STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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Report of Investigation 83-12

MINERAL-RESOURCE MODELING, KANTISHNA-DUNKLE MINE-STUDY AREAS, ALASKA

By

T.K. Bundtzen

STATE OF ALASKA
Department of Natural Resources
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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CONTENTS

FIGURES

Page

TABLES

MINERAL-RESOURCE MODELING, KANTISHNA-DUNKLE MINE-STUDY AREAS, ALASKA

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EXECUTIVE SUMMARY

The Kantishna and Dunkle mine-study areas (fig. 1) have sustained mining activity since the early part of the 20th century. Total mineral production is 265,000 oz of silver, 67,000 oz of gold, 5 million lb of antimony, 64,000 tons of coal, and several million lb of lead and zinc worth $38.37 million at March 1983 national-commodity price levels. With the exception of coal, all mineral production was derived from the Kantishna mining district.

This report summarizes mineral-resource modeling in the Kantishna-Dunkle mine-study areas of Denali National Park Preserve. These results are preliminary and subject to modification pending results of mineral exploration during the summer of 1983. Studies of specific economic viability, claim validity, profitability, employment levels, or economic-multiplier effects have not been attempted.

In this study, a hypothetical resource base for both mineralized areas was established using all available information, including channel and bulk samples, mine maps, and drilling, geological, and geophysical data acquired during past investigations. Half-square modeling techniques were applied to

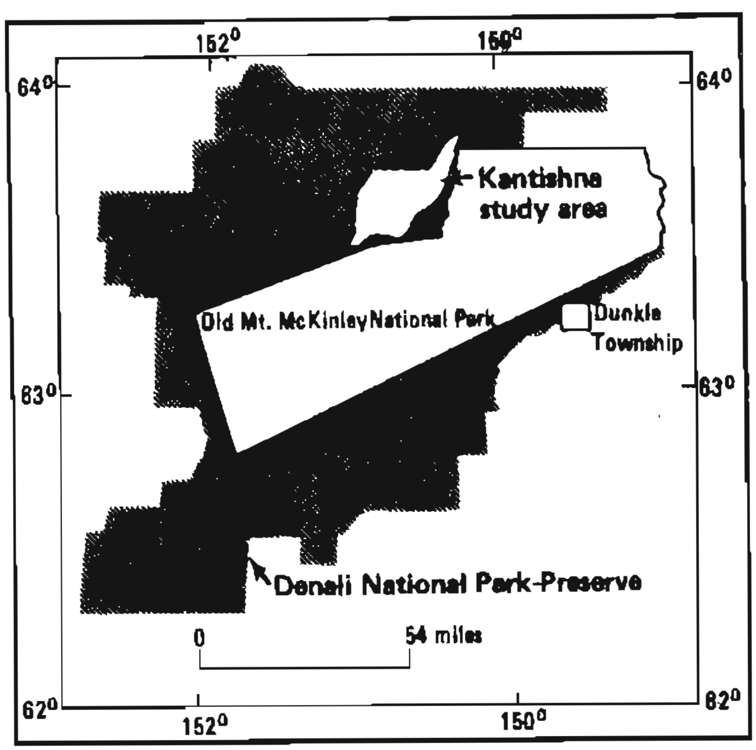

Figure 1. Location of Kantishna and Dunkle study areas, Denali National Park Preserve.

well-known mineralized vein systems in the Kantishna mining district, and the veins were also compared to similar mineral belts in Canada, Idaho, and Montana. Stratiform, metasomatic, and low-grade stockwork base-metal deposits in the Kantishna and Dunkle areas were compared to similar deposits in the southwestern United States. Placer-gold deposits in the Kantishna mining district were evaluated in terms of present activity and speculative reserves and resources. Coal reserves and resources were determined from private exploratory efforts. The resource figures generated from the modeling efforts were then applied to hypothetical low-, medium-, and high-mineral-development scenarios to estimate economic and environmental impacts.

The Kantishna portion of the study area contains an elongate 40-mi-long, northeast-trending mineral belt known for silver- and gold-enriched poly-sulfide crosscutting veins, placer-gold deposits, and antimony and base-metal lodes. Four concentrations of veins---Quigley Ridge, Banjo Mine, Spruce-Glenn Creek, and Slate and Last Chance Creeks and Stampede---were separately evaluated. Twenty-three silver-enriched vein-fault systems concentrated in a 15 mi^2 area near Quigley Ridge contain a half-square resource estimate of 412,892 tons of ore with an average grade of 39.76 oz per ton silver, 0.14 oz per ton gold, 6.4 percent lead, and 2.3 percent zinc. Geologic criteria of the study area were compared with those of lodes of the Coeur d'Alene and Keno Hill districts of Idaho and Yukon Territory, respectively. The Kantishna veins can best be compared to the Keno Hill deposits. Detailed structural, geologic, grade, and reserve-data comparisons indicate that the Kantishna silver lodes may contain up to 1.16 million tons of ore of similar grade to that calculated with the half-square estimate.

Primary gold lodes in the Banjo Mine area contain a half-square resource of 173,960 tons of ore grading 0.39 oz per ton gold, 3.59 oz per ton silver, and 1.2 percent combined lead and zinc. A smaller portion of this resource tonnage contains tungsten.

Six deposits in the Spruce-Glenn Creek area are estimated to contain 83,929 tons of mineralization with an average grade of 0.07 oz per ton gold, 8.05 oz per ton silver, and 2.5 percent combined lead, zinc, and antimony. The half-square resource estimate is not economically viable under present metal-commodity price levels, but the data base is very scant, and additional detailed sampling and exploration are necessary in this mineralized area.

Lodes on Slate and Last Chance Creeks and at Stampede account for over half the antimony production in Alaska and a large percentage of United States domestic production during World War II and the Korean War. A half-square resource estimate of 560,720 tons of ore grading 11.93 percent antimony (with credits of silver and gold) amounts to almost 25 percent of the published United States antimony reserve base; 12,000 tons of high- and low-grade ore have been identified in three main deposits.

The summation of the half-square resource estimates for the Kantishna veins is 1.23 million tons with an 'in-place' worth of $427 million in March 1983 metal-commodity prices (app. B). Silver accounts for 49 percent of the value, followed by antimony (32 percent), gold (13 percent), and lead, zinc, and tungsten (6 percent). Hypothetical mine-modeling scenarios indicate that annual production of antimony and silver would be nationally significant while lead, zinc, gold, and tungsten would not.

Known skarn and stratiform mineral deposits in the Kantishna mining district are thought to be subeconomic, but detailed bulk sampling of these and other occurrences is recommended. Some mineralized tuffs in the Spruce Creek Sequence bear similarities to auriferous systems described in the Red Lake District in Canada.

Placer gold is one of the most important mineral commodities extracted from the Kantishna mining district and accounts for 75 percent of the total dollar value. At least 14 streams have been mined, and more than 12 small- and medium-sized mechanized operations were active last year. Speculative reserves and resources of auriferous gravel amount to 4.52 and 16.78 million yd^3, respectively. Estimates of grade and tenor of pay streaks cannot be made with existing data. The present 3,500-4,000 oz-per-yr gold production will probably be sustained in the foreseeable future.

The Dunkle Mine township is part of the Chulitna-Yentna mining district, a major epigenetic base- and precious-metal province in the southern Alaska Range. Detailed surface and subsurface investigations of the area by government agencies are incorporated in this study. A voluminous collection of private subsurface, geophysical, geochemical, and geological data is the primary source of information for the NIM claim block.

Although there has been no metal production from the area, the nearby Golden Zone Mine is currently under development and has produced gold, copper, and silver. Most mineral deposits are confined to three main areas near Bull River, and all are of the epigenetic-vein, vein-disseminate, and breccia-pipe types. Metals include major copper, arsenic, gold, and silver and minor tin, molybdenum, lead, zinc, and bismuth.

Past data collections show very hypothetical resources of 20,000 tons of relatively high-grade gold and silver vein deposits, 3.23 million tons of gold- and silver-bearing breccia-pipe mineralization, and as much as 100 million tons of low-grade, stockwork-style copper and silver ± gold mineralization. Specific grade computations cannot be made with existing data, and promising target areas need much more exploratory work.

Placer deposits in Colorado Creek are gold-bearing outwash gravels. Intermittent production and development has occurred since 1959, but the potential of the deposits is unknown.

The W.E. Dunkle or Costello Creek Mine in the Dunkle Mine township produced 64,000 tons of lignitic to subbituminous coal from underground-mining operations during 1940-54. Approximately 350,000 tons of bituminous coal remain in the drilled reserve base; up to an 8-million-ton coal resource is estimated in the upper Costello-Colorado-Camp Creeks basin. Small-scale extraction has been studied for many years. Private feasibility studies completed in the 1960s indicate a positive rate of investment return from small open-cut mine developments both in and out of the township. Coal preparation may require the removal of moisture and the addition of an oil base to prevent spontaneous combustion.

INTRODUCTION AND ACKNOWLEDGMENTS

This project is one phase of a multidisciplinary effort mandated by the ANILCA Act of December 2, 1980 (PL96-487) which instructs the Alaska Lands Use Council to:

> "Conduct a study of the Kantishna Hills and Dunkle Mine areas...and report to Congress no later than three years from the enactment of the ANILCA Act."

Mineral-resource estimates in this report are designed to assist government agencies and the private sector in predicting realistic levels of mineral development in two mineralized areas of Denali National Park Preserve. No attempt is made to document claim validity or the economic viability of specific claim blocks.

In addition to mineral potential, fish and wildlife values, public-recreational activities, wilderness potential, and historical resources are also examined.

The continuous aid and encouragement of James Wickes (Division of Research and Development) and the helpful discussions and suggestions (during modeling research) with Bob Hoekzema, Gary Sherman, and Jake Jansons (U.S. Bureau of Mines) are appreciated. I thank Tom Smith and Cheri Daniels (DGGS) for reviewing the manuscript.

GEOGRAPHIC SKETCH

The Kantishna and Dunkle mine-study areas are located in the U.S. Geological Survey Mt. McKinley and Healy (1:250,000-scale) Quadrangles of south-central Alaska. They flank the former Mt. McKinley National Park along its northwest and southeast boundaries respectively, and presently lie within the Denali National Park Preserve.

The Kantishna mining district is part of the low, rugged Kantishna Hills that are separated from the higher terrain of the Alaska Range by the Clearwater Fork of the Toklat River. The region is bordered on the west and northwest by the Kantishna-McKinley River basins. Elevation in the study area ranges from 1,600 ft along lower Moose Creek to 4,982 ft on Kankone Peak.

The rugged nature of the Kantishna Hills is, in part, a result of rapid uplift of the area during late Quaternary time. The northeasterly trend of the region parallels the structural grain of basement metamorphic rocks (fig. 2). Headwater portions of streams such as Glacier, Rock, Caribou, and Flume Creeks flow in rugged 'V-shaped' canyons and parallel the northeast-southwest bedrock structure. These streams swing north into broader meandering valleys subsequent to leaving the hills.

Timberline varies from 1,900 to 2,500 ft in elevation and reaches maximums in the hills west of the Toklat River and in sheltered valleys of the Canyon Creek drainage. Vegetation consists of white and black spruce sometimes intermixed with alder in areas with adequate drainage. Widely scattered

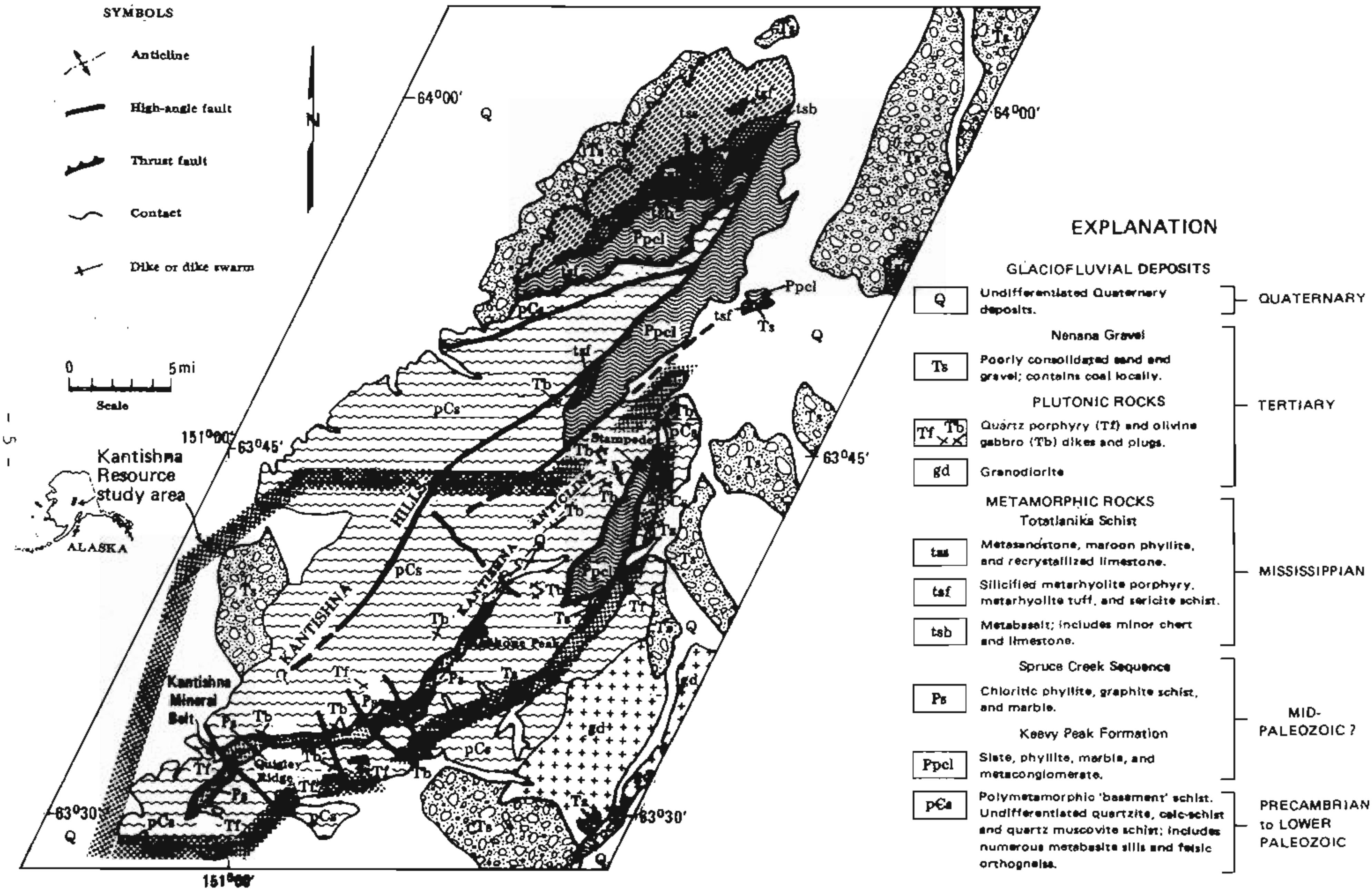

Figure 2. Generalized geology, Kantishna Hills, showing mining district and mineral trends.

birch and aspen stands are located in very well drained south-facing hills. Thick patches of willow and alder grow on active flood plains and in areas of former placer-mining activity. Moist tussock tundra covers both broad, near-horizontal surfaces underlain by Tertiary sedimentary rocks and other poorly drained areas.

