief review of the geological classification of cobalt deposits and related geological environments provides a logical framework for discussing cobalt deposits and mineral terranes in Alaska.

*** CLASSIFICATION OF COBALT DEPOSITS

Cobalt deposits can be classified on the basis of genetic origin and environment of occurrence. According to Vhay, et al. (20) seven different categories can be differentiated:

1. magmatic deposits associated with mafic and ultramafic rocks
2. contact metamorphic deposits associated with mafic rocks
3. lateritic deposits
4. massive sulfide deposits in metamorphic rocks (primarily of volcano-sedimentary origin)
5. hydrothermal deposits
6. strata-bound deposits
7. deposits formed from chemical precipitates.

*** GEOLOGICAL SETTING OF COBALT DEPOSITS

The following discussion briefly outlines the geological settings for the seven types of cobalt deposits. Vhay, et al. (20) provides a more detailed account.

Cobalt-bearing nickel-copper magmatic deposits are associated with intrusive gabbros and norites. Examples include deposits near Sudbury, Ontario and the Duluth Gabbro Complex in Minnesota. Contact metamorphic deposits consisting of magnetite, chalcopyrite, and cobaltiferous pyrite are formed by thermal metamorphism of carbonate rocks by diabasic sills and

dikes. Lateritic deposits are formed by intensive, prolonged weathering of peridotite and serpentinite bodies. Metamorphosed massive sulfide deposits usually occur in volcano-sedimentary rocks; nickel sulfide deposits at Kambalda, Western Australia are one type of massive sulfide deposits. Prediction of the distribution of hydrothermal deposits is difficult because they can occur in a wide variety of geological environments. Two types are recognized: the vein type and the replacement type. Generally a source of heat and metals invades a brittle host that has open spaces or chemically reactive carbonate-rich rocks. Strata-bound deposits occur in sedimentary formations, like the mineralized black shales of central Europe or the fluviatile and lacustrine sediments hosting the Zaire-Zambia copper-cobalt belt of Central Africa. Finally, chemical precipitate deposits are associated with deep sea deposits where manganese nodules and crusts contain a significant cobalt resource.

*** GEOCHEMICAL ABUNDANCE AND GRADE OF COBALT DEPOSITS

The availability of cobalt, which has a low market value, is largely a function of economics and not of geochemical abundance. Therefore cobalt is generally mined in conjunction with other commodities and must be recoverable by commercial beneficiation techniques.

According to Vhay, et al. (20) ultramafic silicates contain an average of 0.027% cobalt, and data presented by Rankama and Shama (16) indicate the average crustal abundance of cobalt in igneous rocks ranges from a low of 0.008% in silicic igneous rocks to a high of 0.024% in ultramafic rocks. Sedimentary rocks like sandstones or carbonates generally have little cobalt but chemically precipitated iron formations, black carbonaceous shales, or volcano-sedimentary rocks can have more than 0.03% cobalt.

The nickel-copper magmatic ores of Sudbury contain an average of 0.07% cobalt while contact metamorphic deposits like those near Cornwall, Pennsylvania (once the major source for U.S.-produced cobalt) can contain 0.02 to 0.056% cobalt (20). Commercial laterite deposits typically contain 0.01 to 0.1% cobalt while massive sulfide deposits contain from 0.01 to 0.3% cobalt. Massive pyrite can contain up to 0.4 to 0.5% cobalt although it is currently not recoverable (20). Hydrothermal vein deposits can contain the highest concentrations of cobalt. For example, the Bou Azzer deposit in Morocco has an average of 1.2% cobalt and the Blackbird Mine in Idaho contains an average of 0.6% cobalt (20). Cobalt-bearing strata-bound copper deposits in Zaire-Zambia range in grade from 0.1 to 0.5% cobalt (1) while deep sea nodules and crusts can contain up to 0.35% cobalt (20).

In Alaska the most important cobalt-bearing deposits include two magmatic sulfide deposits and one hydrothermal deposit with up to 0.3% cobalt. Average cobalt concentrations and potential recovery using commercial beneficiation procedures are unknown or proprietary information except for one deposit which has an average grade of 0.02% cobalt with 50 to 60% recoverable (15).

*** MINERAL TERRANES OF ALASKA

The distribution of mineral terranes is based on Mineral Terranes of Alaska; 1982 (2), a report prepared under a Bureau of Mines contract

in cooperation with the Alaska Division of Geological and Geophysical Surveys. Mineral terranes are characteristic assemblages of rocks that are known or suspected to host mineral deposits. Mapping mineral terranes involves combining deposit and geology information with concepts of ore genesis; boundaries and units can change as new information becomes available.

*** RESULTS

The following section discusses mineral terranes favorable for hosting cobalt deposits. This is followed by a review of the more important cobalt-bearing deposits in Alaska. The locations of 21 cobalt-bearing occurrences are presented in figure 1 in relation to the distribution of known mineral terranes favorable for hosting undiscovered cobalt-bearing deposits.

