Mineral Deposits of Alaska

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False color, composite satellite image of Alaska and adjacent Yukon Territory.

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The simulated color-infrared (CIR) image is a composite of NOAA/Advanced Very High Resolution Radiometer scenes collected during the summer of 1991. Daily scenes were analyzed to select the day for each picture element with the maximum Normalized Difference Vegetation Index (NDVI), a measure of photosynthetic activity. This method of compositing minimizes the clouds, an important consideration in some parts of Alaska, and depicts the vegetation at the height of its growth. The image is built by displaying the sensor's infrared band in red, the visible-red band in green, and an estimated green band, displayed in blue. The resultant simulated CIR image shows the deciduous vegetation in brighter reds, coniferous forest in darker reds, and areas of tundra and lake mosaic, or alpine tundra, in blues and greens. Image generated by Michael D. Fleming, Images Unlimited, Anchorage, Alaska.
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Mineral Deposits of Alaska

Preface

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Mineral resources have been important to the Alaskan economy for hundreds of years. The Indians, Eskimos, and Aleuts used gold, copper, and other metals for jewelry, utensils, and weapons and as items of trade. The Russians, who arrived in 1725, showed only minor interest in minerals, focusing instead on furs. Nonetheless, records show that they mined iron ore on the Kenai Peninsula in 1793 and located gold there in 1834. In addition, the Russians were aware of copper-rich occurrences in the Copper River basin.

The mining industry grew rapidly in Alaska after the United States purchased the region from Russia in 1867. By 1870, gold was being mined near Windham Bay and near Sitka, in southeastern Alaska. The first major hard-rock gold mining began at the Alaska-Juneau, Perseverance, and Treadwell mines near present-day Juneau following the discovery of placer gold near tidewater in 1880. Significant placer mining operations for gold soon spread northward into districts such as Fairbanks, Nome, Iditarod, and Circle.

The exploitation of mineral resources, particularly gold, influenced the settlement and development of much of the state. Major cities such as Nome, Fairbanks, and Juneau, the capital, were originally built around early mining camps. By 1996, more than 33 million oz of gold, as well as significant amounts of copper, lead, zinc, silver, and platinum-group elements, had been produced. In addition, there has been minor production of nickel, tin, mercury, and uranium.

Alaska is presently experiencing a renaissance in mining on federal, state, private, and native lands. From 1990 to 1996, the minerals industry had an annual value of approximately $600 million, with a record 1 billion in 1996. Nearly 3,500 year-round jobs were directly attributed to the minerals industry. Looking forward into the twenty-first century, the outlook is even better. Major mines such as Red Dog are in production. Recently completed exploration at the Red Dog sedimentary exhalative deposit has significantly expanded the reserve base and major mine expansion is contemplated. The Nixon Fork gold skarn deposit was put into production in 1995, with the first ore poured in November. The Greens Creek mine resumed production in late 1996, following renewed exploration and development of the volcanogenic massive sulfide deposit. The Fort Knox gold mine, near Fairbanks, is under construction and is scheduled to yield ore by late 1996. In southwest Alaska exploration success has yielded a significant gold resource at Donlin Creek. In addition, the Kensington-Juolin project is at an advanced stage. Recent actions by the state of Alaska with regard to government-sponsored geophysical mapping, land-use priorities, environmental regulations, taxation, and mineral exploration incentives suggest that responsible growth of the minerals industry will be favored there as projected oil-based revenues decline sharply throughout the remainder of the decade.

Alaska clearly remains elephant country, as evidenced by the discovery of four world-class ore deposits (Greens Creek, Red Dog, Fort Knox, and Quartz Hill) in the past twenty years. Because of the great mineral potential of the state, we believe this monograph will serve as a useful guide to the economic geology of the many and varied mineral deposit types within Alaska. Much of the description will remain useful well into the future. Some of the interpretations may indeed change as more information becomes available about specific deposit types; however, the genetic models presented here reflect our geologic understanding of these mineral systems in the 1990s. In addition to being a useful reference for mineral deposits in the state, the metallogenic setting of Alaska's deposit is similar to other parts of the Pacific Rim, where much exploration and mining is presently being focused. Therefore, this monograph should also be a useful reference for geologists working in cordilleran-type settings that extend beyond the borders of Alaska.

This monograph contains 15 papers. The first is an overview describing the metallogenic evolution of Alaska. Goldfarb (1997) takes us forward in time and synthesizes the tectonic development of Alaska and associated ore formation in oceanic environments between 700 and 150 Ma. Deposits associated with oceanic settings include shale-hosted Zn-Pb-Ag, carbonate-hosted copper, and polymetallic volcanogenic massive sulfide deposits. The last 150 m.y. are characterized by collisional tectonics, voluminous calc-alkaline magmatism, and the formation of epigenetic Cu and Mo porphyry deposits, skarn deposits, epithermal precious metal systems, Fe-rich Alaska-type zoned ultramafic bodies, and mesothermal gold lodes.