The climate is generally continental, but varies somewhat from north to south due to the orographic influence of the Mt. Denali rain shadow and the gradual gain in elevation from north to south. The mean daily minimum temperature in January varies from -22° to -30°C (north to south), while the mean daily maximum temperature in July is 20°C. Average annual rainfall varies from 12 to 15 in. (north to south) (Wahrhaftig, 1965). Permafrost is extensive and absent only in active flood plains and on south-facing slopes.

Primary access to the area is via a secondary road, the Denali Highway, that stretches 8 mi from Wonder Lake to the Friday Creek airstrip on the flood plain of Moose Creek. Approximately 25 mi of unmaintained roads and all-terrain-vehicle trails branch from this road and provide access to mines and prospects on Glacier, Caribou, Glenn, Spruce, Eldorado, and upper Eureka Creeks. A 60-mi-long winter trail was constructed in 1936 from Kobe on the Alaska Railroad to Stampede to haul high-grade antimony ore from the Stampede Mine. Parts of this trail were improved by the Alaska Road Commission in 1960 to provide a transportation corridor into the Kantishna mining district. However, construction work was eventually suspended and the road remains partially overgrown and unused by miners. Unmaintained airstrips include those at Stampede, Friday Creek, and Crooked Creek. As in many other parts of Alaska, the Kantishna region is relatively inaccessible. Principal human activities include mining, trapping, hunting, tourism, and recreation.

The Dunkle Mine township lies in the West Fork, Chulitna River drainage on the southeast flank of the central Alaska Range (fig. 3). Rounded aligned hills and 'U-shaped' valleys that range from 2,000 to 3,200 ft in elevation are the result of extreme glacial scour during late Wisconsinan time (≈10,000 yr B.P.). Bedrock colluvium is mixed with till in many areas. Stands of spruce, birch, and alder are confined to valley floors below 3,000 ft elevation, and scrub brush is present at higher elevations.

The Dunkle Mine area is located approximately 8 mi west of railhead and the Parks Highway. Overland access consists of a poorly maintained road built to service the W.E. Dunkle Coal Mine and Golden Zone (copper-gold) Mine. Three major bridges on this road are currently in a state of disrepair. Several short (<2,000 ft) gravel airstrips are located on the flood plain of the Chulitna River, on isolated ridge tops, and at the Dunkle Coal Mine.

PREVIOUS INVESTIGATIONS

The geological-information base for the Kantishna mining district is much more extensive than that of the Dunkle Mines township. While a large amount of published geological information---including private company reports---accurately describes the mineral potential of the Kantishna mining district, the Dunkle Mine area has received only cursory examinations. However, three important contributions that contain subsurface- and surface-exploration

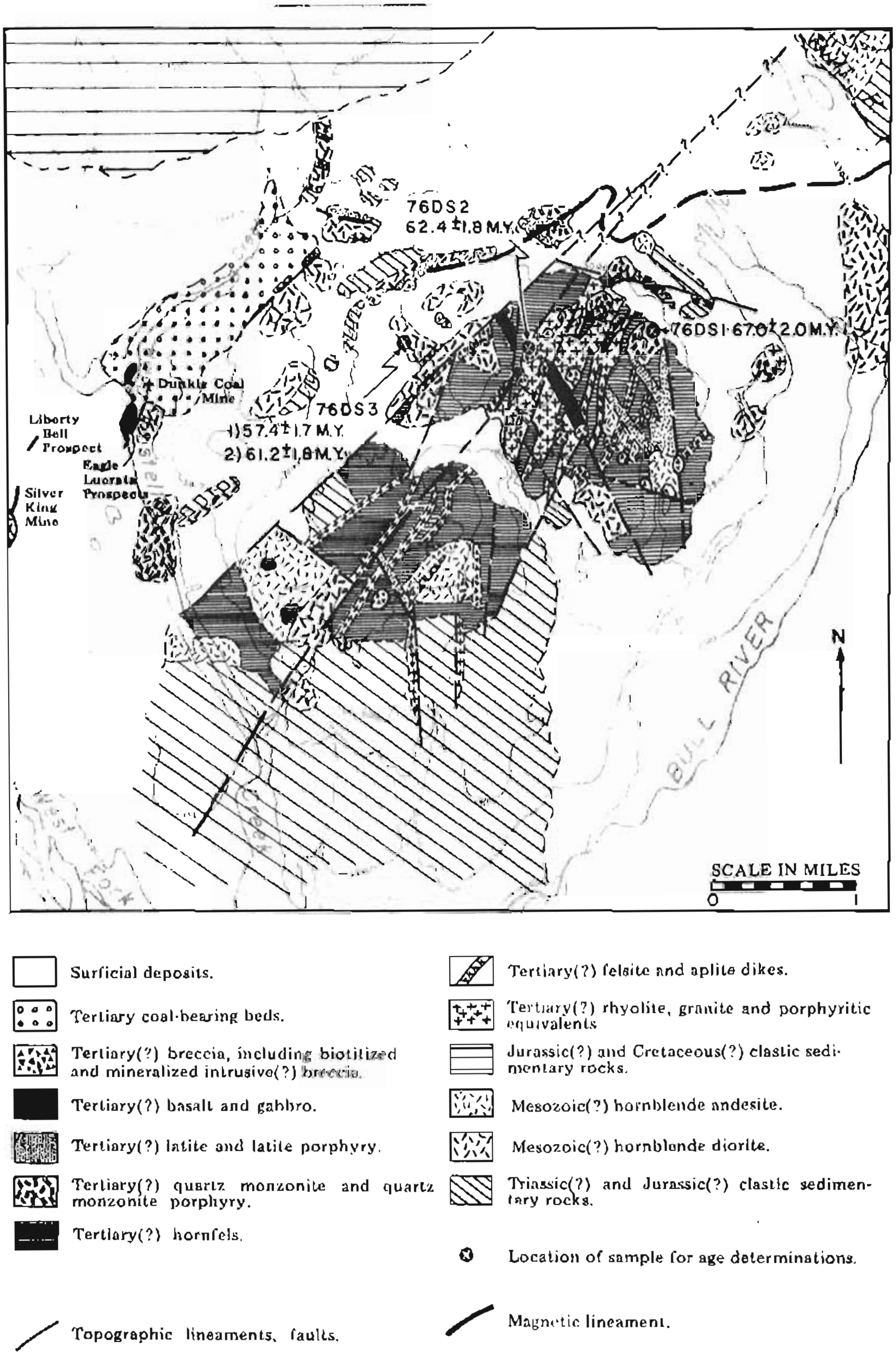

Figure 3. Bedrock geology of the Dunkle township, after Swainbank and others (1978).

results from Dunkle Mine area properties were provided by the private sector or obtained from other unpublished reports.

Most geologic investigations of the Kantishna Hills emphasize studies of mineral resources. Prindle (1907) first described early placer-gold-mining activity in the 'Kantishna diggings' and provided thoughtful observations of the bedrock geology of the region. Brooks (1911) also describes gold-mining activity and metamorphic rocks of the Quigley Ridge area, and later summarized knowledge of antimony mineralization in the Kantishna district (Brooks, 1916). Capps (1918) provided descriptions of lode deposits and information on mining, access, and geography of the area, and later summarized his work (Capps, 1940). Davis (1922), Pilgrim (1929), Moffit (1933), Wells (1933), Saunders (1964), Seraphim (1961; 1962), and Chadwick (1976) describe hard-rock mineral deposits in the Quigley Ridge-Spruce Creek area while White (1942) and Barker (1963) discuss the geology and mining activity at Stampede. Metz and Hawkins (1981) provide gold-fineness data from placer deposits. Reed (1961) compiled a useful geologic map of the Mount McKinley Quadrangle using previous work and his own photographic interpretation. Bundtzen (1981), Bundtzen and Turner (1979), and Hawley (1978) updated information on the geology, geochronology, and mineral resources of the region.

The Dunkle Mine area is part of the upper Chulitna mineral belt, which has been described by various government and private geologists. Capps (1919; 1940) provided a broad reconnaissance of the entire Chulitna district and discussed coal resources in the Broad Pass area. Ross (1933) first recognized important stratigraphic, structural, and mineral elements in the area. Hawley and Clark (1974) is the source document for the entire upper Chulitna district and was used extensively in this evaluation. Hawley (1978) later investigated the mineral resources of the area for the U.S. Bureau of Mines. Blakestad (1981) describes mineralization and exploration efforts on the NIM block. Swainbank, Smith, and Turner (1978) summarize radiometric ages of mineralized intrusives in the Bull River area, and Jones (1976) modified recognized ages of layered rocks with new fossil information. Wahrhaftig (1944) and Rutledge (1948) mapped and evaluated the Costello Creek coal field. Dunkle and others (1962) integrated an economic analysis and mine plan for the Dunkle coal deposits.

GEOLOGIC SETTING

Introduction

The two study areas are in contrasting geologic terranes that are separated by the Denali fault, a major strike-slip fault system in central Alaska. The following geologic summary is largely from Bundtzen (1981) and Hawley and Clark (1974) for the Kantishna and Dunkle areas, respectively.

Kantishna Mining District

The geologic basement north of the Hines Creek strand of the Denali fault system consists of four regionally metamorphosed rock units ranging from Precambrian to late Paleozoic in age (fig. 2). These rocks are a small part of the large complex known as the Yukon Crystalline Terrane (Tempelman-Kluit,

1976) that appear in eastern interior Alaska and Yukon Territory of Canada. The oldest rocks are the polymetamorphic Birch Creek schist, which underlies about 85 percent of the Kantishna study area and consists of variable amounts of quartzite, quartz-mica schist, marble, and greenstone. Coarse-grained quartz- and feldspar-rich protoliths that typify most of the Birch Creek schist were probably formed in shallow-water (miogeosynclinal) sedimentary environments on a continental shelf.

Chlorite and graphitic schist, marble, and metavolcanic rocks of the Spruce Creek Sequence are mainly exposed in a tectonic window underlying Birch Creek schist units from Eldorado Creek to Moonlight Creek (fig. 2). This volcano-sedimentary package probably represents an early(?) Paleozoic rift environment formed on shelf deposits now represented by the Birch Creek schist. According to Bundtzen (1981), a large majority of the structurally controlled ore deposits in the Kantishna mining district are hosted in the Spruce Creek Sequence, and geochemical, geologic, and petrologic evidence suggests that the Spruce Creek Sequence constitutes a 'source bed' for much of the Kantishna district mineralization. Hence, its evaluation has become a focal point of investigations. The Spruce Creek Sequence is nearly identical to rocks described as the Cleary Sequence in the Fairbanks mining district 150 mi to the northwest (Smith and others, 1982).

The youngest crystalline units in the Kantishna area are metasedimentary and metavolcanic rocks of the Keevy Peak and Totatlanika Schist Formations of Late Devonian to Mississippian age. Although the Totatlanika Schist is mainly exposed in the northern Kantishna Hills outside the study area, geologic relationships suggest the formations interfinger locally. Lithologies of similar age are exposed discontinuously from the Brooks Range to Nevada and may be part of an extensive orogenic belt that formed along the North American continent in response to the Antler (and related) Orogeny of the North American Cordillera.

Undeformed mafic- to felsic-dike swarms of early Tertiary age intrude the metamorphic stratigraphy preferentially along the crest of a major fold structure---the Kantishna anticline. Middle to upper Tertiary coal-bearing sandstone and shale overlie older lithologies, often in structural grabens. The layered rocks have been successively deformed by isoclinal to open folds and thrust- and high-angle faults. The region has been uplifted with the Alaska Range since mid-Tertiary time, and shallow gravel thicknesses and steep bedrock canyons indicate that the region is still undergoing uplift. Modern stream alluvium, some of it gold bearing, is being deposited in many streams.

Although at least four ages of late Pleistocene till and outwash blanket much of the southern portion of the study area, most of the rugged upland has not been glaciated during Wisconsinan time (the last 100,000 yr).

Dunkle Mine Township

The Bull River-Costello Creek area is underlain by Jurassic to Cretaceous argillite, sandstone, and conglomerate to the northwest, and Triassic pillow basalt, argillite, and chert to the southeast (fig. 3). A composite Upper Cretaceous to Tertiary quartz diorite stock with associated pipe-like intrusive breccias cuts the older layered rocks.

Oligocene coal-bearing rocks formed in localized swamps are preserved in downwarped or downfaulted basins in the Costello Creek drainage. The study area was covered by a series of ice sheets during much of Pleistocene time, and till that covers most of the area was deposited by one or more large piedmont glaciers that filled the valley of the Chulitna River. As the glaciers receded, outwash was deposited by rapidly downcutting streams. Colluvial aprons are actively forming on valley walls.