COBALT DEPOSITS RELATED TO MINERAL TERRANES

Cobalt deposits can be related to mineral terranes on the basis of lithology, genetic association, and mineralization. The following discussion briefly identifies the mineral terranes associated with each deposit type and generally follows a modified format presented by Mowatt (14) and Mowatt and Roberts (15). The three letter mineral terrane unit designations refer to the 1982 edition of the Alaska mineral terranes map (2), while the A, B, C, or D terrane designations refer to figure 1 of this report.

Magmatic deposits associated with mafic or ultramafic rocks will most likely be present in the IMA or IUM units, respectively. Another likely host for byproduct cobalt deposits is the VOP unit, ophiolite rocks consisting of pillow basalts associated with mafic and ultramafic intrusives. These rock types form the basis for terrane A. Laterite deposits are associated with paleo-weathered horizons in peridotite and serpentinite rocks. No commercial quantities of nickel and cobalt have been found in Alaska; however, if present, they would likely be found in terrane A.

Contact metamorphic deposits and hydrothermal deposits can be discussed together since the host environment is similar. Contact metamorphic deposits are generally associated with carbonate rocks that have undergone thermal metamorphism, but hydrothermal deposits can occur in a variety of environments. In both cases, however, carbonate terranes that have been subjected to localized thermal events are favorable for hosting contact or hydrothermal deposits. Units SGS, SLU, ± SCG, which form the bases for terrane B, include graywacke, shale, limestone, ± conglomerate that have identified or suspected thermal events capable of forming mineral deposits.

Metamorphosed massive sulfide deposits are associated with the rock types outlined by terrane C. This terrane consists of VSM, SBS, and SCH units which, respectively, represent rocks consisting of basalt with associated sediments, black carbonaceous shale and limestone, and chert and siliceous shale. Cobalt-bearing massive sulfide deposits are polymetallic and may contain zinc, lead, copper, silver, and gold.

Strata-bound deposits are associated with a variety of sedimentary rock types, including marine limestone and shale, chert and siliceous shale, and

black carbonaceous shale. These rock assemblages are represented by the SLS, SCH, SBS, and SLU terrane units and, except for the latter two units, form the basis for terrane D. The distribution of SBS and SLU are graphically shown with terranes B and C, respectively, and are not included in terrane D.

Chemical precipitates of nodules and manganese crusts containing byproduct cobalt and other sulfides would likely be present in rocks deposited in a deep sea environment. Deep water turbidites, fine-grained limestones, marls, and shales may be present in the SLS unit (which is part of terrane D), although the primary reference (2) for mineral terranes does not specifically address this type of ancient sea floor deposit.

COBALT-BEARING DEPOSITS IN ALASKA

Twenty-one cobalt-bearing deposits with identified cobalt minerals or anomalous amounts of cobalt associated with sulfides are discussed. Cobalt concentrations of up to 0.03% in peridotites or chromites are not reported here since 0.024 to 0.027% are considered "normal" amounts in ultramafic rocks, and/or because it is not economically feasible to recover cobalt from silicates or oxides at the present time.

Out of 21 occurrences, only three, the Brady Glacier, Yakobi Island, and Bornite deposits, are associated with appreciable tonnages and grades of nickel-copper or copper mineralization. A fourth occurrence, the Jarvis Glacier deposit, indicates the possibility for discovering other cobalt-bearing massive sulfide deposits. Additional cobalt-bearing deposits in Alaska are either associated with apparently low tonnage deposits (for example, Funter Bay or Mirror Harbor) or are too poorly understood to warrant further discussion. All of the occurrences are briefly described in the legend, figure 1.

According to Bundtzen, et al. (7) the Brady Glacier deposit (no. 14, figure 1) contains 54 million lbs. of proven and 54 million lbs. of inferred cobalt reserves. The deposit also contains 100 million tons of proven nickel-copper reserves with an average of 0.5% nickel and 0.3% copper (8). Results from metallurgical testing have not been released so recovery of cobalt using commercial beneficiation circuits is not known.

Kimball (11) states Yakobi Island (no. 17, figure 1) has 20.1 million tons of measured and inferred nickel-copper reserves. Recent work indicates an average cobalt concentration of 0.02% and metallurgical tests indicate only a portion of that amount is recoverable (19). At 50% recovery there is an estimated 0.4 million lbs. of recoverable cobalt at Yakobi Island.

The distribution, grade, and potential recovery of cobalt at the Bornite deposit (no. 3, figure 1) is either proprietary information or unknown. The deposit has a stated reserve of 40 million tons with 2% copper (8) and high grade grab samples collected on the dump have yielded values of up to 0.29% cobalt (5). Preliminary reports indicate cobalt concentrations tend to be spatially associated with pyrite-rich zones and not with the copper-rich ore so it may be prohibitively expensive to recover.