Among the world-class ore deposits in production in Alaska, the Red Dog mine stands out. In the paper on shale-hosted Zn-Pb-Ag and barite deposits of Alaska, Schmidt (1997a) describes Red Dog as a vent-dominated end member of the shale-hosted type of massive sulfide deposits. Most of the significant shale-hosted mineralization in northern Alaska is shown to be within Carboniferous rocks that are mainly associated with restricted basins proximal to extensional faults. In a related chapter, Schmidt (1997b) describes two types of strata-bound carbonate rock-hosted deposits in nearby platform environments that represent additional base metal-rich exploration targets developed along the passive
North American Paleozoic continental margin. The first type, which she favors as being similar to Mississippi Valley-type or Irish-type deposits, includes Zn-Pb ± Ag stockworks, lenses, breccias, and disseminations; the second deposit type includes epigenetic stockworks of Cu-Co ± Zn. Schmidt synthesizes and presents the available information on both the shale- and carbonate-hosted deposit types, concluding each chapter with a discussion of the potential for favorable host rocks in Alaska.

It takes a rare deposit to make a major mining company, such as the replacement copper ores in the Wrangell Mountains did for Kennecott. In the paper on the Kennecott deposits, MacKevett, Cox, Potter, and Silberman (1997) describe and evaluate the unique setting of these deposits and propose a model of ore genesis in which oxidized copper-bearing brines circulated through the Nikolai greenstone. The copper was deposited at low temperatures in karst-type openings that exploited a series of northeast-striking joints. Although this type of deposit is not widely recognized, its characteristics serve as a reminder that not all deposit styles fit established models. Hence, the explorationist should beware.

Ninety percent of the gold production in Alaska has been derived from Cretaceous and Early Tertiary lode deposits and associated placers in metamorphosed terranes. In the paper on gold deposits in metamorphic rocks of Alaska, Goldfarb, Miller, Leach, and Snee (1997) present the regional setting as well as the geochemical, structural, and mineralogical characteristics of the major lode systems in the state. These deposits all formed under mesothermal pressure-temperature conditions in greenschist facies rocks. Mass balance work supports the hypothesis that gold was mobilized from background concentrations in midcrustal rocks and that the ore-transporting fluids have a metamorphic signature. Goldfarb and the others summarize their paper with a genetic model in which the lode deposits are shown to have commonly formed in second- and third-order structures in convergent tectonic settings. Although their paper is an overview, much specific deposit information is introduced that will help the explorationist.

Three other papers are concerned with epigenetic gold-bearing lodes in Alaska. Two of these discuss the auriferous ore settings in east-central and southwestern Alaska, where data from fissure-type veins and stockwork systems are interpreted as showing distinct genetic relationships with magmatism. In a paper on precious metals associated with Late Cretaceous-earthy Tertiary igneous rocks of southwestern Alaska, Bundtzen and Miller (1997) describe the deposits in the Kuskokwim mineral belt and define a magmatic model for the development of the gold-silver-polymetallic deposits of the region. This paper is an excellent descriptive summary of an underexplored region in Alaska that has recently been the focus of widespread exploration efforts, with recent exploration success at Donlin Creek. With the discovery and development of the Fort Knox deposit during the past few years, there has been a boom in exploration and development in the Yukon-Tanana terrane in east-central Alaska and adjacent Yukon Territory. Recent exploration successes at the True North and Stone Boy projects have highlighted the need for reassessment of exploration models. The magmatic origin for mid-Cretaceous gold systems in this area is explored and discussed in the paper by McCoy, Newberry, Layer, DiMarchi, Bakke, Masterman, and Minehan (1997). The authors integrate new 40Ar/39Ar ages with fluid inclusion and stable isotope data to support a model in which low-salinity, CO2-rich, gold-bearing fluids were derived from the evolving magmas of host intrusions.

The paper by Gray, Gent, Sneel, and Wilson (1997) describes the geologic and geochemical setting of epithermal Hg-Sb veins of southwestern Alaska and epithermal gold veins of the Alaska Peninsula and the Aleutian Islands. These regions represent parts of the state where shallow crustal rocks are still preserved and are therefore favorable for epithermal ore deposits. New geochronologic data from the Hg-Sb veins deposits temporally link ore formation to Late Cretaceous magmatism. Significant precious metal exploration targets may exist at depth in these systems, with Au-As-W-rich mineralization occurring below exposed Hg-Sb ores. Perhaps more intriguing, from the standpoint of exploration, is the potential for large epithermal lode gold systems associated with Tertiary volcanic rocks on the Alaska Peninsula. Gray and the others forward the hypothesis that the gold-bearing systems may be associated with arc-related Cu porphyry systems. Between the remoteness of the region described in this paper and the extensive magmatic activity of the Aleutian arc, the potential for discovery of significant new ore systems is high.