MINERAL RESOURCES

Introduction

Various metallic-mineral deposits have been identified in both study areas, but most are concentrated in trends associated with specific layered rock sequences, intrusive suites, and major structures. In the Kantishna area, three major types of complex metallic-vein mineralization, metal-bearing tactite and stratiform occurrences, and heavy-mineral placer deposits (gold) constitute the known mineral resources. Bundtzen (1981, tables 9, 10) summarized descriptions of mineral lodes and 380 assays from 62 deposits in the Kantishna study area. Coupled with other data, this information served as a primary source for the Kantishna portion of this study.

The Dunkle Mine township is part of the Chulitna-Yentna mining district, the major epigenetic precious-base metal province in the southern Alaska Range. Prominent northeast-trending shear zones appear to control the distribution of many mineralized intrusives that are the focal point of metallic-mineral exploration in this region. Tertiary coal-bearing rocks that crop out in the area have been exploited in past years. Hawley and Clark (1974) and Hawley (1978) include summaries of known mineral occurrences in the Dunkle township.

Mining History

According to Bundtzen (1978), who summarized the mining history of the Kantishna Hills, placer gold was first discovered in Chitsia Creek (northern Kantishna Hills) by Judge James Wickersham while in route to his 1903 unsuccessful bid to climb Mount McKinley. This initial discovery prompted others to search for gold in the foothills of the Alaska Range. In 1904, Joe Dalton located placer-gold deposits on Crooked Creek in the central Kantishna Hills, and in 1905, coarse gold was discovered at about the same time by Dalton and Joe Quigley on Eureka and Glacier Creeks, respectively. The 1905 discoveries stimulated a brief but colorful gold rush that involved several thousand miners; however, it was soon learned that pay in the creeks, although locally rich, was limited to shallow gravel deposits in confined canyons. By 1906, only a handful of the original stampeders remained to work the gold placers. Total production of gold from deposits on Eureka, Glacier, Caribou, Friday, Moose, Glenn, Spruce, Little Moose, Stampede, and Crooked Creeks is estimated at 65,000 oz through 1980.

The immediate discovery of galena, stibnite, and other sulfide cobbles caught in sluice-box riffles prompted a successful search for hard-rock mineral deposits. The high price of antimony during the Russo-Japanese War

(1905) led Joe Quigley to mine and ship 12 tons of stibnite ore from the Last Chance lode on Caribou Creek, and thus began the development of lode mining in the region. By 1919, numerous mineralized vein faults containing antimony, silver, lead, zinc, gold, copper, arsenic, and tungsten were located in a 40-mi-long, northeast-trending belt extending from Slate Creek to Stampede. After World War I, high silver prices resulted in development of eight small, high-grade silver lodes in the Quigley Ridge area, and from 1919 to 1924, 1,435 tons of ore averaged 174 oz silver per ton and 0.5 oz gold per ton. In the late 1930s and early 1940s, gold, silver, and minor base metals were extracted from the Banjo Mine. In the early 1960s, silver was again in strong demand, and a private company and the U.S. Bureau of Mines conducted exploratory work on the Quigley Ridge ore bodies. Antimony was sporadically recovered from the Last Chance, Slate Creek, Eureka, and Stampede deposits, largely during high price levels of World Wars I and II and the Korean and Vietnam Wars. Large increases in gold and silver prices since 1974 have again caused an increase in activity in the hills, principally from placer deposits. Total mineral production from the Kantishna Hills is estimated at 67,000 oz of gold, 265,000 oz of silver, approximately 5 million lb of antimony, and several million lb of lead and zinc concentrates worth nearly $35 million at 1983 commodity-price levels.

The presence of mineralization in the upper Chulitna district was first noted when the district was intensively prospected for gold from 1911 to 1915. Coal was found on upper Costello Creek and used by prospectors and miners for blacksmithing. In the Dunkle Mine study area, coal is the only mineral resource with sustained production. In 1941, increased demand for government defense projects lead to exploitation of the Dunkle and other coal seams on upper Costello Creek. By 1943, over 5,000 tons of subbituminous coal had been mined---with underground room and pillar methods---and sold to military installations in south-central Alaska. After a brief shutdown, mining resumed with open-cast methods, and by 1954 an estimated 59,000 tons was extracted (Barnes, 1967). No commercial mineral development has occurred since that time. Intensive prospecting in the 1960s and 1970s led to the discovery of several promising base-precious metal prospects in the southwest and north-central parts of Dunkle township. A considerable amount of exploration, including drilling, geophysics, and geochemistry, has been completed on several mineral deposits.

Resource Analysis

Background and methodology

Methods of estimating mineral resources in the study areas are dependent on the types of ore deposits evaluated and the quality of available information. The Kantishna vein system has been explored intermittently since 1905, and a considerable amount of high-quality surface and limited subsurface information exists for many of the better deposits. In contrast to this, rather sparse exploration and development work have been completed on metal-bearing lodes in the Dunkle Mine area, where no underground work exists and assay data is limited to reconnaissance studies reported by Hawley and Clark (1974), Hawley (1978), and Ross (1933). Some private information (including drilling) has been provided by Resource Exploration Consultants, Inc., and

Resource Associates of Alaska for the NIM claim block. Several thousand feet of underground drilling have been completed in the Dunkle Coal Mine (including step drilling) that allow fairly good estimates of the coal resources.

Because of significant levels of uncertainty for the data base, hypothetical resource-base models have been applied, particularly for the vein systems of the Kantishna mining district. Comparisons with similar mineralized systems in other parts of North America are also made.

It is important to understand the difference between reserves and resources. As used in this report, 'reserves' refers to grades and tonnages of ore measured three dimensionally by drilling or subsurface development to a confident degree of accuracy in an economically viable deposit. 'Resources' are generally defined on two sides by exposure and projected into a third dimension on the basis of geologic inference. Hence, the basis for presenting volume and grade 'resource' estimates involves considerable geological judgment. To illustrate, a mining company probably would not put a property into an expensive development stage without systematically establishing reserves by drilling and subsurface work even though a good resource estimate was available.

Modest tonnage and yardage reserves are known for placer- and lode-mineral deposits in the Kantishna district. Although there are inferred reserves of coal in the Dunkle Coal Mine, no other mineral deposits in Dunkle township contain reserves, and no deposits in either study area have been sufficiently explored to be classified as 'proven.'

Few businesses in the world contain higher risk factors than mining, and the term 'economic viability' must be qualified. Usually only a small minority of prospects in a promising mineral belt or trend are worthy of development expenditures, and an even smaller percentage ever reach a production phase. A successful mining venture must pay three basic costs:

1. Annual operating costs, taxes, and royalties

2. Capital costs associated with infrastructure, including mine, mill, power, transportation, and housing development, that may amount to a significant percentage of the gross-metal value in the deposit

3. Provide a satisfactory return on investment to the company stockholder.

Furthermore, economic potential is often associated with specific ore-deposit parameters. If evidence shows small tonnage potential for a deposit or group of deposits, then indicated metal values per ton must be very high to cover the expensive cost of underground mining and milling. Likewise, if mineralization yields low to modest metal assays, then available evidence must show the existence of a large ore body or series of ore bodies amenable to relatively inexpensive, large-scale mining methods. The Kantishna veins are good examples of small, high-grade deposits, while the NIM and NIMBUS properties in Dunkle township best illustrate a large, modest-grade deposit.

Certain empirical rules have been used to calculate probable extensions of ore bodies at depth. According to McKinstry (1948) and Harding (1923), 'ore' will probably extend down the dip of a mineral deposit at least half the horizontal length of the shoot as exposed on the bottom level. This empirical rule, known for many years as a 'half-square resource estimate,' is supported by local experiences, especially when applied to a large number of ore bodies within a mineral district. The method has been used by mining companies to make predictions of ore potential during the development planning phase. However, it can be largely inaccurate in individual cases and can lead to incorrect conclusions if regarded as a method of predicting maximum ore potential.

The half-square resource-estimate method was applied to the Kantishna vein system. Even though over 400 channel-chip analyses from nine different sources were utilized in this analysis, only a few deposits contain 'mine-face' assay plans (assays of samples taken at regular intervals along the strike of the vein). Hence, the chip-channel assay data are only a relative estimate of average grade and do not account for paucity of mineralization (known to exist in these vein systems) nor exceptionally high-grade, kidney-shaped ore bodies. Additionally, resource-tonnage figures were not rounded off in the analyses.

Kantishna vein system

The Kantishna vein system is a central focus of this resource assessment. The following descriptions, including deposit names, are from Bundtzen (1981, tables 9, 10). Veins in the Kantishna district are mainly structurally and stratigraphically controlled, crosscutting, sulfide-quartz-carbonate-filled fissures confined to a semi-continuous 40-mi-long, northeast-trending zone extending from Slate Creek to Stampede. The Kantishna vein faults strike N. 30° - 70° E. and dip steeply to the southeast; a few dip steeply to the northwest. According to Wells (1933), those veins that dip steeply to the northwest intersect the southeast-dipping veins. This crosscutting relationship probably localized the bonanza silver-sulfide lodes on Quigley Ridge (Seraphim, 1961) and some of the large, massive stibnite lodes at Stampede (White, 1942; Barker, 1963), thus producing the elongate, kidney-shaped ore bodies that were mined. Barker (1963) suggests that mineralization at Stampede occurred before, during, and after movement along the Stampede fault, as evidenced by both crushed and undeformed ore shoots in the Surface, Emil Winze, and East Mooney ore bodies. Veins in the district that strike N. 20° - 40° W. appear to cut the older northeast-trending veins and to be only weakly mineralized.

Mineralized vein faults in the study area range in length from less than 90 ft to over 1500 ft and vary in width from 3 in. to over 27 ft. They occur in the Birch Creek schist and Spruce Creek Sequence, but differ in geometry when cutting through amphibolite, greenschist, quartzite, quartzo-feldspathic schist, marble, or pelitic rocks. In amphibolites or quartzite, the vein faults consist of thick, relatively continuous breccia or sheeted zones up to 20 ft thick, as illustrated in the Jupiter-Mars, Last Chance, Glenn Ridge, and Stampede deposits. In pelitic rocks, marble, or other lithologies that undergo plastic folding rather than brittle fracturing, the vein faults are represented by narrow, discontinuous crenulated zones that are rarely more than 2 ft thick. Vein faults in these rocks are difficult to trace because they consist of small fractures a few inches wide filled with clay gouge and schist that are often barren of economic quantities of sulfides. Examples of this type of vein fault are found in uneconomic portions of the Little Annie, Arkansas, and Fluorence Lodes. In general, competent rocks such as siliceous phyllite and metafelsite of the Spruce Creek Sequence and amphibolite and quartzite of the Birch Creek schist appear to host the largest and most economically viable sulfide vein-fault deposits. Fryklund (1964) and Boyle (1965) describe similar controls for vein-fault deposits in the Coeur d'Alene and Keno Hill districts, respectively.

A relationship of further exploration significance lies in the alignment of 13 vein-fault deposits that extend from Slate Creek through Alpha and Quigley Ridge, across the north side of Wickersham Dome, and culminate in the Last Chance Lode on Caribou Creek. This 'lode line' coincides with a possible southwestern extension of the Crooked Creek fault system (fig. 2). The intersection of this major fault system with the metalliferous(?) Spruce Creek Sequence may be responsible for the high concentrations of vein faults in the Quigley Ridge and Banjo Mine areas.

As first suggested by Wells (1933), the vein faults can be crudely subdivided into three types on the basis of mineralogy: 1) quartz-arsenopyrite-pyrite-(scheelite)-gold veins, 2) galena-sphalerite-tetrahedrite-pyrite-chalcopyrite veins with conspicuous siderite gangue, and 3) stibnite-quartz veins largely free of other sulfides. The Jupiter-Mars, Arkansas, and McGonigill deposits are good examples of the 'type-1' deposits, while the Weiller and Gold Dollar prospects illustrate the best exposed 'type-2,' silver-rich vein faults in the district. Stampede, Slate Creek, and Last Chance deposits are all fairly good representatives of the 'type-3' lodes.

The following summary may add some insight to future examination of the Kantishna vein faults.

- The 'Kantishna antiform' is the regional structure that controls mineralization and should be explored along strike for more undiscovered sulfide veins. The veins are preferentially hosted in rocks that have undergone brittle deformation, for example, quartzose phyllite and metafelsite.

- Chlorite phyllites and marble are generally poor hosts of economic sulfide material.

- There is no textural evidence for supergene enrichment of the bonanza silver veins, although some enrichment by oxidation may occur at the surface (Wells, 1933; Seraphim, 1961). This implies that high-grade ore bodies can exist at depth in the vein systems.

- Some bonanza silver veins and the large massive stibnite-quartz veins are located where a northwest-dipping vein intersects a southeast-dipping vein. This fracture relationship is a structural guide for ore.

. Polybasite, pearceite, stephanite, pyrargyrite, and argentiferous tetrahedrite are the main silver-bearing minerals. Thus, copper, antimony, and perhaps arsenic from silver-antimony sulfosalts and tetrahedrite could be effective geochemical guides for the exploration of high-grade silver lodes.