The Jarvis Glacier deposit (no. 12, figure 1) appears to be similar in geologic setting to the recently announced Windy-Craggy deposit located about

50 miles to the northwest in British Columbia. Recently released information indicates the Windy Craggy deposit contains more than 100 million tons of copper mineralization with up to 0.3% cobalt. No information on the potential recovery of cobalt has been released to date. Little information is available on the recently discovered Jarvis Glacier mineralization, but it is known to consist of sphalerite-pyrite-barite with up to about 0.03% cobalt (17). Other massive sulfide deposits are known to exist in southeastern Alaska so the potential for discovering metamorphosed cobalt-bearing massive sulfide deposits is considered high.

*** SUMMARY

A total of 21 cobalt-bearing deposits with identified cobalt minerals or anomalous concentrations of cobalt associated with sulfides are present in Alaska. Three occurrences (Brady Glacier, Yakobi Island, and Bornite) have trace amounts of cobalt associated with significant tonnages of other minerals. One occurrence (Jarvis Glacier) indicates that geological conditions are favorable for locating undiscovered cobalt-bearing massive sulfide deposits.

Four mineral terranes, A, B, C, and D presented in figure 1, outline areas favorable for locating undiscovered cobalt-bearing deposits. Determining areas favorable for ancient sea floor deposits hosting manganese nodules or crusts and ancient paleosols containing laterite deposits is difficult because present mineral terrane information does not address these types of deposits.

Four of the 21 cobalt-bearing deposits are in areas where data are too scanty to map mineral terrranes. The mineral terranes map is a regional summary of known mineral occurrences and geology related to concepts of ore genesis. Omissions should be expected because of the general lack of data on Alaskan mineral resources. As new data become available the mineral terranes map should be periodically updated.

REFERENCES

1. Alaska Office of the Governor, Division of Policy Development and Planning. Policy Analysis Paper No. 82-12, Strategic Mineral Markets and Alaska Development Potentials, V. I. Prepared under contract by Charles River Associates, Nov. 1982, pp. 4-1 through 4-24.

2. Arctic Environmental Information and Data Center, University of Alaska. Mineral Terranes of Alaska; 1982. Prepared under contract number J0123029 for the U. S. Bureau Mines and the Alaska Division of Geological and Geological Surveys, 1982, 6 sheets.

3. Barker, J.C., J.C. Still, T.C. Mowatt, and J.J. Mulligan. Critical and Strategic Minerals in Alaska, Cobalt, the Platinum Group Metals, and Chromite. BuMines IC 8869, 1981, p. 7.

4. Barker, J.C., and W. S. Roberts. A Copper-Cobalt Occurrence in the Cape Krusenstern Area. Proposed BuMines OFR, 1984.

5. Bottge, R.G. Chromite, Cobalt, and Platinum Group Metals in Alaska: Their Occurrence and Mining Feasibility. Proposed BuMines IC, 1984.

6. Bundtzen, T.K. Overview of Alaska's Strategic Minerals, chapter in International Minerals ed. by A.F. Agnew. Westview Press, 1983, pp. 37- 70.

7. Bundtzen, T.K., G.R. Eakins, and J.T. Dillon. Strategic and Critical Minerals in Alaska - An Overview. Division of Geol. and Geophysical Surveys, Alaska Dept. of Natural Resources, February 1980.

8. Bundtzen, T.K., G.R. Eakins, J.G. Clough, L.L. Lueck, C.B. Green, M.S. Robinson, and D.A. Coleman. Alaska's Mineral Industry, 1983. Division of Geol. and Geophysical Surveys, Alaska Dept. of Natural Resources, Special Report 33, 1984.

9. Cobb, E.H. and D.R. St. Aubin. Occurrences of Selected Critical and Strategic Mineral Commodities in Alaska. U.S. Geol. Survey OFR 82-719, 1982, 24 pp.

10. Jansons, U. Cobalt Content in Samples From the Omar Copper Prospect, Baird Mountains, Alaska. BuMines MLA 109-82, 1982, 16 pp.

11. Kimball, A. L. Mineral Land Assessment of Yakobi Island and Adjacent Parts of Chichagof Island, Southeastern Alaska. BuMines MLA 97-82, 1982, 199 pp.

12. Kirk, W.S. Cobalt, Mineral Commodity Profiles 1983, BuMines, 16 pp.

13. Mowatt, T.C. Alaskan Mineral Deposit-Types of Potential National Significance: I. Ultramafic-mafic igneous rocks related to chromium-platinum group elements-nickel-cobalt-copper mineralization. Jan 12, 1980, unpublished BOM report, 12 pp; available upon request from W. S. Roberts, BuMines, Juneau, AK.