The voluminous information on Alaskan volcanogenic massive sulfide deposits is brought together in the paper by Newberry, Crafford, Newkirk, Young, Nelson, and Duke (1997b). Spatially distributed throughout much of Alaska, such deposits provide exciting exploration opportunities for precious and base metals. Past development of Late Cretaceous, Tertiary Cyprus-type, and Besshi-type ores characterizes much of the Prince William Sound area. The Late Triassic belt of mainly kuroko-type systems within rocks of the Alexander terrane in southeastern Alaska and British Columbia includes the huge Windy Craggy deposit and the extremely precious metal-rich Greens Creek ores. Early Paleozoic massive sulfides in the southern part of southeastern Alaska have been the focus of consistent industry attention during the past few years, and middle to late Paleozoic ores of the Ambler district in northwestern Alaska are again being evaluated. The paper by Newberry and the others describes and catalogs these deposits in addition to presenting interesting models for exploration.

Young, St. George, and Bouley (1997) address the tectonic association of porphyry copper occurrences through time in Alaska. Over the geologic history of the state, the authors identify ten distinct episodes of porphyry copper formation. Computer-generated palinspastic reconstructions are used to place these episodes in appropriate tectonic settings. The most abundant and the most economically significant occurrences are associated with Cretaceous intermediate igneous rocks. In the paper on molybdenum porphyry occurrences, Ashleman, Taylor, and Smith (1997) present the most detailed geologic description to date on Quartz Hill, one of the largest porphyry molybdenum deposits in the world. They tie a detailed understanding of the local deposit geology to the current models of porphyry systems to develop an improved genetic model for Quartz Hill. Development of such a local...
model has been a long-term problem, because Quartz Hill shows features characteristic of both typical subduction-related ore systems and Climax-like, rift-related porphyry bodies.

The paper on skarn deposits of Alaska by Newberry, Allegro, Cutler, Hagen-Levelle, Adams, Nicholson, Weglarz, Bakke, Clautice, Coulter, Ford, Meyers, and Szumigala (1997a) describes over 300 skarn deposits and occurrences throughout Alaska. This paper is an extensive compilation of published material as well as recent research by the authors. As an interesting exploration guide, the authors suggest that although the host terrane seems to have little influence on the type of skarn, it may influence pluton composition, which will in turn control the skarn oxidation state. Additionally, Newberry and the others forward a model whereby the metals are derived from the plutons. After presenting all their descriptions and data, the authors point out how pluton characteristics should be used in skarn exploration.

Mafic and ultramafic complexes account for the production and existing resources of platinum-group elements, asbestos, and iron in Alaska. In the paper on mineral occurrences associated with these complexes, Foley, Light, Nelson, and Harris (1997) classify these igneous rock types based upon age, lithology, tectonic setting, structural and petrologic features, and metallogeny and identify five distinct types of related ore deposits. For the precious and base metal explorationist, this paper will provide some intriguing ideas for targets, since many of the platinum-group element placer and lode deposits also have yielded by-products of gold, silver, and copper.

Tin has not received the same attention that precious metals have in Alaska; however, Hudson and Reed (1997) forward the suggestion, based upon their geologic models, that under the right economic conditions, the state could be a significant producer of tin. They describe tin deposits associated with placers, veins, skarns, and greisens. Their optimistic view of the potential for significant discovery of tin is based upon the link between widespread Middle Cretaceous crustal melting in central and western Alaska and their new recognition of a broad regional tin belt.

Uranium, thorium, and rare metal deposits are uncommon in Alaska, but minor production of uranium has occurred from Bokan Mountain, in southeastern Alaska. In the paper on rare metal deposits, Thompson (1997) describes the igneous-hosted uraniumiferous Bokan Granite Complex and the sedimentary rock-hosted Death Valley deposit on the Seward Peninsula. Although the economic outlook for uranium is bleak, this paper presents some important geologic characteristics of unique mineral deposits that may provide economically valuable minerals in the future.

The metallic minerals industry has figured significantly in the economics of Alaska and the future looks bright, but few all-encompassing geologic references are available that detail the numerous and varied mineral deposit types of the state. The lack of a comprehensive, up-to-date reference on the economic geology of Alaska has spurred the idea of this monograph. Such an effort was deemed timely given the resurgence of exploration and mining in the 1980s and 1990s, both in the state and internationally. Three years of work has culminated in this volume.

This monograph is a team effort representing the work of 48 authors and some 35 Economic Geology reviewers, each of whom devoted much free time to this project. In addition, various companies and organizations have generously contributed money to help defray printing costs. The contributors include Cominco Exploration, Cyprus Metals, Echo Bay Mines, Kennecott Exploration, Placer Dome U.S., Inc., and Sealaska Corporation. We thank the numerous people and companies who have been connected with this project.

We hope the reader will find this to be a useful volume on the geology of Alaska's mineral deposits. We are excited about what the future holds for the development of mineral resources in Alaska. Clearly, a sound knowledge of the economic geology of Alaska's mineral deposit types is integral to successful exploration and development of these resources.

REFERENCES