In summary, although the Kantishna vein system can be traced for over 40 mi, distinctive zones of concentration comprise the most economically attractive areas. These zones are outlined in figure 4 and are referred in this analysis as:

. Quigley-Alpha Ridge silver-gold-base-metal system

. Banjo gold-silver lode system

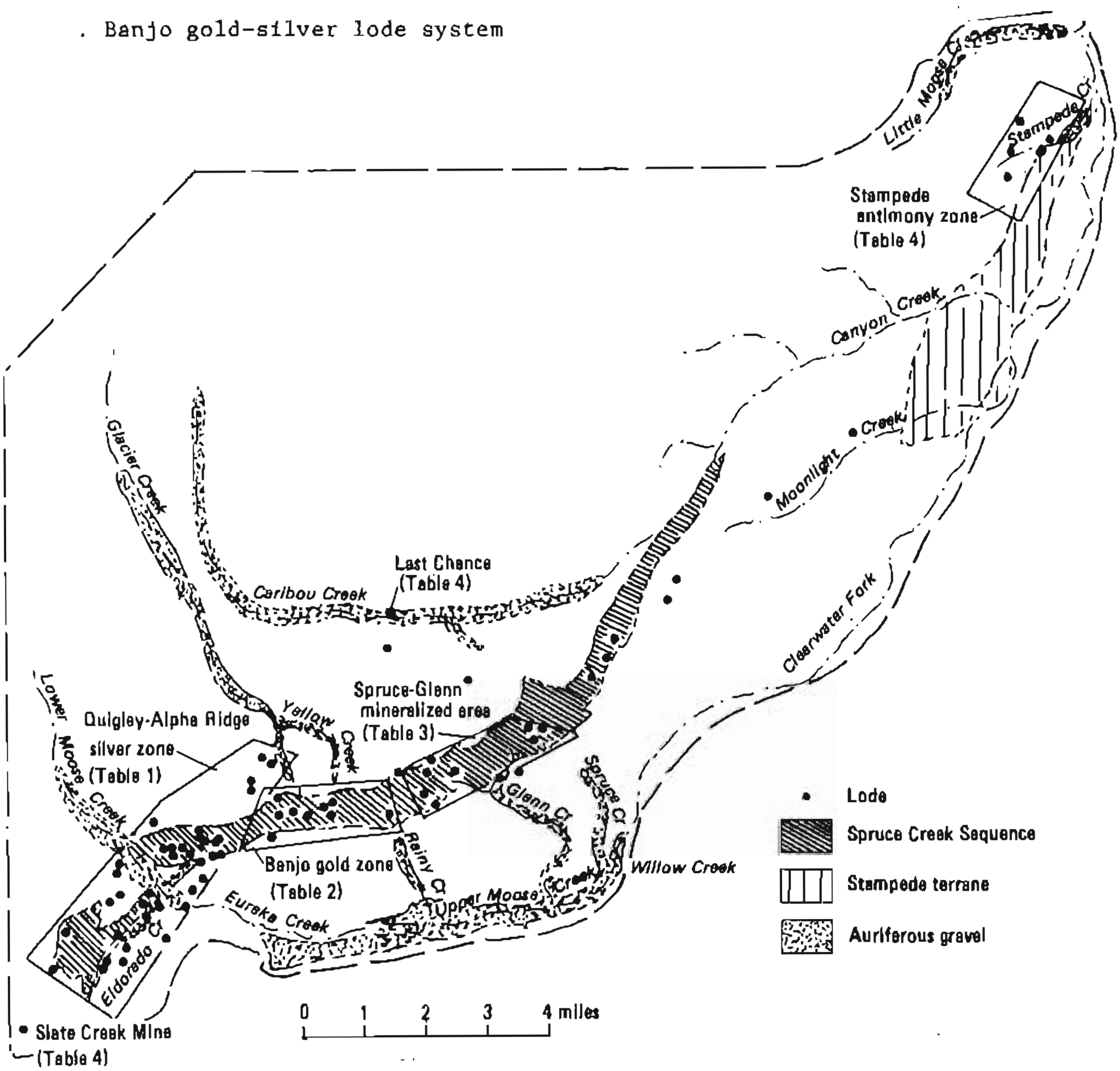

Figure 4. Location of vein concentrations, Kantishna mining district, Alaska.

- Spruce-Glenn Creek vein concentration

- Slate Creek antimony deposit

- Last Chance Creek antimony deposit

- Stampede antimony deposit.

The last three deposits are discussed collectively in the resource-analysis section. The sources for assay and physical dimensional data for this analysis include Barker (1963), Bundtzen (1981), Chadwick (1976), Davis (1972), Hawley (1978), Saunders (1964), Seraphim (1961), Wells (1933), White (1942), and unpublished data from the Territorial Department of Mines. Standards for tonnage calculations are 8.5 ft^3 per ton for massive-sulfide-rich veins, 12.0 ft^3 per ton for carbonate-quartz-rich veins, and 10.0 ft^3 per ton for stibnite- or disseminated tungsten-rich veins.

Quigley-Alpha Ridge silver lodes

A 15 mi^2, northeast-trending area extending from Alpha Ridge to the north flank of Wickersham Dome contains at least 27 promising, silver-enriched vein deposits. Physical measurement of maximum strike length and channel-chip grade estimates are available for 23 of the 27 deposits (table 1). Using the half-square estimate, the 23 veins contain a minimum of 412,892 tons of ore with grades of 39.76 oz per ton silver, 0.14 oz per ton gold, 6.4 percent lead, 2.3 percent zinc, and a small credit of tungsten. Antimony and copper are also present in several deposits, but assay information is too sketchy to make reliable resource estimates for these commodities. Inferred reserves of 30,410 tons of similar-grade mineralization exist mainly in past productive ore shoots or in properties where considerable surface or subsurface data are available.

Ore-potential estimates range from the 468-ton Francis system to the 169,411-ton Silver Pick system. Conservative estimates of strike length and ore width were utilized in all cases. Widths are generally those corresponding to sampled zones and do not indicate total width of ore structures (which are up to 30 ft in several deposits).

The Kantishna Quigley-Alpha Ridge silver system was compared to two very similar vein systems---the Keno Hill district in Yukon Territory, Canada, and the Coeur d'Alene district near Kellogg, Idaho. Over 25 different physical parameters including strike length, width, depth, density, district size, grade, and various metallic ratios were analyzed (table 2), and the results indicate some rather striking similarities for all three districts. First, Keno Hill deposits are more analagous to the Kantishna district deposits than Coeur d'Alene lodes. For example, all appear to be intrude low- to medium-grade metamorphic crystalline terrane along structurally controlled conduits. Similar structural controls, including competency of host rock, cross structures, and roofing are present in all settings, and the mineralogy is essentially identical: galena-sphalerite-tetrahedrite-siderite ± other sulfides and sulfosalts. Silver sulfosalts and galena appear to contain most of the silver values. Evidence for classic hydrothermal igneous sources is not convincing in these districts, although small dike swarms in the Keno Hill and Kantishna areas are at least locally associated with mineralization.

Table 1. Summary resource model for silver veins in the Quigley and Alpha Ridge area, Kantishna mining district, Alaska.

Name of deposit	Number Bundtzen, (1981, pl. 1)	Strike length (ft)	Average width (ft)	Known depth (ft)	Ag (oz/ton)	Au (oz/ton)	Pb (%)	Zn (%)	Half-square resource estimate (tons)	Known reserves (tons)
Bunnell	4	275	4.0	140	14.95(N=13)	0.02(N=13)	16.0(N=6)	14.7(N=4)	17,730	17,100
Whistler	11	75	2.0	40	15.21(N=2)	0.05(N=2)	7.9(N=2)	0.3(N=2)	652	
Alpha	9	300	5.0	35	79.53(N=10)	0.02(N=10)	8.9(N=10)	2.7(N=7)	26,470	
Red Top	19	295	4.0	130	111.60(N=6)	0.75(N=7)	17.6(N=9)	8.2(N=4)	20,407	3,500
Galena	20	150	2.0	15	54.50(N=6)	0.10(N=6)	4.7(N=6)	5.9(N=5)	2,647	2,100
Dalton Group	22	150	3.5	-	45.72(N=3)	0.29(N=3)	51.8(N=1)	4.1(N=1)	3,281	
Silver Pick	24	1,200	2.0	25	45.67(N=10)	0.18(N=11)	2.3(N=11)	2.9(N=11)	22,050	2,160
Gold Eagle	25	300	1.0	10	46.33(N=3)	0.12(N=3)	6.3(N=3)	0.1(N=2)	5,294	50
Gold Dollar	26	420	3.0	50	35.01(N=43)	0.15(N=11)	2.3(N=11)	2.9(N=11)	169,411	3,000
Lucky Strike	21	125	6.0	-	8.20(N=2)	0.05(N=2)	-	-	3,875	
Galena 2	-	150	4.0	-	71.65(N=2)	0.02(N=2)	32.9(N=4)	-	3,750	
Merry Widow	34b	125	5.0	-	16.30(N=2)	0.03(N=2)	0.3(N=2)	-	3,229	
Little Annie	27	600	6.0	-	19.00(N=45)	0.02(N=40)	1.5(N=40)	0.7(N=40)	90,000	
Francis	23	150	0.5	-	8.18(N=4)	0.20(N=4)	2.0(N=2)	0.1(N=1)	468	
White Hawk	31	450	2.0	-	2.89(N=2)	0.04(N=2)	17.0(N=1)	-	23,823	
Silver King	34a	150	6.0	-	26.60(N=22)	0.22(N=3)	7.1(N=3)	6.4(N=3)	5,625	2,000
Water level	32	150	4.0	-	7.81(N=4)	0.04(N=4)	0.8(N=3)	0.5(N=3)	3,750	
Fluorence	39	135	1.5	15	39.10(N=4)	ND(N=4)	42.7(N=3)	2.2(N=6)	1,139	
Bosart	41-2	150	2.0	60	80.60(N=4)	tr(N=4)	33.8(N=4)	12.8(N=4)	1,875	400
Waterloo	44	100	1.8	-	14.14(N=6)	tr(N=6)	16.7(N=6)	0.2(N=6)	750	
Wieler	45	200	4.0	25	82.70(N=10)	0.07(N=8)	2.3(N=6)	8.4(N=6)	6,666	100
Subtotal[1]					39.76	0.14	6.4	2.3	412,892	30,410

[1]Assays are weighted averages of all deposits.
- Not available.

Table 2. Comparison of silver-rich vein systems in the Kantishna mining district with Keno Hill, Yukon Territory, Canada, and Coeur d'Alene mining district, Idaho.

	Kantishna mining district (Bundtzen, 1981; Wells, 1933; Seraphim, 1962)	Keno Hill, Yukon Territory (Boyle, 1965; Sinclair and others, 1975; Templeman-Kluit, 1981)	Coeur d'Alene mining district (Fryklund, 1964; Bennett and Venkatakrishnan, 1982)
Geologic synopsis	Northeast-trending sulfide-quartz-carbonate veins intrude Precambrian-Paleozoic metamorphic rocks of Yukon Crystalline Terrane; source beds probably Spruce Creek Sequence; mainly galena-sphalerite-tetrahedrite-sulfosalt-siderite-quartz mineralogy.	Northeast-trending sulfide-quartz-carbonate veins cut metamorphic rocks of Yukon Group of disputed age. Mainly galena-sphalerite-tetrahedrite-sulfosalt-siderite mineralogy. Source bed (graphitic schist) suggested.	Northwest-trending mineral belt contains near-vertical quartz-carbonate near sulfide veins in 11 discrete belts. Galena-tetrahedrite-sphalerite-siderite vein mineralogy. Source bed (Belt sediments) suggested.
Vein strike length (ft)			
a) shortest	45	120	100
b) longest	1,200	3,500	4,308
c) average	275 (23 veins)	960 (30 veins)	644 (114 mines)
Width (ft)	3.3 (23 veins)	4 (30 veins)	4-25
Depth (ft)			
a) deepest	600	1,300 (30 veins)	7,290
b) average	135	444 (30 veins)	985 (114 mines)
Number of veins	23 (silver veins); 31 (district-wide)	30 (major silver lodes); 62 (district-wide)	114 producing mines; 280 (district-wide)
Total strike length of mining district	5 mi (silver veins); 40 mi (entire district)	12 mi (silver veins); 28 mi (entire district)	42 mi concentrated silver veins; 95 mi-long mineral belt
Average width of mining district	3 mi	4 mi	8-10 mi wide (all 11 belts)
Average number of veins per mi²	3.1/mi²; maximum 8/mi², Quigley Ridge	2.5/mi²; maximum 9/mi², Keno Hill	2.4/mi²; up to 12/mi²
Dominant host lithology			
a) brittle quartzose rock units and greenstone	75% (23 veins)	84% (62 veins)	79% (114 mines)
b) ductile rock units	24% (23 veins)	16% (62 veins)	21% (114 mines)
Average grade Ag	39.76 oz/ton (23 veins)	35.60 oz/ton (30 veins)(1947-74)	5.60 oz/ton (through 1957) (114 mines)
Average grade Au	0.14 oz/ton (23 veins)	minimal	0.003 oz/ton
Average grade Pb	6.40% (23 veins)	6.20%	6.23% (through 1957)
Average grade Zn	2.3% (21 veins)	3.6%	1.91%
Ratio Ag:1% Pb	6.27:1	5.74:1	0.90:1
Total production Ag (oz)	257,000	189,628,810	935,287,000 (1980)
Total production Au (oz)	449	Not known	500,553 (1980)
Total production Pb (lb)	504,000	607,000,000	15,359,500,000 (1980)
Total production Zn (lb)	188,000	347,332,000	6,103,480,000 (1980)
Total ore mined (tons)	1,655	4,725,000 (est. through 1982)	101,332,364 (through 1957)
Average tons mined/yr	-	128,117 (average 1947-74); has been 80-100,000 since then	-
Average number veins mined/yr	1-3 sporadic	7-10 (1920-82)	27-67 (1904-1957)

- Not available.

Ore horizons that appear to be stratigraphically controlled include the Spruce Creek Sequence in the Kantishna area, the Central Quartzite Member Yukon Group for Keno Hill, and quartzite members of the Belt Group for the Coeur d'Alene mining district. Coeur d'Alene ore shoots differ from those at Keno Hill and Kantishna in depth of mineralization. Available evidence shows that ore shoots in the Keno Hill mining area bottom out (on the average) in four or five mine levels (400-500-ft vertical depth). The depth of ore shoots (444 ft) is approximately half the average strike length (960 ft) of the largest 31 veins, which suggests that a half-square resource estimate would predict the tonnage of ore mined at Keno Hill within a 14-percent error bar. Depth of ore shoots in the Coeur d'Alene district is 50 percent more than average strike depth, which indicates a more continuous, structurally favorable zone---probably a thick, competent host. Because of exponential increases in vein volume during parameter computations, a half-square resource estimate would underestimate the size of the Coeur d'Alene mining district by an order of magnitude.