14. Mowatt, T.C. Alaskan Mineral Deposit-Types of Potential National Significance: II. Some general considerations regarding cobalt mineralization. Jan 21, 1980. Unpublished BuMines report. 26 pp; available upon request from W. S. Roberts, BuMines, Juneau, AK.

15. Mowatt, T.C., and W.S. Roberts. Comments on Mineral Terranes of Alaska at Map E (1:2,500,000) Scale. BuMines Internal Report, Dec. 20, 1980; available upon request from W. S. Roberts, BuMines, Juneau, AK.

16. Rankama, D. and T.G. Sahoma. Geochemistry. University of Chicago Press, 1950, pp. 677-687.

17. Still, J. C. Stratiform Massive Sulfide Deposits of the Mt. Henry Clay Area, Southeast Alaska. Proposed BuMines OFR, 1984.

18. Roberts, W. S. Field notes, available upon request, BuMines, AFOC, Juneau, AK.

19. Thornsberry, V.V., and P.P. DeWilliam. Prospectus, ALECO Mining Group, Nickel-Copper Property (Bohemia Basin and Mirror Harbor), Southeast, Alaska. Dec 6, 1982, 14 pp.

20. Vhay, J.S., D.A. Brobst, and A.V. Heyl. Cobalt in United States Mineral Resources. U.S. Geol. Survey Prof. Paper 820, 1973.

APPENDIX

Map units of

Mineral Terranes of Alaska: 1982

Appendix.-- Map units of Mineral Terranes of Alaska; 1982.

INTRUSIVE TERRANES

Granitic Rocks

IGU - Undivided granitic rocks-includes rocks of the three groups below.

IGA - Alkalic granitic rocks-syenite, locally includes peralkaline granite and monzonite; favorable for deposits of uranium and rare earths.

IGF - Felsic granitic rocks-granite and quartz monzonite; favorable for deposits of tin, tungsten, molybdenum, uranium, and thorium.

IGI - Intermediate granitic rocks-granodiorite and quartz diorite; favorable for deposits of copper, gold, and molybdenum.

Mafic-ultramafic rocks

IMA - Mafic intrusive rocks-gabbro, locally includes mafic-rich intermediate rocks; favorable for deposits of copper and nickel with by-product platinum and cobalt.

IUM - Ultramafic rocks-peridotite and dunite; favorable for deposits of chromium, nickel and platinum metals with by-product cobalt.

VOLCANIC-SEDIMENTARY TERRANES

Felsic Volcanic Rocks

VFU - Undivided felsic volcanic rocks-rhyolite and quartz latite; favorable for deposits of copper, lead, and zinc with by-product silver and gold.

VFA - Alkalic felsic and intermediate volcanic rocks-trachyte, phonolite, trachyandesite, and peralkaline volcanics; favorable for deposits of uranium and thorium.

VSF - Undivided sedimentary and felsic volcanic rocks-rhyolite, quartz latite, and associated sediments favorable for deposits like those those of felsic volcanic rocks.

Mafic Volcanic Rocks

VMU - Undivided mafic volcanic rocks-primarily basalt; favorable for copper and zinc deposits with by-product silver and gold.

VSM - Undivided sedimentary and mafic volcanic rocks-basalt and associated sediments; favorble for deposits like those of mafic volcanic rocks.

VOP - Ophiolite terrane-pillow basalt and associated mafic and ultramafic intrusives with minor chert and other pelagic sediments; favorable for deposits of copper, nickel, and chromium with by-product platinum metals and gold.

SEDIMENTARY TERRANES

Marine Rocks

SLS - Limestone and shale-limestone and dolomite with interbedded shale; favorable for deposits of copper, lead, and zinc.

SBS - Black, carbonaceous shale and limestone-limestone, dolomite, black shale, and chert; favorable for deposits of zinc, lead, and barium with by-product silver.

SPS - Phosphatic shale-phosphatic shale and phosphorite; favorable for deposits of phosphate with by-product uranium and vanadium.

SCH - Chert-chert and siliceous shale; may be favorable for deposits like those of volcanic, ophiolite, or black shale terranes.

Continental Rocks

SCG - Conglomerate-conglomerate and sandstone; favorble for deposits of gold or deposits like those of black shale terranes.

SCB - Coal-bearing sandstone and shale-coal-bearing, continental sandstone, shale and conglomerate; favorable for deposits of coal and uranium with by-product vanadium. Coal rank:

- a - anthracite
- b - bituminous
- sb -subbituminous
- i - lignite

SEDIMENTARY TERRANES

SGS - Graywacke and shale-interbedded graywacke and shale with minor volcanic rocks; favorable for deposits of gold or deposits like those of igneous terranes.

SLU - Limestone-limestone and dolomite; favorable for deposits of copper or deposits like those of igneous terranes.