Lead and zinc contents of the three districts are essentially the same. Silver grade for the Kantishna area and Keno Hill are essentially identical, but average silver grade is much lower in the Coeur d'Alene area.

An estimate of the relative size of the Kantishna silver district is accomplished indirectly. This method assumes that volume and grade of mineralization per unit area in both districts is the same, thus accounting for the lack of full dimensional data for the Kantishna mining district. The Kantishna silver lodes cover 15 mi^2, while those of Keno Hill cover 48 mi^2 and those of Coeur d'Alene several hundred mi^2. Vein density is about the same for all three districts. Kantishna contains about 74 percent as many 'significant' silver lodes as Keno Hill. By mathematically comparing these factors, the overall Kantishna mining district appears to be about 0.245 (one-quarter) the size of Keno Hill. Because Keno Hill is at least a 4.75-million-ton district (ore reserves have not been exhausted), Kantishna contains at least 1,160,000 tons of ore of presumably the same grade as calculated in the half-square model. The resource range, therefore, is 412,890 to 1,160,000 tons of ore for the 'silver' zone in the Kantishna mining district.

Banjo lode-gold system

East of the Quigley-Alpha Ridge silver system is a series of crosscutting quartz-gold-arsenopyrite ± scheelite lodes. Although essentially part of the same vein system as the Quigley silver ores, the Banjo system consists mainly of primary gold ores with byproduct silver, tungsten, and very minor credits of lead, antimony, and zinc.

The Banjo vein constituted Kantishna's largest single mine in amount of ore processed---13,650 tons during a 4-yr milling period. The half-square resource model estimates that 173,960 tons of mineralization with an average grade of 0.39 oz per ton gold, 3.59 oz per ton silver, and credits of lead and zinc exist in five of the largest deposits (table 3).

The Banjo system was compared to the Pedro Dome-Cleary Hill area of the Fairbanks mining district, which contains very similar ore deposits (Hill,

Table 3. Summary resource model of primary gold lodes for the Quigley and Banjo Ridge area, Kantishna mining district, Alaska.

Deposit name	Number Bundtzen (1981, pl. 1)	Strike length (ft)	Average width (ft)	Known depth (ft)	Au (oz/ton)	Ag (oz/ton)	Base-metal assays (%)	Half-square resource estimate (tons)	Known reserves (tons)
Pennsylvania	30a	500	1.8	-	0.17(N=6)	8.16(N=6)	2.85 Pb; 1.83 Zn(N=6)	18,750	-
Keystone	30b	400	4.0	30	0.60(N=2)	-	-	26,660	-
Banjo	35	600	3.0	85	0.49(N=185)	0.52(N=185)	0.2 Pb + Zn; 0.45 WO_3 (N=185)	45,000	1,595
Jupitor-Mars	36	780	3.0	70	0.33(N=4)	5.79(N=4)	0.95 Pb; 0.14 Zn(N=4)	76,050	2,540
McGonnigal	51	300	2.0	35	0.23(N=5)	1.17(N=5)	2.54 Pb; 0.48 Zn; 0.85 Sb(N=5)	7,500	-
Subtotal[1]					0.39	3.59	0.88 Pb; 0.35 Zn	173,960	4,135

[1] Assays are weighted averages of all deposits.

\- Not available.

1933; Chapman and Foster, 1969). In both areas, metallic content, structural control, and strike lengths, widths, and projected depths of known veins approximate those of the Banjo area. The Cleary and adjacent veins produced 165,000 tons of high-grade ore prior to 1950, a figure similar to the half-square estimate for the Banjo system. Ore deposits were not mined out in either district, and recent exploration disclosed promising new mineralization in the Fairbanks area. The half-square estimate of the Banjo system is an absolute minimum figure.

Spruce-Glenn Creeks veins

A concentration of quartz-carbonate veins cuts lithologies of the Spruce Creek Sequence near the head of Glenn Creek about 8 mi east of Quigley Ridge. Mineralization contains gold and silver values and credits of antimony, arsenic, lead, and zinc. The half-square model estimates that 83,929 tons grading 0.07 oz per ton gold, 8.05 oz per ton silver, and about 2.7 percent combined antimony, lead, and zinc exist in the six poorly sampled deposits (table 4). These veins, which contain significantly lower values of precious metals from those in the Banjo and Quigley Ridge areas to the west, have received the least attention and deserve additional exploratory efforts.

Primary antimony deposits

About 40 percent of the antimony produced in Alaska came from the Kantishna mineral belt, principally from deposits at Stampede and Slate Creeks. Total production has exceeded 5,000,000 lb of antimony in high-grade ores and concentrates. Four major deposits contain half-square resources of over 560,720 tons grading 11.93 percent antimony, equivalent to almost one-fourth of the nation's reserve base of this strategic metal (table 5). Approximately 80 percent of the half-square resources are found in the Stampede system, known to contain at least seven discrete ore bodies. Almost 12,000 tons of ore grading 15-20 percent Sb_2S_3 are classified as inferred reserves in four deposits. Credits of silver and gold may be recoverable with proper milling circuits.

The summation of all half-square resource estimates of metals in the ores is presented in table 6. The model predicts that 1.23 million tons of ore worth $427.75 million (1983 commodity-price levels) are contained in the Quigley-Alpha Ridge silver zone, the Banjo gold system, the Glenn-Spruce Creek mineralized area, and four antimony deposits including Stampede (tables 1-5). Approximately 49 percent of the values are in silver followed by antimony (32 percent), gold (13 percent), and lead, zinc, and tungsten (6 percent). The tenor of 'ore' ranges from $135 per ton for the Spruce-Glenn Creek lodes to $578 per ton for the Quigley-Alpha silver zone; the average is $337 per ton for all lodes evaluated.

Stratiform-deposit potential, Spruce Creek Sequence

The Kantishna vein system was formed by hydraulic fracturing of metalliferous host lithologies of the Spruce Creek Sequence (Bundtzen, 1981). The origin of this hypothesis is the 'source-bed concept' (Hunt, 1873; Knight, 1957). Five stratiform mineral occurrences have also been identified in the

Table 4. Summary resource model of gold-silver veins in the Spruce - Glenn Creeks areas, Kantishna mining district, Alaska.

Deposit name	Number Bundtzen (1981, pl. 1)	Strike length (ft)	Average width (ft)	Known depth (ft)	Au (oz/ton)	Ag (oz/ton)	Base-metal assays (%)	Half-square resource estimate (tons)
Glenn	52	300	4	180	0.03(N=4)	2.82(N=3)	2.15 Sb; 4.29 Pb; 0.03 Zn(N=2)	15,000
Glenn Ridge 1	53	400	10	-	0.08(N=8)	7.58(N=8)	0.46 Pb(N=5); 0.30 Zn	66,670
Pension	54	125	1	-	0.16(N=1)	75.60(N=2)	2.76 Pb(N=1); 1.05 Sb	645
Arkansas	55	150	1.5	-	0.08(N=1)	45.60(N=2)	0.71 Pb; .74 Sb(N=1)	1,406
Lena and Silver Wire	60	50	2	-	0.50(N=1)	75.00(N=1)	-	208
Subtotal[1]					0.07	8.05	1.16 Pb; 1.0 Sb; 0.50 Zn	83,929

[1]Assays are weighted averages of all deposits.
- Not available.

Table 5. Summary resource model of antimony deposits in the Kantishna mining district, Alaska.

Name of deposit	Number Bundtzen (1981, pl. 1)	Strike length (ft)	Average width (ft)	Known depth (ft)	Sb (%)	Ag (oz/ton)	Au (oz/ton)	Half-square resource estimate (tons)	Known reserves (tons)
Slate Creek	1	400	5	60	18.66(N=35)	-	-	40,000	3,600
Eagles Den	6	200	4	35	28.50(N=3)	1.74(N=2)	-	8,000	1,750
Last Chance	63b	560	4	50	14.30(N=6)	0.34(N=6)	0.05(N=10)	62,720	300
Stampede deposits		1,500	1-26 (average=6)	350+	12.00	trace to significant	trace to significant	450,000	
Glory Hole									700[1]
Unnamed surface body									-
Neese Winze									80[1]
Emil Winze									4,000[1]
Mooney									250[1]
Kobuk									250[1]
Composite of colluvial deposits									1,000 (20% Sb)
Subtotal[2]					11.93			560,720	11,930

[1]Average Sb grade of 15-20% Sb_2Sb_3.
[2]Average grade is weighted from all deposits.
- Not available.

Table 6. Summation of half-square resources, Kantishna vein system, Alaska.

	Au (oz)	Ag (oz)	Pb (lb)	Zn (lb)	Sb (lb)	WO_3 (lb)
Primary gold lodes, Quigley-Banjo Ridge area	67,844	624,516	3,061,696	1,217,720	127,500	405,000
Gold-silver base-metal veins Glenn-Spruce Creeks area	5,875	675,628	1,947,152	839,929	679,400	-
Silver veins, Quigley-Alpha Ridge	57,804	16,416,585	52,850,176	18,993,032	-	-
Primary antimony lodes, Stampede and Quigley-Eldorado Creek area	3,136	35,244	-	-	133,787,000	-
Total	134,659	17,751,973	57,859,024	21,050,681	134,593,900	405,000

study area, including the Saddle (nos. 1964, 1815), Lloyd, and other deposits (Bundtzen, 1981, tables 9, 10) usually associated with chloritic schist and metamorphosed tuff (or exhalite) in the Spruce Creek Sequence of the study area.

Although anomalous amounts of antimony, silver, copper, and zinc have been identified, none of the assay data approaches economic concentrations. Rock units essentially identical to the Spruce Creek Sequence have also been recognized in the Fairbanks district 150 mi to the northeast. These rocks have been informally designated the Cleary sequence and contain gold-tungsten(?)-bearing stratiform mineralization (Smith and others, 1982). I am not aware of any discoveries of economic significance other than vein or metasomatite deposits in the Cleary sequence.

Occurrences in the Spruce Creek Sequence are similar to mineralization at Greens Creek in southeastern Alaska, the Telesequah district in northern British Columbia, and the Red Lake district in Ontario. Deposits in these areas are precious-metal-enriched, base-metal lodes usually associated with distal volcanogenic exhalations in a submarine environment. They are not exceptionally large by most ore-deposit standards, and range from 1 to 10 million tons, with grades of 5-15 percent copper, lead, zinc, and barite, up to 20 oz per ton silver, and 0.2 oz per ton gold. Sulfides are notably absent in gold deposits in the Red Lake district, and ore zones are difficult to recognize.

It is not possible to predict if or where economic mineralization of this type exists in the Spruce Creek Sequence in the study area, but the formation has potential mineralization and should be rigorously prospected along strike.

Placer deposits

Placer gold in streams in the Kantishna mining district was largely derived from the Kantishna vein, and its economic extraction on Eureka, Friday, Caribou, Glenn, Spruce, Yellow, Rainy, Moose, Little Moose, Crooked, and Stampede Creeks has constituted a large percentage of the area's past and present gold production. The location of active mines is shown in the National Park Service analysis of mining effects. Since the late 1970s, annual production has fluctuated from 3,000 to 5,000 troy oz of gold,[1] with a significant silver byproduct resulting from the district's low gold-fineness values. Much of the recovered bullion is coarse, angular nugget gold that is sold to jewelers at significantly higher prices than quoted metals-market prices. The placer deposits can be classified into two major categories:

- Auriferous alluvial-colluvial gravel deposits of limited yardage in steep tributary streams (accounts for most of past production)
- Large-volume, low-grade auriferous terrace gravels (glacial outwash) on Moose, Caribou, and Glacier Creeks.

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[1] The gold-production estimate is based on interviews with miners and on information from DGGS annual activity questionnaires; it probably understates production.

Some deposits have been worked as many as four times, and future exploitation will require enhanced systems for recovery of fine gold and mine side pay left by previous operations and for removal of debris slides that overlie pay streams.

Terrace deposits contain the largest potential resource in the district. Most operations in these poorly understood, low-grade auriferous gravels have been economic failures, but the large-yardage plants with efficient recovery technology that are available today could significantly alter mining patterns.

No proven placer reserves were made available to this study. Most youthful stream alluvial-colluvial placers probably do not have an extensive reserve base because most current development expenditures have concentrated on production.

Chadwick (1976) utilized private input and his sampling to arrive at inferred reserve estimates (on nine drainages) of just over 4 million yd^3 of variable-grade ore. In this study, an additional gravel-resource estimate of 16.4 million yd^3 was obtained (table 7) by examining past information and physically measuring blocks of terrace alluvium and colluvium-alluvium in modern streams using aerial photographs and 1:20,000-scale maps (as suggested by Wells, 1973).

An estimate of grade of these resources or reserves was not attempted because of lack of information. Limited reserves and resources in modern 'V-shaped' streams probably have higher gold tenor (by several times) than those of the larger terrace deposits. Economically viable deposits presently mined in the district have values ranging from \$3.50-$\geq$\$10 per yd^3.

At the present cumulative volume of mining (15 operations; 600,000 yds^3 annually), the reserve and resource base could sustain existing operations for at least 30 yr. However, because of complex economic factors, it is impossible to predict how long the current placer industry will operate.

Dunkle township

The Dunkle township is part of the Chulitna-Yenta mineral belt, a major epigenetic metal province 30 mi long and 10 mi wide that extends from Eldridge Glacier to Bull River. Hawley and Clark (1974), Hawley (1978), and Swainbank and others (1978) reviewed the geology and mineral resources of the area (figs. 3, 5). No metal production is recorded for the township, but the nearby Golden Zone Mine has produced copper, silver, and gold. Although the Dunkle Mine has produced coal, the general lack of data prevented systematic half-square modeling like that used in the Kantishna mining district. Instead, comparisons are made with other better known mineral deposits. Hawley (1978) provides resource estimates for some deposits, and resource and reserve estimates of Dunkle coal deposits include Rutledge (1948), Dunkle and others (1962), and Barnes (1967), although all significantly disagree with each other. The following information is from the previously cited sources.

Table 7. Inferred resource and reserve estimates for placer deposits in the Kantishna Hills, Alaska.

Stream	Inferred reserve (yd^3)	Resource (yd^3)	Percentage of production through 1968	Comments
Willow	Unknown	50,000	-	Narrow stream 40-60 ft wide, maximum 6-ft pay zone.
Spruce	800,000	975,000	4.5	Narrow upper drainage, lower fan complex thickens.
Glenn (upper)	60,000[1]	400,000	8.7	Narrow pay zone $\leq$60 ft wide, fault zone at fork juncture thickens pay zone to 10 ft.
Glenn (lower)	200,000	500,000		Narrow canyon breaks out onto alluvial fan.
Rainy	Unknown	190,000	-	Steep, narrow canyon breaks out onto flat alluvial plain.
Moose (upper)	Unknown	5,300,000	-	Terrace deposits up to 800 ft wide in 6 mi of drainage.
Eldorado	Unknown	270,000	-	Narrow canyon with wide plain above, alluvial fan below.
Eureka (upper)	80,000[1]	170,000	21.6	Narrow canyon with auriferous colluvial deposits.
Eureka (lower)	300,000	175,000		Alluvial fan contains pay 10 ft thick.
Friday	670,000		1	Alluvial fan and stream placers contain thick pay zone.
Moose (lower)	1,100,000[1]	3,730,000	-	Terrace deposits up to 800 ft wide contain two auriferous zones.
Yellow	Unknown	20,000	1.2	Rich placers in narrow canyon.
Glacier (lower)	500,000[1]	-	4.4	Narrow canyon, broad canyon opening; variable thickness.
Glacier (upper)	Unknown	50,000		Very narrow, steep canyon with sporadic pay.
Caribou (lower)	500,000[1]	4,000,000		Lea bench contains low-grade pay streak up up to 900 ft wide.
Caribou (middle)	185,000[1]	500,000	44.8	Steep and narrow canyon contains discontinuous pay.
Caribou (upper)	130,000[1]	180,000		Lower end narrow pay; upper end contains terrace deposits.
Little Moose	Unknown	140,000	7.5	Narrow canyon with restricted high-grade pay.
Stampede	Unknown	100,000	-	Narrow canyon with sporadic pay.
Last Chance	Unknown	30,000	2.5	Very narrow, steep canyon with sporadic gravel.
Totals	4,525,000	16,780,000		

[1] Modified from Chadwick (1976); portions of these reserves have been depleted.

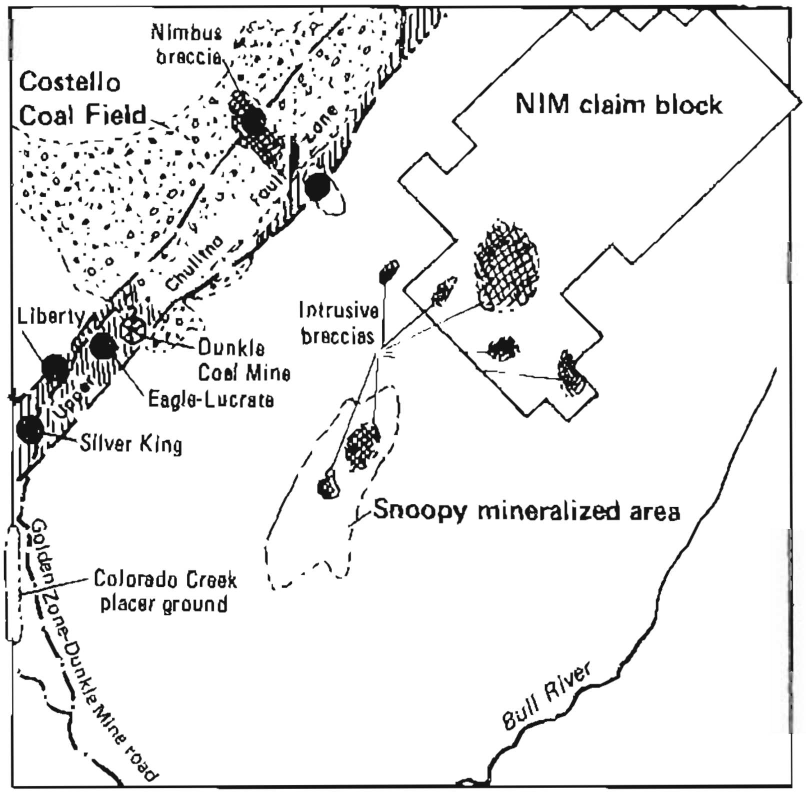

Figure 5. Location of mineral deposits, Dunkle township.

Silver King area

The Silver King mineralized zone lies in the southwest corner of Dunkle township and is bounded on the west by Colorado Creek and on the north and east by Costello Creek. Known vein, tactite, disseminate, and breccia-pipe mineral lodes include the Silver King, Lucrata, Eagle, and Liberty prospects. All appear to be associated with Cretaceous-Tertiary plutons aligned along northeast-trending fractures such as the Upper Chulitna fault.

The Silver King prospect is a composite mineralized tactite-breccia-pipe zone in silicified Mesozoic sediments cut by diorite dikes and intrusive(?) breccia. Anomalous values of copper, antimony, bismuth, gold, silver, cobalt, arsenic, lead, tin, and zinc have been found in rock samples (Hawley and Clark, 1974). The prospect was evaluated for precious-metal potential, and gold values range from traces to 8.29 oz per ton. Because rich assays are quite spotty and erratic, resource estimates are somewhat tenuous. Hawley and Clark (1974) show sporadic mineralization over a 800-ft by 2,000-ft area. A 100-ft-diameter breccia zone contains some of the best mineralization. If projected 100 ft vertically, this smaller zone would amount to 85,000 tons of mineralization. Additional data is needed to evaluate the deposit(s).

The Eagle prospect consists of several northeast-trending gold- and silver-bearing quartz veins exposed south of Dunkle Coal Mine. The veins are inches to a few feet wide with pods of sulfides discontinuously exposed along strike. The average assay of seven chip-channel samples reported by Hawley and Clark (1974) and Ross (1933) is 0.23 oz per ton gold and 4.55 oz per ton silver along undisclosed portions of the vein(s). Ross (1933) estimated that approximately 12,000 tons of mineralized vein material exists along 300 ft of vein-system strike length above the level of Costello Creek. Hawley and Clark (1974) followed this vein about 700 ft north from Costello Creek and believe it may project 1,000 ft further; hence, the Ross (1933) reserve estimate probably understates the size of the deposit.

The Lucrata (or Lucrative) prospect is located in the shear zone of the Upper Chulitna fault. Unpublished assays as high as 1.47 oz per ton gold and 3.8 oz per ton silver are known, but those reported by Hawley and Clark (1974) average 0.49 oz per ton gold and 1.03 oz per ton silver (N=4). Mineralization is quite erratic along a several-hundred-foot strike length, and further work is necessary to evaluate the zone.

The Liberty prospect is a mineralized shear system similar to the Lucrata deposits. Assays reported by Ross (1933) range from 0.06 to 0.14 oz per ton gold and 1.20 to 8.60 oz per ton silver over 2- to 4-ft-wide mineralized zones. Hawley (1978) reports values ranging from 0.005 to 0.06 oz per ton gold with traces of silver in the same mineralized trenches as reported by Ross (1933).

Nimrod-Nimbus

I was unable to locate detailed geologic descriptions of this deposit. Hawley (1978) describes the mineralization as a poorly understood 'explosion breccia' intruding Mesozoic sedimentary rocks, with grades of 0.5 to 3.0 oz per ton silver and credits of lead, zinc, antimony, and gold; he regards it as a bulk-tonnage, low-grade silver deposit. Assuming dimensions of 250 ft by 250 ft by 125 ft, the ore potential is in the range of 650,000 tons or more.

NIM-Snoopy mineralized area

The following descriptions are largely from confidential private company reports, maps, and charts constructed during exploration in the 1970s. Bedrock in the NIM-Snoopy mineralized zone consists of hornfelsed clastic and volcanic rocks of Mesozoic age intruded by hypabyssal igneous complexes of diorite porphyry and subvolcanic intrusive breccias. At least five breccias reportedly run in a crude northeast trend across the strike of the claim block. Ground traversing indicates the presence of a complex multiphase intrusive event (fig. 3), and several brecciated intrusive masses have been delineated. According to Swainbank (1981), magnetic, induced-polarization (IP), self-potential, resistivity, chargeability, and VLF geophysical methods have been used on the property. All confirm the presence of the five major 'breccia-pipe' anomalies outlined during the geologic-mapping program. These anomalies are very similar and about equal in size to those mirrored by the Golden Zone breccia pipe several miles to the southwest. Magnetic highs that approach 300 gammas further outline these brecciated intrusive masses.

According to Swainbank (1982, personal commun.), the IP surveys seem to indicate an area approximately 4,000 ft by 4,000 ft underlain by material containing 2 to 4 percent total sulfide.

A reconnaissance rotary-drilling program was initiated on the property during 1975. Approximately 1,700 ft of drilling in 18 holes intersected both a thick colluvial-drift apron and mineralized bedrock, but two holes did not penetrate Quaternary cover. Although the deepest hole was 250 ft, most averaged about 80 ft, and hence they primarily serve to indicate extent of mineralization rather than to block out tonnage. All, however, intersected zones up to 50 ft thick containing anomalous copper, molybdenum, silver, and gold. Sulfide materials identified during both ground reconnaissance and rotary drilling include chalcopyrite, bornite, pyrite, arsenopyrite, and traces of galena and sphalerite. Selected samples run as high as 5 percent copper, 360 ppm molybdenum, 2 ppm gold, and 9 oz per ton silver. The silver appears to follow copper at a ratio of 1 percent copper to 2 oz per ton silver.

The geologic interpretation of the NIM deposits is controversial. Problems with the area include the extensive till and colluvial cover that overlies much of the bedrock and the lack of adequate geochemical analyses during exploratory efforts. I was unable to locate drill cuttings (from the exploration work) to run additional elemental analyses (including tin). Swainbank and others (1978) suggest that the mineralized breccias indicate the presence of a concealed porphyry copper-molybdenum-precious metal system associated with calc-alkaline intrusions as described by Sillitoe (1973). Available geologic and geophysical data are consistent with models of stockwork-style, large, low-grade copper-gold-silver 'porphyry' systems discussed by Titley and Hicks (1966). In particular, the NIM Block mineralization is somewhat similar to that found at Ray, Arizona. However, despite the analogy, both Hawley (1978) and Blakestad (1981) stress that open-space veinlets and cracked brecciation commonly regarded as important in strong copper-molybdenum mineralization appear to be lacking in the NIM block mineralization.

Blakestad (1981) regards the claim block as a potential tin-precious metal greisen system. Hawley and Clark (1974) first recognized the importance of tin anomalies in the Chulitna district. Recently, significant tin discoveries were made in the mineral belt less than 15 mi from the NIM block. Within Dunkle township, the Silver King mineralized area (previously described) has anomalous tin zones. Two distinctive igneous suites are known in the district:

- The 60-70-million-yr-old McKinley-Yentna trend associated with copper, gold, bismuth, and other base metals

- The 55-60-million-yr-old McKinley type known to be associated with the strategic mineral tin and associated elements.

Radiometric age dating reported by Swainbank and others (1978) suggests that intrusives and intrusive breccias on the NIM block (68-million-yr mica ages) are from the former suite, as is the Golden Zone gold breccia pipe. Hence, available evidence suggests that the NIM block should be evaluated for precious-metal-bearing intrusive breccias or breccia pipes (as at the Golden Zone Mine) rather than for porphyry copper-molybdenum or 'porphyry' tin deposits. Hawley (1978) summarizes reserves at the Golden Zone Mine at 581,000 tons of high-grade ore (0.14 to 0.3 oz per ton gold) and up to 6 million tons of lower grade resources that probably average 0.05 to 0.10 oz per ton gold.

Five breccia-pipe targets about the same size as the Golden Zone deposit exist on the NIM block and in the Snoopy mineralized area. I emphasize that these targets are presently unevaluated prospects.

Summary of hard-rock metal deposits

Table 8 summarizes the reserve-resource picture of hard-rock metal deposits in Dunkle township. Unlike the Kantishna mining district, deposit types in Dunkle township are somewhat irregularly grouped and contain highly variable resource estimates. Nonetheless, three major types of deposits emerge: veins, breccia pipes, and large, bulk-tonnage stockwork systems.

These results show possible resources of 20,000 tons of relatively high-grade gold-silver vein mineralization, a very hypothetical resource of 3.23 million tons of gold-bearing breccia-pipe mineralization, and a speculative 100-million-plus-ton resource of low-grade copper-silver-gold porphyry mineralization. Grade computations for most of these deposits cannot be made with existing data, and more extensive research must be completed on most of these deposits.

Placer deposits

Gold-bearing placer deposits occur along the length of Colorado Creek in the study area, but no published information is available on the nature of these deposits. Intermittent development by several Anchorage-based prospectors has occurred since 1959. Production levels are unknown but probably small. The best ground apparently occurs in thick outwash gravels at the mouth of Colorado Creek where it enters the Chulitna River. Previously described gold-bearing lodes are probably the source of these placers. Tenor and size estimates are not available, and field evaluation of these gravel deposits should receive top priority.

Dunkle Coal Mine

Coal deposits at the Dunkle Coal Mine are part of the Broad Pass coal field that spans the Alaska Railroad for 25 mi south of Cantwell. According to Hawley and Clark (1974), the coal-bearing arenaceous sedimentary rocks at Costello Creek were formed in local swamps of down-faulted basins. Coal seams at Dunkle Coal Mine, which are overlain by 50 ft of poorly consolidated silty sandstone and siltstone, appear to underlie a 3-mi^2 area in the basin of Upper Costello Creek. Waste-ore ratios (3:1) are amenable to open-pit extraction.

Small-scale, underground room-and-pillar and open-pit production occurred on the property at the onset of World War II. However, past records of development and production are contradictory. Rutledge (1948) and Hawley

Table 8. Summary of metallic resources, Dunkle township, Alaska.

Deposit type	Name	Tonnage	Metallic grade	Remarks
Vein shear zone	Eagle	12,000 3,000+	0.23 oz/ton Au 4.55 oz/ton Ag (N=9)	Promising small deposit. Deserves additional work
	Lucrata	5,000+	0.49 oz/ton Au 1.03 oz/ton Ag (N=3)	Same as above
	Liberty	-	Variable trace to 0.14 oz/ton Au 1.2 to 8.6 oz/ton Ag	Low-grade Au-Ag lode
Tacite-breccia pipe	Silver King	85,000 minimum (1 target)	Trace to 8.29 oz/ton Au, contains Cu, Sb Bi, As, Co, As, Sn, Pb, Zn	Several target areas known, poor exposure, needs drilling and more sampling
	Nimrod-Nimbus	650,000 (1 target)	0.5 to 3 oz/ton Ag, credits of Pb, Zn, Sb, Au	Bulk-tonnage, low-grade Ag deposit
	Nim-Snoopy	Speculative 500,000 - 2.5 million (5 targets)	Anomalous Cu, Ag, Au, As; may contain Sn, Bi	Needs drilling and additional evaluation
Bulk-tonnage porphyry	Nim	4,000 ft x 4,000 ft 100 to 120 million tons (low grade)	Anomalous Cu, As, Ag, Au	Lacks brecciation and silicification typical of this type of deposit

- Not available.

(1978) report that approximately 5,000 tons of subbituminous coal were shipped to markets along the Alaska Railroad during World War II. However, Barnes (1967) reported production of about 64,000 tons of coal from 1940 to 1954, but did not cite references for these figures. A feasibility report by a private company (Dunkle and others, 1962) did not resolve the discrepancy.

Rutledge (1948) calculated a coal reserve of 192,700 tons for three seams at the Dunkle Mine, but believed that a significant percentage of this reserve was lost during previous underground-mining operations (in caved pillars). However, drilling conducted during the 1940s indicated the presence of fairly continuous coal intercepts ranging from 2 to 9 ft thick over a 2-mi^2 area near the mine. Barnes (1967) reports indicated reserves of coal at Costello Creek at 350,000 tons, with a 13-million-ton resource base for the Broad Pass field, including Dunkle Mine. Accolade Mines (Dunkle and others, 1962), reported "total lignite available for strip mining is 8 million tons," but these figures probably include coal outside the Dunkle township study area.

Mineral-development Models

Resource estimates generated from the modeling effort are applied to hypothetical low-, medium-, and high-mineral-development scenarios to assess economic and environmental impacts. These levels of development are based on assumptions similar but not identical to those proposed by Louis Berger and Associates (1982).

For this study, economic and land-use policy are both taken into consideration for the three levels of activity. Low-level development forecasts no major changes in mineral-commodity prices. Existing levels of mineral activity would continue under current National Park Service restrictions.

Medium-level development assumes an increase in world-market prices of silver, gold, and high unit-value commodities such as tungsten, antimony, tin, and cadmium. The base-metal prices would be equivalent to 1972 constant dollars. Additionally, National Park Service policy would allow development on valid existing claims in known mineralized areas in the Kantishna and Dunkle Mine areas.

High-level development assumes fundamental increases in world-market prices for copper, lead, zinc, tin, tungsten, gold, silver, antimony, and cadmium over production costs that would attract a variety of development investments. Additionally, federal incentives and subsidies for development of 'strategic' metals such as antimony, tin, and tungsten would be under consideration. National Park Service policy would allow leasing of mineralized ground currently closed to mineral development and development of valid claims.

I recognize that such speculative mineral-development levels are dependent on complex economic factors that are almost impossible to forecast. Furthermore, no attempt is made to speculate on economic viability, net profit, or employment and monetary multiplier effects for any deposits. The primary effort is to model metallic output and its national importance as a requirement of the ANILCA legislation. Resource-modeling estimates allow the operation of lodes and placers for 6 to 30 yr. Hard-rock extraction probably involves several types of underground-mining methods, depending on the geologic-engineering constraints of the exploitable deposits. Data for the following summary is from appendixes A and B (this report) and the U.S. Bureau of Mines 1982 Commodity Summary. The latter source is a compilation of production and consumption from trends prior to the current economic recession. These older figures were used because they better model commodity activities during healthy economic times.

Kantishna area

A low-level development essentially models the existing level of operations in 10-15 placer mines currently producing 3,000 to 5,000 oz of gold annually. Additionally, I assume the existing 35-ton-per-day (TPD) Red Top silver mill would operate for 100 days. This scenario will generate $2.78-3.62 million from the sale of gold, silver, and minor base metals; 90 percent of the value is from placer gold.

The half-square resource estimates in tables 1-5 (summarized in table 6) serve as the basis for the medium-level development base. This model envisions operations of a 250-TPD hard-rock mill on Quigley Ridge, a 40-TPD plant at Stampede, and current-level placer operations. Ore from the Quigley Ridge silver-base metal and Banjo gold lodes would feed the former plant, while stibnite-quartz deposits (antimony ore) would feed the Stampede installation. This level of mineral development would annually produce 1,708 tons of antimony, 1.91 million oz of silver, 20,900 oz of gold, 67 tons of tungsten, and 4,795 tons of lead and zinc worth $38.96 million. In terms of national significance, annual metal output amounts to 220 percent of current domestic antimony production (4.5 percent of apparent United States consumption) and 5.9 percent of domestic silver production (1.9 percent of apparent United States consumption). Production of tungsten, lead, zinc, and gold would not be nationally important ($<$ 1/2 percent apparent consumption). However, total metallic output would amount to 18 percent of 1982 Alaskan mineral production.

A high-level mineral development utilizes a 500-TPD mill at Quigley Ridge and a 250-TPD plant at Stampede. Complex ores from the Quigley Ridge, Banjo, Glenn Creek, and Slate Creek mineralized areas would feed a complex mill circuit at Quigley Ridge. Stibnite-quartz deposits at Stampede only would feed the latter facility. This resource level assumes the summation of half-square estimates and high-level ranges for the Quigley silver lodes previously presented. The half-square estimate for the Stampede deposits would be adequate for the 250-TPD plant. This level of activity would annually generate 3.81 million oz of silver, 41,900 oz of gold, 9,435 tons of antimony, 133 tons of tungsten, and 9,902 tons of lead and zinc worth $87.60 million. In terms of national significance, annual metal output would amount to 1,179 percent (or more than tenfold) of the domestic antimony output (27.4 percent of apparent United States consumption), 11.9 percent of domestic silver production (4 percent of apparent United States consumption), and 3.8 percent of domestic gold production (1 percent of apparent United States consumption). Production of lead, zinc, and tungsten are not nationally significant. However, production levels of all metals would be important to statewide metallic output and would amount to 44 percent of the value of total Alaskan 1982 mineral production.

Dunkle township

Limitations in the data base prevent the formation of specific mineral-development models as presented for the Kantishna area. A low-level development mode (as is) forecasts no mineral production (except a modest amount of placer gold) in the township. Advanced prospecting for gold and exploratory work on lode deposits would be conducted.

No medium-level development models are presented here. A high-level development model would involve lode and placer metallic-mineral and coal production. Several placer operations on Colorado Creek would recover gold from low-grade auriferous outwash deposits. I assume that 'ore-grade' for breccia-pipe deposits approximates that of the Golden Zone Mine. Block-caving or similar underground-mining methods would resemble those used in the Whitehorse Copper Belt of Yukon Territory, Canada (Tempelman-Kluit, 1981). Either a 500- or 2,500-TPD mill would be fed by one or several copper-gold-silver-bearing breccia pipes from the Silver King, Nimrod, NIM, or Snoopy mineralized areas. Annual revenues from such an operation would range from $8 million to $34 million, and copper, silver, and gold (possibly tin) would be the principal mineral commodities recovered (revenue estimates based on grades at Whitehorse copper and Golden Zone deposits). Small, high-grade gold-silver veins such as the Eagle or Lucrata deposits could be fed through the same mill. Alternatively, a smaller plant could be constructed and produce a several-million-dollar annual gross value of the two precious metals from these smaller deposits.

Speculative future development of the Dunkle coal deposits would probably utilize small-scale, open-cast-mining methods and revolve around all or parts of three scenarios:

- Supply power and concentrate drying heat for local hard-rock metal mine (10,000-35,000 tons per yr)

- Supply limited railbelt market with 50,000 tons to several hundred thousand tons of coal annually (?)

- Supply high-quality treated coal for export market (same output as second scenairo).

Dunkle and others (1962) present a mine model that would produce 432,000 tons of coal based on a 360-day-per-yr production schedule, about half the current production at Healy. Because of high moisture and ash content, they recommend a special washing and drying circuit; because heat-drying could cause spontaneous combustion, they also recommend mixing the coal with fuel oil or other liquid fuels.

In my estimation, this level of production is too optimistic in terms of the existing resource base of about 8 million tons, not all of which is necessarily minable.

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APPENDIX A

Mineral-development Scenarios
Kantishna Hills and Dunkle Mine Study Area

Kantishna Hills Area

Placer deposits would be mined by small- to large-scale open-cast methods similar to those presently used. The Quigley Ridge, Banjo, and Antimony lodes would probably be mined by underground mining methods that depend on stope-vein angles. Because of the size of the ore bodies (small individual shoots), vein systems would be mined collectively, with ore simultaneously drawn from several small mines to feed a mill facility for the medium- and high-level developments. It is assumed in this analysis that 'ore trucks' would haul 35 tons of concentrates and tanker trucks would have an 8,000-gal capacity. Plant infrastructure requirements are similar to those proposed by Jansons and others (1977), Cummings and Bruce (1977), and Louis Berger and Associates (1982) for northern mining developments.

A. Low-level development (existing level of operations)

1. Placer mining

a. Ten to fifteen operations and 10-15 support camps

b. Two to six people per operation (total 75-90 people)

c. Production - 3,000-5,000 oz of gold per yr

d. Approximately 600,000 yd^3 of gravel processed per yr by all operations; would affect 100 acres (excluding roads but including settling ponds)

e. Five thousand acres are covered by existing placer claims of which probably only 1/5 to 1/3 of the acreage would actually be mined

f. Fifty-five to sixty mi of existing access roads currently occupy approximately 150 acres

g. Operations would continue through yr 2000 or longer as previously mined areas may be reworked

h. One hundred ninety-four placer claims are currently recorded with BLM as illustrated on maps currently in 'Environmental overview and analysis of mining effects, Denali National Park and Preserve,' National Park Service

i. Mining-related activity for 4-5 mo each yr (occurs between late May and early October)

j. Would occur in addition to lode mining

k. Three thousand to five thousand gal diesel fuel required per yr per operation; six tanker truckloads for entire district per yr

2. Lode mining

a. Thirty-five-TPD mill located at current Red Top mill location, processing primarily silver and some gold ore from Quigley Ridge

b. Utilizes underground-mining method

c. Mill heads grading 35 oz per ton of silver, 0.14 oz per ton of gold, 3,500 tons of ore mined per season

d. Mine tailings placed underground for structural support; mill tailings stored in 5-10 acre tailings pond on claims near mill site

e. Operations to continue through yr 2000 and longer

f. Operates 100 days per season, one shift per day

g. Utilizes existing access roads

h. Six hundred tons per season of silver concentrates hauled over existing Denali Park road to Alaska Railroad or Parks Highway requiring 17 round-trip truckloads at 35 tons per trip (this would be controlled by load limits of bridges and existing road)

i. Twenty-five tons per yr of supplies hauled over Denali Park road (explosives, repair parts, reagents, fuel, food, and support equipment)

j. Existing roads would be used (see 'surface access' figure in environmental Overview document)

k. Would occur in addition to placer mining

B. Medium-level development

1. Placer mining

Same level and assumptions as for low-level development

2. Lode mining

a. Two hundred fifty-TPD mill located at current Red Top mill location. One mill with separate circuits to process silver and gold ores from Quigley Ridge and Banjo lodes, respectively

(1) Three to seven underground mines involving five distinct ore shoots operated collectively to feed mill; mine tailings stored underground for structural support; mill tailings stored in 25-acre pond

(2) Eighty-two thousand five hundred tons per yr of ore mined and processed per season

(3) Sixteen thousand five hundred tons per yr of concentrates requiring 470 round-trip truckloads to Alaska Railroad either on existing Denali Park road or northern extension via the Stampede Road corridor, or precious-metal concentrates possibly transported by aircraft. Although aircraft transportation of concentrates could reduce truck transportation traffic up to 25 percent, it may not be economically preferable

(4) Operates 330 days per season, two shifts per day

(5) Four hundred fifty tons of supplies, at a minimum, would be hauled in (explosives, tires, repair parts, flotation reagents, mill steel, employee food, etc.) per season to support operations

(6) Five hundred thousand to six hundred thousand gal per season of #1 stove fuel equivalent would require 60-80 tank-truck trips into area

(7) One hundred thirty-five to one hundred sixty people associated with mines, maintenance, and other surface operations would be required

(8) Infrastructure support requirements: Various heavy equipment, workshop and repair facilities, service haul roads, possible headframe, several tunnel sites, employee quarters, sewage and waste disposal; could require 25-40 acres of surface occupancy

(9) Water-supply sources and systems for mill and support uses would have to be developed on site

(10) Operates for 10 yr at present known reserve level; could operate longer if additional reserves are discovered

b. One thousand two hundred tons per season 'high-grade' ore mined at Slate Creek and Last Chance antimony deposits

(1) No mill

(2) Two mining camps, one at each deposit

(3) Ore either transported by aircraft or hauled out via the Denali Park road

(4) Two to six people involved in operation

(5) Operations would continue for a minimum of 10 yr

c. Forty tons per day (13,200 tons per season) milled at Stampede

(1) One thousand eight hundred to two thousand two hundred fifty tons of concentrates transported by aircraft (125 Hercules flights per yr at 20 tons per load) or hauled out the old Stampede Road, which would have to be improved (50-65 truckloads at 35 tons per load)

(2) Operates 330 days per yr per season

(3) Fifteen to twenty people employed in mining and milling operation

(4) Mill and associated structures at existing mill site

(5) Two to three lodes within the Stampede system mining collectively to feed mill

(6) Could operate for 10 yr

(7) Tailings would be stored in 4-6-acre tailings pond as necessary

C. High-level development (assumes all significantly mineralized areas are open to mineral development)

1. Placer mining

a. Same assumptions as medium-level placer development, but in addition, larger operations commencing on previously unmined and unstaked areas on lower outwash gravel systems in the lower canyon of Moose Creek and Caribou Creek, upper benches of upper canyon of Moose Creek and Glacier and Caribou Creeks, and auriferous areas on Little Moose and Stampede Creeks. Prospecting activities would occur on Bearpaw River

b. Thirty to fifty total operations

c. One hundred fifty to three hundred personnel

d. Production 10,000 oz or more of gold per yr

e. Four million yd^3 of gravel would be moved each yr

f. Access would be via existing Denali Park road for employee and equipment movement

g. One hundred thousand gal of equivalent #1 stove fuel requiring 13 tank-truck trips per season.

2. Lode mining

   a. Five hundred-TPD mill at Red Top location servicing Quigley Ridge, Banjo, and Glenn Creek lodes; would also process 50-100 TPD of antimony ore mined at Eagles Den or Slate Creek claims

      (1) Each ore type requires a different circuit and water treatment. Ore from lode claims on Glenn Creek would be transported from mines via 8-mi haul road

      (2) One hundred sixty-five thousand tons of ore mined; mine tailings would be stored underground; mill tailings would be stored in a 30-40-acre tailings pond

      (3) Thirty-three thousand tons per yr of concentrates requiring 945 round-trip truckloads at 35 tons per trip would be hauled to the Alaska Railroad either on existing Denali Park road or northern extension via old Stampede Road, which would have to be improved. Haul weights and round-trips would be controlled by load limits of existing bridges and roads

      (4) Two hundred sixty to three hundred people associated with mines, mill, maintenance, and other surface operations would be required

      (5) Assumptions regarding mines, employees access, and infrastructure, etc., are essentially the same as for medium-level development

      (6) Nine hundred thousand gal of equivalent #1 stove fuel per yr; 115 truckloads

   b. Two hundred fifty TPD of antimony ore mined and processed at Stampede mine and mill

      (1) Transportation of 12,000-14,000 tons per yr of concentrates requiring 350-400 round-trip truckloads (assuming 35 tons per truckload) would either tie in with existing internal circulation related to Quigley Ridge or utilize old Stampede Road. Number of round-trip truckloads and tons per trip would be controlled by existing road and bridge capacities. Concentrates could also be transported by a Hercules aircraft making two flights per day or 700 trips per yr

(2) Tailings would be stored in a 25-acre pond

(3) Fifty to one hundred employees; 300 tons dry supplies per yr

c. Prospecting would be principal activity for the next 20 yr on old lodes except the antimony deposits could start high-grade production immediately

3. Spruce Creek Sequence stratiform development (hypothetical)

a. Eight hundred-TPD mill located somewhere in 'Sequence' area to process ore mined from 1-10 million-ton deposit of good-grade silver, gold, lead, zinc, and copper. Could yield 26,000 tons per yr of concentrates, requiring 750 round-trip truckloads on Denali Park road or old Stampede Road, which would have to be improved

b. Underground-mining method

c. Mill tailings would be stored in a 25-40-acre tailings pond. Mine tailings put underground for structural support

d. One million gal of #1 equivalent stove fuel required per yr; would necessitate 125 round-trip tanker truckloads

e. Operation and activity levels could be compared to Greens Creek in southeast Alaska

Dunkle Area

Several possible sites exist for hard-rock development. Five intrusive breccias are known on the NIM claim block, and several more exist in the Silver King, Nimbus, and Snoopy areas. It is assumed that ore would be confined to rims of concentrically shaped, vertically plunging ore bodies 200-1,000 ft in diameter. However, the entire breccia pipe(s) may be sufficiently mineralized to constitute ore. A single mill could service several deposits.

For the Dunkle-Costello coalfield, a small open-pit coal development is the model used here---6-8-ft-thick seams mined with a 3:1 overburden to ore ratio. Equipment needed would include Caterpillar loaders, two bulldozers, and two 35-ton haul trucks. Small-scale, open-cast placer operations are also possible.

1. Placer mining

Some advanced prospecting

2. Lode mining

a. No existing development or extraction activities. However, 103 unpatented lode claims that exist in the area are presumed valid and could legally be mined

b. Approximately 7 mi of access road currently exists in this township

B. Medium-level development

1. Placer mining

One to three operations possible processing 10,000-200,000 yd^3 of gravel per yr could result in 6-20 acres of surface disturbance

2. Lode mining

a. Small open-pit coal mine at old Dunkle Mine site

b. Fifty thousand to one hundred fifty thousand tons per yr hauled to Alaska Road for shipment, requiring 1,430-4,200 round-trip truckloads on an improved access road

c. Operates 330 days per yr

d. Operation would require 30 people associated with mine, washing plant, and large maintenance facility

e. Water source would have to be developed for washing plant

f. Fuel requirements could be offset by use of coal

C. High-level development

1. Placer mining

a. Three to five operations processing 200,000 yd^3 of gravel per operation; mining possible glacial-outwash gold and tin placers on Colorado Creek

b. Six hundred thousand to one million yd^3 could be processed and potentially disturb 60-150 acres

2. Lode mining

a. One hundred fifty thousand tons per yr open-pit and underground coal mine at Dunkle Mine site extending to Costello Creek; same scenario as medium-level development

b. If coal supplements lode-mining operation, shipment of any excess production could require 3,200 round-trip truckloads on existing access road to Alaska Railroad. If all mined coal is shipped to Alaska Railroad, 4,200 round-trip truckloads could be required

c. Five hundred to two thousand five hundred-TPD mill processing copper, silver, and gold ore from underground shrinkage stope or block-caving method or open-pit mining of the five breccia-pipe formations associated with NIM, Nimbus, and Silver King claim groups in northeastern and southwestern portion of study area. A range of tonnage that could be milled is given; however, in actuality mills would probably be one of two levels, either a 500-TPD or a 2,500-TPD capacity

(1) Operates 330 days per yr

(2) Production 165,000-825,000 tons per yr

(3) Eighteen thousand to ninety thousand tons per yr of copper, gold, silver, and tin concentrates shipped to the Alaska Railroad 8 mi to the east. Would require 515-2,570 truckloads per yr to railhead

(4) Mill tailings would be disposed of in a 40-60-acre tailings pond; mine tailings and possibly dried mill tailings pumped underground for structural support

(5) Open-pit or underground-mining method could be used, depending upon geometry of ore bodies. Existing information supports underground method

(6) Six hundred eighty to four thousand tons of supplies such as explosives, reagents, repair material, mill steel, and food would be necessary to support operation

(7) Fuel requirements: 900,000-2.5 million gal of #1 stove fuel equivalent or 180,000-1.3 million gal of oil if 26-36,000 tons of coal from the Dunkle Mine were substituted. Would require 112-312 tanker loads of fuel per yr without coal use and 23-162 loads with coal use. Provisions would be necessary for prevention of spillage

(8) Other infrastructure requirements same as for medium- to high-level development lode mining in the Kantishna Hills

(9) One hundred thirty-five to three hundred people would be required at mines, mill, and maintenance and support facilities

(10) Access would continue via the existing road from the rail siding at Colorado Creek to the West Fork of the Chulitna River and uphill along the east side of Colorado Creek; two additional alternatives are:

a. Fifteen mi rail spur alternative into the mouth of Colorado Creek for coal and metal mine transport

b. Route from eastern edge of township to access NIM block

d. Support facilities including living quarters, haul road, shop, and other surface requirements would be approximately 160 acres. Many of these facilities could be located a distance from the mining and milling operation outside the study area

APPENDIX B

Volume, Gross Value, and National Significance of Mineral-development Scenarios, Kantishna-Dunkle Mine Study Area

Kantishna Hills Area

Basic assumptions

Assume the following metal prices, which are roughly the metal prices as quoted in Metals Week, March 20-26, 1983 (Larson, 1983).

Gold at $425 per oz
Silver at $11.80 per oz
Lead at 26 cents per lb
Zinc at 35 cents per lb
Antimony at $1 per lb
Tungsten at $106 per short ton unit
Tin at $7.50 per lb

Also assume 80-percent recovery of silver, 70-percent recovery of antimony at Stampede, and 90-percent recovery of other metals from lodes based on experiences from Keno Hill and Coeur d'Alene mills (without cyanide).

Low-level development scenario

Placer: $1,275,000 (3,000 oz gold) to $2,125,000 (5,000 oz gold) with up to $10,000 in byproduct silver produced from existing placer operations.

Lode: 110,250 oz of silver worth $1,300,950 and 441 oz of gold worth $187,400 from silver-lode development (Gold Dollar, Bosart, Red Top lodes).

Hence, total annual mineral production would be $2,744,610 to $3,464,515 with 80-100 seasonal workers.

Medium-level development scenario

Placer: $2,125,000 of gold bullion as in low-development scenario (high production estimates).

Lode: Silver-gold-lead-zinc-tungsten mine(s) operational for 330 days.

In calculating gross volumes of metals, assumption is that for Red Top development mill, feed from Banjo and Quigley Ridge ores would be at an approximate ratio of half-square resource estimates. This equates to total of 586,852 ton 'resource' base, of which 70.3 percent is silver ore and 29.7 percent is gold ore, so:

175 TPD from Quigley Ridge silver lodes and
75 TPD from Banjo System; total 250 TPD

Quigley Ridge

1,836,912 oz silver worth	$21,675,561
7,276 oz gold worth	3,092,512
3,326 ton lead worth	1,729,728
1,195 ton zinc worth	836,797
Subtotal	$27,334,598

Banjo

8,687 oz gold worth	$ 3,692,081
71,082 oz silver worth	838,767
196 ton lead worth	101,930
78 ton zinc worth	54,573
668 ton tungsten worth	1,400,000
Subtotal	$ 6,087,351
Total	$33,421,949 gross

High-grade antimony, Slate and Last Chance Creeks (1,200 tons high grade ore or 600 tons antimony metal)

1,200,000 lb worth $ 1,200,000 gross

Stampede

Mill rate of 40 TPD; 330 days per yr, 1,108 tons antimony or 2,216,000 lbs worth $ 2,217,600

Total all medium-level mining scenario (including placer):

1,907,994 oz silver
20,963 oz gold
3,522 ton lead
1,273 ton zinc
1,708 ton antimony
66.8 ton tungsten, worth $38,964,549

5.6 percent placer gold
94.4 percent lode products

59.6 percent = silver production
9 percent = antimony production
23.7 percent = total gold production
7.6 percent = lead, zinc, tungsten production

National significance:

Antimony
215 percent of domestic mine production
4.5 percent of apparent U.S. consumption
Net Import Reliance = 50 percent

Silver	5.9 percent of U.S. mine production 1.9 percent of apparent U.S. consumption Net Import Reliance = 45 percent
Gold	2.0 percent of U.S. mine output 0.5 percent of apparent consumption
Lead	0.6 percent of U.S. mine production 0.3 percent of apparent consumption (We export lead.)
Zinc	0.4 percent of U.S. mine production 0.1 percent of apparent U.S. consumption Net Import Reliance = 58 percent
Tungsten	66.8 tons 0.9 percent of domestic mine production 0.27 percent of apparent U.S. consumption Net Import Reliance = 54 percent

High-level development scenario

Placer: $4.25 million plus gross on placer-gold production; seasonally employs 150 workers.

Lode: Silver-lead-zinc-gold-tungsten; based on assumptions of mill feed derived from 'medium-level' scenario, Red Top 500-TPD mill would annually produce:

3,816,000 oz silver worth	$45,028,800
31,926 oz gold worth	13,568,550
7,044 ton lead worth	3,662,880
2,546 ton zinc worth	1,782,200
133.6 ton tungsten worth	2,832,320
1,369 ton antimony worth	2,738,000
Total	$69,612,750

The Stampede Mine, at 250 TPD, 330 days per yr, would produce 6,889 tons antimony worth $13,778,000.

Spruce Creek Sequence stratiform model is not evaluated at this time (poor data base; too speculative).

Summary:

Total annual metal output from Kantishna district for high-level development (lodes + placers) is:

3,816,000 oz of silver	
41,926 oz gold	
7,044 ton lead	
2,858 ton zinc	
133.6 ton tungsten	
9,435 ton antimony, worth	$87,640,750

Percentage of production of each commodity very similar to that calculated for medium-level scenario. Employs 400-600 people (probably the low employment figure is correct).

National significance:

Antimony	27.4 percent of apparent U.S. consumption Increase U.S. mine output more than 10 fold or about 1,179 percent
Silver	11.9 percent of domestic mine production 3.8 percent of apparent U.S. consumption
Gold	4.0 percent of U.S. mine output 1 percent of apparent U.S. consumption
Lead	1 percent of U.S. mine output 0.4 percent of apparent U.S. consumption
Zinc	0.8 percent of U.S. mine output 0.2 percent of apparent U.S. consumption
Tungsten	1.8 percent U.S. mine output 0.5 percent apparent U.S. consumption

(Net Import Reliance same as in medium-development scenarios.)

Dunkle township area

Low-level development

No lode or coal production. Minor production of placer gold worth a few thousand dollars.

High-level development

Placer: $2.5 million placer-gold gross from several mechanized operations on Colorado Creek.

Underground mining of vein, tactite, or breccia-pipe deposits such as Silver King system, NIM, Nimbus, and Eagle-type vein deposits.

Lode:

$32 million - (high scenario, 2500 TPD).

$8 million - (low scenario-500 TPD)

Totals for high-level development of metals, coal, and placer gold would range:

$10.5 million to $34.5 million gross of copper, silver, and gold concentrate and coal. The strategic mineral tin might be recovered.